19th
NITROGEN
WORKSHOP

Efficient use of different sources of nitrogen in agriculture – from theory to practice

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Abstracts

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SLU

19th NITROGEN WORKSHOP: “EFFICIENT USE OF DIFFERENT SOURCES OF NITROGEN IN AGRICULTURE – FROM THEORY TO PRACTICE”

The Nitrogen Workshop is since 1982 a leading international network on issues related to nitrogen in agriculture. The 19th Nitrogen workshop was arranged in Skara, Sweden, by the Swedish University of Agricultural Sciences (SLU) supported by International Nitrogen Initiative (INI) Europe. Financial support was given by The Swedish Research Council Formas, Region Västra Götaland and Yara. The workshop had a scientific program with 26 oral presentations and 192 poster presentations from more than 30 countries around the world addressing important issues on efficient use of nitrogen in agriculture at different scales, from system approaches to the fine tuning of specific parts of the agricultural management.

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AGRONOMIC CRITERIA TO DESIGN A VARIABLE RATE NITROGEN STRATEGY IN CROPPING SYSTEMS

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Nitrogen (N) fertilizer can increase crop yields but its management remains complex due within season uncertainties related to weather, soil conditions, and crop establishment. N losses from the cropping systems is one of the most widely recognized environmental problems today [1]. The mismatch between plant N demand and its supply is one of the main reason why N use efficiency (NUE) remains generally low. Less than 40% of the N fertilizer added to an annual grain crops is taken up by the crop [2]. The remainder is available for loss through air, surface water, or groundwater pathways [3]. N lost as nitrate pollutes groundwater and surface waters, contributing to human health risks [4] and freshwater eutrophication [5]. The objective of the paper is to summarize methods and tools currently used to manage N fertilizer application at the field scale.

Economic Optimum Rate

From an economic point of view the optimal Nitrogen (N) fertilizer amount should be the rate at which the farmer's financial return is maximized and it known as Economic Optimum Rate (EOR). The optimal N amount (N_{opt}) varies between cultivar, site location and between years [6]. For the same field cropped with the same cultivar the N_{opt} is not constant across the field because of the spatial variability of crop growing conditions and soil properties [7]. The determination of the N_{opt} is made by subtracting the crop N uptake from the soil N supply and N inputs. One way to quantify N_{opt} is to base the estimation of final yield upon the "expected yield", which is function of known crop average yield and its N content. However, long-term experiments have showed that yield might be difficult to predict because the yield potential can vary substantially between years [8] and the N content will vary as function of cultivar, and N supply. This is because of the unpredictability of weather conditions, in fact a year with lower rainfall causes a reduction of biomass yield and low crop N uptake. Moreover, the spatial distribution of soil properties interacts with weather conditions, determining a within-field spatial variability of crop growth even for the same growing season. For example, the different distribution of clay and sand content and their interaction with the growing season rainfall can affect the soil water holding capacity, which will affect crop growth in the field and its N uptake.

Soil N

Another method used to estimate N fertilizer requirements is analyses of soil samples. This method takes into account the soil N supply, which influence crop N uptake throughout the growing season. Soil N can be divided into two components, the soil mineral N (SMN), which is the N immediately available to crops; and the organic N (ON), that will be mineralized and be available to crops through the growing season. The test for SMN is made before planting, and it is known as the pre-plant Nitrate test (PPNT) and/or during the vegetation period (pre-sidedress Nitrate test; PSNT) [9]. Along with soil N, the assessment has to include the estimation of soil N mineralization rates. N mineralization rates can be estimated under field conditions by using a reference plot with no N applications. But several studies found that the net N mineralization is site-specific and affected by weather conditions and amount of N applied in the fertilized plots. Laboratory experiments such as incubation procedures, assessment of microbial biomass activity, and chemical soil extractions might estimate a *"potential N"* available to crops but under field conditions such *potential* may vary considerably and that is why those tests are used only in research studies rather than for practical agronomic decisions.

Crop N

The estimation of crop N content is an alternative method to estimate the N fertilization rates, because the crop is also a good indicator of the soil N at certain point during the growing season. In fact, the crop N content is function of soil N content, N mineralization rates, crop residues, soil water content, root growth, and N uptake efficiency. There are several methods for assessing crop N status such as the total crop N concentration, and the plant petiole nitrate recommendation. The former, is done in the laboratory but for field application is time-consuming and few plant samplings might be not representative of the spatial variation of crop N. The latter, has been developed to make decision on the time and the rate of N fertilization directly into the field. For example, on potato crop the petiole test has been widely used for a quick assessment of crop N status. However, the nitrate concentration in the petiole varies according the sampling dates, position of the petiole on the plant, plant age, cultivar, time of the day when samples are collect, and weather condition prior to the test such as drought or rainfall [10]. Another non-destructive method to determine crop N status is the use of the optical transmission measurements with a hand-held chlorophyll meter such as Minolta SPAD-502 (Minolta, Japan). The instrument measures the leaf red transmittance at 690 nm and the near infrared transmittance at 940 nm, which are found to be a measure of chlorophyll level in crops. The use of the hand-held chlorophyll meter is time consuming, and its values are affected by the leaf water status, and the specific leaf weight. Moreover, the instrument measures only one point of the last fully developed leaf, but the nitrogen distribution is not uniform within the leaf. At canopy level, the chlorophyll meter does not give accurate values of nitrogen content because the canopy nitrogen distribution follows a vertical gradient distribution within the canopy. The nitrogen content decreases in the lower leaf layers, and the decrease is linearly related with decreasing in light intensity; moreover, it is also limited to point measurements and cannot practically be deployed spatially across a large field.

Remote Sensing

Remotely sensed vegetation indices can be used for the estimation of crop N, and indices such as the Normalized Difference Vegetation Indices (NDVI; Rouse et al., 1973) has been extensively used in commercial sensors, such as the Yara N-Sensor/FieldScan (Yara International, ASA, Oslo, Norway), GreenSeeker (N Tech Industries, Inc., Ukiah, CA) and the CropCircle (Holland Scientific, Lincoln, NE). NDVI is affected by the developmental stage, LAI and canopy geometry can affect crop N content [11]. Also, NDVI saturates at values of LAI between 3 and 6, causing low index sensitivity for detection of crop nutritional status [12]. An indirect method to detect canopy N is by estimating the canopy chlorophyll content [13], by using the red-edge position of the electromagnetic spectrum, which is the slope of the reflectance located between the red wavelength and the maximum reflectance in the Near-Infrared bands (NIR). It is a very narrow part of the spectrum, but its changes are very sensitive to the chlorophyll content and it can be thought as the boundary between chlorophyll absorption (Red) and leaf scattering (near infrared). The time of season when those spectral readings are made is an important parameter to consider for both early prediction of nitrogen deficiencies and its subsequent management. For example, on wheat the targeted growth stage might be around DC 31, which corresponds to the first node detectable at stem elongation, when quantify nitrogen stress on crops is useful for the nitrogen fertilisation. Raun [14] successfully used remote sensing for developed an algorithm that adjusts top-dress N application by integrating in-season prediction of wheat yield, PPNT, within season mineralisation rates and predicted crop N removal. The potential yield was estimated by two NDVI readings, collected between January and March, which were divided by the cumulative Growing Degree Days between the two dates. The determination of the potential yield in the field is done by using well fertilised reference crop. Sensors mounted directly on applicator machines are used to adjust nitrogen fertilisation in real time; the sensors read canopy colours of the field and apply the proper nitrogen rate based on the canopy colour of the well fertilised reference crop [15]. The use of well fertilised crops as a reference has limited use in rainfed agriculture. The reference crop is supposed to reflect the potential growth of a canopy in that particular environment; provided no stresses are present. Then, when the remote sensing is used elsewhere in the field, the differences in growth rates are quantified and the fertilisation is adjusted with the aim of increase the final yield. However, in rainfed agriculture, where water is the most limiting factor, the reference plot might not reflect the potential growth; water will limit it and an additional fertilisation will not increase the final yield. In rainfed environments there are two major problems for the assessment of canopy nitrogen with remotely sensed vegetation indices, namely the effects of soil reflectance and water stress. In addition, in these environments the presence of both water and nitrogen stress can cause confounding effects on the estimation of crop nutrient requirements because water deficiency can mask the crop spectral response for nitrogen stress through changes in reflectance patterns in the Near-Infrared (NIR) and middle infrared reflectance [16]. The use of thermal images along with reflectance measurements might help to improve the prediction for an in-season nitrogen application even though they do not completely remove the soil effects. Some indices have been developed for this particular purpose, such as the Canopy Chlorophyll Content Index, which is based on a planar domain approach, where two vegetation indices, the NDVI and the NDRE (Normalised Difference Red Edge), were used as a surrogate for canopy cover and leaf N. For instance, the combination of this index and some classical vegetation indices gave useful information regarding the degree of nitrogen stress [17]. Understanding the N fertilization efficiency might require the availability of long-term studies, because few years of field experiments might not reflect the potential crop response, due to variation in growing season rainfall. Process-oriented crop growth models can be useful to simulate the long-term effects of water and N stresses and their temporal interactions on daily crop growth and development rates through the growing season [18, 19]. They have been extensively validated and applied under a wide range of environmental conditions [20].

Crop Modeling

Crop simulation models have the potential to integrate the effects of temporal and multiple stresses interaction on crop growth under different environmental and management conditions [21, 22, 13]. The strength of these models is their ability to account for stress by simulating the temporal interaction of stress on plant growth each day during the season (Batchelor et al., 2002). However, crop simulation models cannot simulate every position in the field because of the costs associated with gathering data and the availability of detailed inputs. As a consequence, delineating zones within the field of similar crop response may provide the right amount of data to execute the model (Basso et al., 2007). Two case studies will be illustrated to quantify the risk associated in making N rate selection using crop models.

References

[1] Stuart et al., 2015 Bioscience 65,6, 571-578
[2] Cassman et al. 2002. Ambio 31: 132-140.
[3] Follett RF, Delgado JA. 2002. Journal of Soil and Water Conservation 57: 402-408.
[4] Peel et al. 2013. Biogeochemistry: 114: 121-134.
[5] Conley et al. 2009. Science 323:1014-1015
[6] Sambroski et al. 2009. Agron. J. 101, 800–816.
[7] Pierce, F.J., Nowak, P., 1999. Aspects of precision agriculture. Adv. Agron. 67, 1–85.
[8] Scharf, et al., 2006. Soil Sci. Soc. Am. J. 70, 2154–2160.
[9] Bundy and Andraski 2004. Agron. J. 96, 608–614.
[10] Vitosh, M.L., Silva, G.H., 1996. Soil Sci. Plant Analysis 27, 1137–1152
[11] Penuelas et al., 1994. Remote Sens. Environ. 48, 135–146.
[12] Carlson, T.N, Ripley, D.A., 1997. Remote Sens. Environ. 62, 241–252.
[13] Gitelson, A.A., Merzlyak, M.N., 1994. J. Photochem.and Photobiology 22, 247–252
[14] Raun, W.R., et al. 2001. Agron. J. 93, 131–138.
[15] Blackmer T.M., Schepers J.S., 1995. J. Prod. Agric. 8, 56-60.
[16] Rodriguez et al., 2005. Aust. J. Agric. Res. 56, 983–993.
[17] Barnes et al., 2000
[18] El-Shikha, et al 2007. Ag. Water Management 92, 183–193.
[19] Batchelor et al., 2002. Eur. J. Agron. 18, 141-158.
[20] Basso et al. 2007 Basso et al., 2007. Eur. J. Agron. 26, 82–91.
[21] Basso et al., 2016. Advances in Agronomy 136, 27-132
[22] Basso et al., 2001. Agric. Syst. 68, 97–112.
[23] Basso et al., 2011. Eur. J. 35 215– 222

[24] Basso et al., 2016b. Science of The Total Environment Vol. 545–546, 1,227–235

REFINED N-FERTILIZATION OF WINTER WHEAT

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Objectives

Nitrate (N) leaching into groundwater from agricultural sources has been identified as a major environmental issue within the European Union. Over-restrictive N fertilization is economically risky since it can cause reduced yield and baking quality. Hence, there is a need to adapted N fertilization planning to year-specific N demand of the crop. As the site-specific averages for yield and soil N supply are accessible to most producers, inter-annual variability of these values is the actual target of N fertilization planing.

In this context, we want to portrait a model supported automated online recommendation tool for N fertilization of winter wheat (*Triticum aestivum L.*). The tool is implemented at the ISIP internet platform (www.isip.de).

Method

The tool is based on the balance sheet method, modified by the mechanistic crop-soil model *HumeWheat* [1]. *HumeWheat* is used for the year-specific adjustment certain balance-sheet components. For this purpose actual and historical weather records are used for the constitution of a relative prognosis via projections and reference calculations [1].

Field trails were carried out in order to evaluate the tool at 5 locations in Lower Saxony over the last 5 years. A second evaluation based on N response curves derived from N rate experiments. This dataset contained 72 collective seasons and was carried out at seven federal states across Germany. For both evaluations, the available weather data was limited until end of May (last N application). The site specific N rate, recommended by the respective provincial authorities, served as a reference for both evaluations. The calculations of the reference rates considered mineral soil N content at spring (0-90cm), yield level (average yield over the last 5 years), preceding crop and expected protein content. In addition, the online tool uses soil texture, soil value (“Bodenwertzahl”), sowing date and a few input parameters which are available to every farmer. The evaluation covers yield and grain protein content, N rate and N balance surplus (difference between the amount of fertilized N and grain N export). For the monetary evaluation, net revenue was calculated at different N price scenarios.

Results

Compared to the reference, the online tools achieved a slightly enhanced average net revenue at Lower Saxony (+ 66€ per ha). Regarding the evaluation via N response curves, the average net revenue was identically to the reference. The same applied to the grain yields and protein contents. However at the first evaluation the average N input could be reduced by 6 kg N/ha. At the second evaluation the N input could be reduced by 8 kg N/ha, on average. The standard derivation of the N balance surplus was smaller compared to the reference (29/ 37 kg N/ha). Although the results are encouraging, the concept still needs further improvement and refining with particular regard to N form, gaseous N losses, tillage, and environmental objectives.

Conclusions

The combination of balance-sheet approach and crop-soil model allows the identification of year specific variation in fertilizer N demand. Therefore, this method can be seen as an additional important constituent in attaining a more effective N fertilization recommendation. However, the availability of accurate local weather data is an important precondition for year-specific adjustments.

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References

[1] Ratjen, A.M., Kage, H., 2015. Forecasting yield via reference- and scenario calculations. Comput. Electron. Agric. 114, 212 - 220. doi:http://dx.doi.org/10.1016/j.compag.2015.03.020

SENSING COINCIDENT NITROGEN DEFICIENCY AND WATER STRESS IN WHEAT

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Objectives

Precision agriculture has a large potential to yield more efficient and environmentally sound agriculture. It has primarily been geared towards site-specific application of fertilizers using on-the-go spectral reflectance sensors (e.g. N-Sensor) [1]. Varying plant water status influences the reflectance spectra, leading to the erroneous plant N content estimation, and therefore sub-optimal N fertilizer rates. The direct spectral detection of water-related information requires relatively expensive short-wave infrared detectors. The cost-effective visible and near-infrared spectra provides the information that is strongly convoluted with chlorophyll (nitrogen) and biomass signaling. Water stressed plants typically show a temperature rise [2], and thermal data may be used for water stress detection. The objective of the study was to improve detection of coinciding nitrogen deficiency and water stress in wheat crop in two steps: (1) by integrating spectral reflectance with thermal information and (2) by using numerically transformed spectral data only.

Method

As a part of two projects (“MULTISENS”, www.nibio.no/multisens and “STRESSLESS”, www.nibio/stressless) a field trial was designed for measuring stress in spring wheat, caused by N deficiency and/or sub-optimal water supply. The multi-seasonal experiment (2012 - 2015) was performed at Apelsvoll research station (60° 42’ N, 10° 51’ E, ca. 250 m a.s.l.). The field trial included varying N fertilizer rates at sowing (50, 70, 100 kg N/ha), and three water regimes (limited water supply by plastic shelters when precipitation, W-; natural water supply, W0; irrigation, W+). The design included six replicates of each treatment in 2 x 7.5 m treatment plots, with adjacent border plots to prevent from neighboring effects. The volumetric soil water content was monitored by TDR measurements and the weather parameters were recorded at the nearby weather station (100 m away). Canopy reflectance was measured at growth stage 32, by a portable field spectroradiometer (tec5 AG, Germany) with an effective spectral range of 400 - 900 nm, spectral resolution of 10 nm, and 51 aggregated bands. The instrument was operated at 1.5 m above the crop canopy with a field of view angle of 60°, and the measurements were performed from each corner of the plots. Thermal data was recorded with a calibrated analog Tau 320 thermal camera (FLIR, USA, resolution: 324x256 pixels, thermal sensitivity of 85 mK), from handheld setup or an airborne UAV platform. Immediately after radiometric measurements, 0.25 m^2 plant biomass samples were collected from each treatment plot and analyzed for moisture and N content. Data analyses were carried out using R (R Development Core Team). Spectral data was pre-processed by logarithm linearization, normalization for scattering effects and by taking the first derivatives using the Savitzky-Golay algorithm. The potential of treatment aggregation of the high dimensional spectral data was analyzed using Principal Component Analysis (PCA). The models estimating the canopy properties were build using Powered Partial Least Squares (PPLS) regression. The combined spectral-thermal analysis included combination of model parameters by means of Multiple Linear Regression (MLR). The model performance was analyzed by ratio of performance to deviation (RPD), R^2 and relative RMSE.

Results

The three water regimes affected the plant biomass and water concentration significantly, not influencing the N concentration. Plants with higher N fertilizer rate tended to have more biomass and higher concentrations of both water and nitrogen than less fertilized plants. There were substantial seasonal differences in biomass between the water treatments. In dry seasons (e.g. 2012) the W0 plots yielded similar amount of biomass to the W- plots, whereas in wet seasons (e.g. 2013) biomass in W0 and W+ was similar.

We noted a substantial variance in the reflectance data collected throughout the experiment. The variance was not evenly distributed in the function of wavelength, higher in the NIR range (700-900 nm) than in the visible part of the spectrum (400-700 nm). The canopy in the irrigated plants (W+) reflected up to 10% more radiant energy in the NIR then the plants with a limited water supply (W-). The effect of N treatment was less pronounced in the reflectance data, with a tendency towards higher reflectance with increasing N content throughout the spectrum. Pre-processing of the raw reflectance data leveled out the differences in variance across the spectrum. Using Principal Components Analysis we combined the correlating spectral bands into new variables, and the three first principal components contained over 95% of the total variance in the spectral data.

In the first step, we analyzed single-season datasets for separation between treatments. We found that: (1) the use of pre-processed reflectance spectra improved the separation; (2) it was easier to obtain the spectral separation between N treatments than W treatments. In order to improve the results, we included thermal data into our models [3]. By multiplying the normalized temperatures (higher for W-, lower for W+) with water-related PCA scores (PC1) it was possible to obtain a well-pronounced separation between all treatments. In a failed attempt to use the same procedure on multiple-season datasets we learned that raw thermal data tend to be dataset-specific and not robust enough for complex datasets.

Therefore, in the second step, the multi-seasonal analyses were conducted on spectral data only. We performed in-depth investigation of spectral data pre-processing methods to reduce between-seasonal data differences and included a targeted PPLS regression method to build quantitative models for plant properties estimation [4]. When combining the spectral information and the ground truth data we were able to calibrate multi-seasonal models which fitted well with measured nitrogen at RPD = 2.52 (R2 = 0.86) and water concentration at RPD = 2.35 (R2 = 0.84) in aboveground spring wheat biomass. The PPLS method was superior to the traditional index-based approach. The ongoing research involves validation of the modeling procedures based on spectral data and extending the scope of the models with additional data.

Conclusions

- By combining thermal and spectral data, it was possible to improve a single-season separation between treatments with different combinations of water stress and nitrogen availability in wheat.
- Raw thermal data are not robust enough for enhancing multi-seasonal datasets for coincident nitrogen deficiency and water stress.
- Spectral data pre-processing methods may be used to reduce between-seasonal data differences and improve the modeling of complex datasets.
- Powered Partial Least Squares regression is and efficient method to build quantitative models for plant properties estimation from wheat crop spectra when nitrogen deficiency and water stress coincide.

References

[1] Link, A., Panitzki, M., Reusch, S. 2002. Hydro N-Sensor: Tractor-mounted remote sensing for variable nitrogen fertilization. p. 1012-1018. In: Proc. Int. Conf. on Prec. Agric., 6th, Minneapolis, MN 14-17 July 2002 [CD-ROM].
[2] Jackson, R.D., Reginato, R.J., Idso, S.B. 1977. Wheat canopy temperature: a practical tool for evaluating water requirements. Water Resources Research 13, 651-656.
[3] Kusnierek, K., Korsaeth, A. 2013. Combining thermal and spectral data to account for water stress at split-fertilization of wheat. Poster at 9th Conference on European Precision Agriculture, Lleida, Spain, 7-11 July 2013.
[4] Kusnierek, K., Korsaeth, A. 2015. Simultaneous identification of spring wheat nitrogen and water status using visible and near infrared spectra and Powered Partial Least Squares Regression. Comput. Electron. Agric. 117, 200-213.

DETERMINATION OF FERTILISER REQUIREMENTS IN DAIRY PRODUCTION SYSTEMS BASED ON PASTURE NITROGEN CONCENTRATIONS

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Objectives

Early estimates of nitrogen (N) fertiliser requirements for pastures are desirable to ensure an adequate N supply for targeted pasture growth, as well as to minimise N losses. High spatial and temporal variability of both N supply by the soil and demand by the plant means that synchronising these is very challenging. The objective of this study was to determine optimum N fertilisation rates dependent on pasture N concentrations based on biophysical modelling. The approach, when linked to remotely sensed measurements of the nitrogen status of pasture plants, can be used adjust fertiliser management practices to temporal and spatial N demand.

Method

To determine optimum N fertilisation rates which will maximize plant growth based on the pasture N content and environmental conditions, a simulation study using the Agricultural Production Systems Simulator (APSIM), was set up. The APSIM model, with a refined version of the pasture module (AgPasture), which allowed N remobilisation to occur from all the different tissue stages, was used for an irrigated ryegrass pasture in the Canterbury region of New Zealand. All APSIM simulations for this study were derived from a base simulation by varying either the simulation year or fertilisation rate. The pasture simulated contained ryegrass only, which was harvested at a monthly interval down to a standing dry matter of 1500 kg/ha. The pasture was irrigated according to a centre pivot system, with the irrigation period from October to April, and a return period of 10 days. Irrigation was applied at a rate of 6 mm/d whenever the soil water deficit (SWD) in the upper 300 mm soil profile was ≥ 30 mm, and stopped when the SWD ≤ 5 mm. For the modified remobilisation procedure in AgPasture optimum N concentrations of 2.8 for mature and 2% for senescing tissue was used (Vogeler et al., 2016). Simulations comprised 10 different fertilisation rates (ranging from 10 to 100 kg N/ha), which were applied on the 15th of every month after harvesting at alternating rates, resulting in 90 different fertiliser treatment combinations. These were run for 20 consecutive years, giving a total of 1800 combinations of pasture N contents and pasture growth responses for each month. For the analysis pasture N concentrations were grouped into six different categories: Category 1: 2.0 to 2.4% N; Category 2: 2.5 to 2.8% N; Category 3: 2.9 to 3.2% N; Category 4: 3.3 to 3.6% N; Category 5: 3.7 to 4.0% N, and Category 6 > 4.0%. Based on statistical analysis, the optimum N fertilisation rate dependent on pasture N content and environmental conditions was determined.

Results

The harvested amount of pasture one month after fertilisation was, as expected, dependent on the pasture N concentration of the biomass prior to fertilisation. For example fertilisation in October at a rate of 60 kg N/ha gave an average yield of 3088 kg/ha when the pasture N content of the standing biomass ranged between 2.5 and 2.8% (Category 2), whereas an average yield of 3826 kg/ha was obtained when the N content ranged between 3.7 and 4% (Category 5).
These yield response curves for the different N categories were fitted with the Mitscherlich equation, which is widely used in agricultural science to relate yield response to nutrient supply. The equation can be written as:

$$Y=Ymax- (Ymax-Y0\,)\exp(-\beta Nr)$$

where Y is the dry matter yield (kg/ha), Ymax is the maximum or potential yield under the climatic and edaphic conditions, Nr is the rate of N applied (kg/ha), Y0 is the yield when no N is applied in the form of an external source (Nr = 0), and β is an ‘activity’ coefficient which is a measure of the availability of the applied nutrient to the crop. The maximum yield is an important parameter in the Mitscherlich equation and is assumed to be constant. The value for Ymax for the growth conditions in October/November was set as 4200 kg DM/ha, estimated from the simulated yield responses of the high N content category, and assuming that under irrigation N is the only limiting factor.

The fitted Mitscherlich response functions indicate that value of Y0 increases with increasing pasture N concentration of the standing biomass. Note that these different N categories are not only a measure of pasture N status, but also reflect the N supply by the soil. These response functions were used to determine optimum N fertilisation rates depending on the pasture N concentration of the standing biomass, which provide 90% of the maximum yield. For example in October, optimum fertilisation rates were estimated to be 160 kgN/ha if the pasture N content was below 2.4%. However, at much higher pasture N contents (between 3.6 and 4%) only 60 kg N/ha was required to obtain the same yield, reflecting the much higher supply of N by the soil.

Conclusions

The simulation study has identified optimum N fertilisation rates which provides 90 % of the maximum yield one month after fertilisation in October, based on the pasture N concentration of the standing biomass. Optimum N fertilisation rates decreased from about 160 kg/N ha at very low pasture N concentrations (N Category 1: 2.0 to 2.4%) to about 60 kg N/ha at high pasture N concentrations (N Category 5: 3.7 to 4%). The approach, based on biophysical modelling to determine optimum N fertilisation rates dependent on N pasture N concentrations seems promising, but needs to be extended to different environmental conditions, and validation is required before the approach can be used to help adjusting fertiliser management practices to temporal and spatial N demand based on the nitrogen status of the pasture.

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APPLICATION OF A NITRIFICATION INHIBITOR (PIADIN®) ALONG WITH SLURRY USING STRIP TILL APPROACH FOR OPTIMIZING N FERTILIZER EFFICIENCY – LABORATORY AND FIELD RESULTS

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Objectives

Slurry application bears the risk of loss of nitrogen (N) in form of ammonia volatilization (NH3), leaching of nitrate (NO3-) and nitrous oxide emissions (N2O). Application in strips about 7 cm under maize seeds (strip till) for slurry-based fertilization considerably reduces the loss of gaseous NH3. Otherwise, strip till approaches increase the risk of NO3- and N2O loss. However, a concomitant application of nitrification inhibitors (1H-1,2,4-triazole/3-methylpyrazole e.g. PIADIN®, SKW Piesteritz GmbH, Germany) which delays the transformation of ammonium (NH4+) into NO3- may significantly reduce this risk. A combined application of strip till and nitrification inhibitor (NI) might therefore represent an effective tool of N-loss mitigation with respect to slurry application. The impact of a combined approach of strip till and NI application was evaluated concerning soil NO3- formation and soil N2O release at laboratory scale as well as concerning yield and N uptake at field scale.

Method

Lab experiments (without crops) were based on soil boxes (0.75 m width, 0.4 m height, 0.1 m thick) using a loamy sand (60 % WFPS). Width represents the distance of strip till application for maize and, when slurry is applied at the center of a box, the impact zone on both sides of a single slurry line depot. Three different treatments have been studied in parallel (repeated three times in succession - Exp. I to III):

1) unfertilized control, 2) slurry application without PIADIN® and 3) slurry application with PIADIN®. Used cattle slurry was applied equivalent to 160 kg N/ha (= 40 m³/ha). Liquid formulated NI was applied equivalent to 6 L/ha. All treatments were pre-incubated for 2 weeks. Then frozen slurry (cylindrical shape, Ø 8 cm) was put manually into the soil (depth 15 cm). Afterwards N2O release at soil surface was analyzed over a period of 4 weeks by an automatic steady-state approach using a gas chromatograph coupled online to 15 emission chambers (1.5 h measuring interval per treatment). Chambers (inner volume 0.26 L / area 40 cm²) were placed at the center as well as at both sides of slurry location (12.5 and 25 cm). NO3- concentration in soil solution below slurry application depth was analyzed twice a week (6 samplings positions per treatment) by using Rhizon samplers (www.rhizosphere.com).

Field trials growing silage maize (randomized block design, 4 replicates) were conducted on sandy loam and loamy sand, respectively, in 2014 and 2015. Four treatments were tested 1) slurry shallow incorporation, 2) slurry strip till placement, 3) slurry strip till placement with 3 L/ha PIADIN®, 4) slurry strip till placement with 6 L/ha PIADIN®. Slurry applications were equivalent to 100 and 63 kg plant available N/ha, respectively (= 25 m³/ha). Slurry shallow incorporation and strip till placement were in depths of 3-5 and 17-18 cm, respectively. The distance of strip till application was 75 cm adjusted accordingly sowing row distance of maize. All applications occurred in March, respectively, approx. four weeks before sowing depending on weather conditions. Yield and N uptake were determined at harvest in September.

Results

Soil NO_3^- formation – In all three lab experiments it was shown that a combined application of strip till and NI significantly delayed the slurry-based formation of NO_3^- for at least 4 weeks. While the NO_3^- concentration around the uninhibited slurry increased by a factor of ten (up to 658±53 mg NO_3^--N/L), NO_3^- concentration around the NI-treated slurry increased only by a factor of two (up to 178±51 mg NO_3^--N/L).

Soil N_2O release – In two of three lab experiments (I and III) it was proved that a combined application of strip till and NI significantly reduced soil N_2O release compared to a strip till application using uninhibited slurry. In Experiment II soil N_2O release was low in all three treatments, most likely due to higher soil density and soil moisture. On the one hand, this promoted N_2O reduction to N_2 (by denitrification) and, on the other hand, hampered N_2O transport towards the atmosphere due to diffusional constrains within the soil matrix. This assumption is supported by the observed soil NO_3^- concentration, which reveals a general effectiveness of the applied inhibitor in all three experiments and simultaneously discloses that NO_3^- was always sufficiently available for N_2O production in the uninhibited slurry treatments. Moreover, in all three experiments soil N_2O release in the NI-treatment was always equally low or even lower as in the unfertilized control. Within 28 days after slurry application the cumulative N_2O loss (average of three replicates for each treatment) of uninhibited and NI-treated slurry reached 359 and 77 %, respectively, of the soil N_2O loss of the unfertilized control treatment (164±25 g N_2O-N / ha 28 d).

Silage maize yield – Strip till placement of slurry significantly improved the yield by 1.1 t/ha compared to shallow incorporation of slurry. Yield increased additionally in tendency by 0.4 and 0.8 t/ha when strip till was combined with NI at 3L/ha and 6L/ha, respectively.

N uptake – In field experiment 2014, N uptake by silage maize was 16 kg N/ha larger when slurry was strip tilled compared to shallow incorporation (non-significant). Furthermore, a significant increase of N uptake of 33 kg N/ha was observed with the combination of strip till and NI compared to shallow incorporation. An additional increase in N uptake by 6…17 kg N/ha was achieved with the combined use of strip till placement and NI compared to strip till without NI in the experiments 2014 and 2015.

Both years of field trials were affected by limited rainfall in spring. Thus, higher impact of NI could be expected under wetter soil conditions.

Conclusions

Based on the results of lab experiments, it can be concluded that under leaching conditions a combined use of strip till placement and the nitrification inhibitor PIADIN® could reduce the loss of slurry-based N in form of NO_3^- and hence, would prevent negative impacts on the environment and simultaneously increase the nitrogen use efficiency of plants. Furthermore, using a nitrification inhibitor significantly reduces the risk of N_2O loss after slurry application and therefore, would prevent additional negative impacts on earth's atmosphere.

Finally, this results in benefits of yield and N uptake and also contributes to an increased N efficiency of liquid manure application. Therefore, strip till placement combined with application of a nitrification inhibitor (e.g. PIADIN®) represents an efficient tool to meet both, economic and ecological requirements facing the crucial challenge within the framework of sustainable intensification approaches.

PLANT-MEDIATED NITROGEN CYCLING IN AGRICULTURAL SYSTEMS

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Background

Humans have more than doubled the rate of reactive nitrogen (N) creation over the past 50 years, primarily through fertilizer applications to agricultural systems [1]. In contrast to the relatively closed cycling of N in unmanaged ecosystems, the N cycle in agroecosystems is an open system with large fluxes in via fertilizers and amendments and large fluxes out via harvested crops as well as significant losses to the surrounding environment. Fertilizer N use efficiency (NUE) is often less than 50% for major grain crops despite decades of effort to improve efficiencies and reduce losses [2]. Efforts to improve NUE have primarily focused on improving inorganic fertilizer delivery to crops through improvements in timing, placement, form, and application rates [3]. Even under well fertilized conditions, however, most field crops acquire about half of their nitrogen from the mineralization of soil organic matter [4]. To address growing demands for food with reduced environmental impacts, new strategies are needed that leverage plants in managing N cycling from both inorganic fertilizers and the mineralization of soil organic matter pools. Demonstrated and emerging strategies with potential to reduce N losses include retaining inorganic N through the use of cover crops and managing microbially-mediated N transformations to improve NUE of agricultural systems.

Part 1. Improving N retention with cover crops

Increasing plant diversity in space and time has the potential to improve N retention and recycling in agroecosystems. Nitrogen losses via leaching from temperate cropping systems are temporally variable. Most N leaching losses occur in the off-season between cash crops. Cover crops, or catch crops, provide a carbon sink for residual fertilizer N during this off-season period with the potential for substantial reductions in N leaching losses. From a simulation of a 3-year crop rotation with and without cover crops, the cover crop-based system reduced N leaching by 32% [5]. These results are supported by other meta-analyses of field studies [6]. In addition, cover crops have the potential to provide many other services, such as erosion prevention, soil carbon accrual, and mycorrhizal colonization, which also contribute to more efficient nutrient cycling [5]. However, not all cover crops are created equal and there is a growing interest in cover crop mixtures to provide multiple functions within cropping systems. For example, non-legumes reduced potentially leachable soil nitrate by 85 to 97% while legumes had no effect on leachable soil nitrate in comparison with a no cover crop control in a 2-year cover crop study comparing 8 single species and 9 mixtures [7]. However, maize (*Zea mays*) yields following the cover crops were highest following legume cover crop species in pure stands or in mixtures due to their capacity to supply nitrogen. Mixtures of cover crop functional types have the potential to balance N retention and provisioning services.

Part 2. Plant mediated cover crop decomposition

Increasing soil organic matter pools also has the potential to benefit N retention and recycling, but only if we can improve management of N mineralization dynamics. The black box surrounding plant-microbe interactions that mediate rhizosphere processes is opening with new methods, tools, and understanding. We can leverage this understanding to improve N management. Plants allocate up to 10% of carbon to root exudates [8], which can stimulate soil organic matter and litter decomposition. We conducted field and greenhouse experiments to quantify the relative impact of maize belowground carbon allocation on cover crop litter decomposition rates. We used the natural abundance of stable isotopes to distinguish between maize-derived C4- carbon and C3-derived carbon (Figure 1). Using litterbags, we measured the decomposition rates of red clover (*Trifolium pratense*) and cereal rye (*Secale cereale*) root and shoot litter in the presence or absence of maize plants. In both studies, maize accelerated decomposition rates of N-rich cover crop litters. In the field experiment, maize increased the decomposition of N in clover litter by 19% compared to rye litter and a no-maize control. This resulted in greater maize N uptake and biomass compared to maize grown in the absence of a cover crop. In the greenhouse experiment, maize increased root biomass in the presence of cover crop litter and increased decomposition of N-rich litter from clover shoots and roots. Our results suggest that there is a positive feedback between organic matter quality and crop belowground carbon allocation. Increasing our understanding and intentional management of these processes has the potential to tighten N cycling processes.

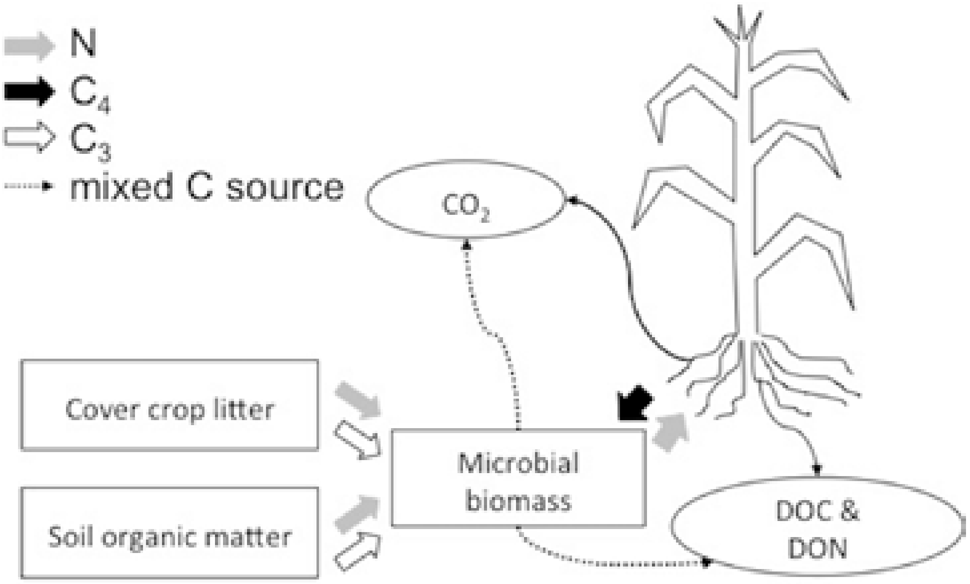

Figure 1. Measured sources and sinks of carbon and nitrogen in field and greenhouse experiments to quantify crop effects on cover crop litter decomposition rates.

Summary

The use of cover crops and improved understanding of plant-mediated decomposition and N mineralization dynamics provide opportunities to increase internal N cycling in agroecosytems. To take advantage of these opportunities, areas for future research include identifying the best cover crop mixtures for different management scenarios and improving our understanding of how crop genotypes influence rhizosphere processes and N cycling dynamics. Together, these strategies offer opportunities to improve NUE and support crop productivity through reducing, reusing, and recycling N inputs to agricultural systems.

References

[1] Robertson, G. P., & Vitousek, P. M. 2009. Annual Review of Environment and Resources, 34, 97-125.
[2] Zhang, X., Davidson, E. A., Mauzerall, D. L., Searchinger, T. D., Dumas, P., & Shen, Y. 2015. Nature, 528(7580), 51-59.
[3] Quemada, M., Baranski, M., Nobel-de Lange, M. N. J., Vallejo, A., & Cooper, J. M. 2013. Agriculture, ecosystems & environment, 174, 1-10.
[4] Gardner, J. B., & Drinkwater, L. E. 2009. Ecological Applications, 19(8), 2167-2184.
[5] Schipanski, M. E., Barbercheck, M., Douglas, M. R., Finney, D. M., Haider, K., Kaye, J. P., White, C. 2014. Agricultural Systems125, 12-22.
[6] Tonitto, C., David, M. B., & Drinkwater, L. E. 2006. Agriculture, Ecosystems & Environment 112(1), 58-72.
[7] Finney, D. M., White, C. M., & Kaye, J. P. 2016. Agronomy Journal, 108(1), 39-52.
[8] Kuzyakov, Y., & Domanski, G. 2000. Journal of Plant Nutrition and Soil Science, 163(4), 421-431.

NITROGEN BUDGETS OF ORGANIC AND CONVENTIONAL CROPPING SYSTEMS: SIGNIFICANCE OF SPECIFIC INPUTS AND OF SOIL NITROGEN STOCKS

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Objectives

Organic and conventional cropping systems differ in the nature and amounts of nitrogen (N) inputs, which may affect efficiency and sustainability of N use. In the DOK (bio-Dynamic, bio-Organic, Konventionell) field experiment, organic and conventional cropping systems have been compared since 1978 [1]. Simple soil surface N budgets with subtraction of N exports via harvested products from N inputs via manure and/or mineral fertilizers resulted in negative balances, suggesting soil N depletion in all systems [2]. However, in those estimates the symbiotic N2 fixation by soybean and clover grown in the trial had not yet been included. These inputs have now been measured [2, 3] and have been integrated into a soil system budget [4]. We here present these budgets, discuss their components and examine their impact on the soil N stocks.

Method

We included the following treatments of the DOK field experiment: non-fertilized control (NON) which received no fertilizer input since 1978; conventional control (MIN) with exclusively mineral fertilizers since 1984 (unfertilized from 1978 to 1984); bio-organic (ORG) system receiving slightly aerobically rotted farmyard manure and slurry; and the conventional system (MINORG) with stacked farmyard manure and slurry as well as mineral fertilizers. The fertilized treatments MIN, ORG and MINORG received nutrient forms and amounts that are typical for the respective cropping system.

Nitrogen inputs were estimated in kg ha^{-1} yr^{-1} for the period 1978-2006 as the sum of N inputs by organic and mineral fertilizers, symbiotic N2 fixation, seeds N, and atmospheric N deposition [4]. Average annual inputs with fertilizers were taken from [2]. Inputs of N fixed in grass-clover leys were estimated based on two years lasting field measurements of N2 fixed in clover shoots and N transfer to the associated grasses [2]. Fixed N contained in clover roots was estimated considering a shoot to root N ratio of 2.46 [5], using clover shoot biomass produced during one season per crop rotation period and the same proportion of N derived from the atmosphere (%Ndfa) for roots as for shoots. The N2 fixation in soybean shoots was calculated using %Ndfa obtained by [3] and soybean yields of [6]. Fixed N in roots was estimated using a soybean shoot to root N ratio of 1.63 [5] and same %Ndfa as in shoots. The N added by seeds was calculated from average sowing/planting density and N concentrations of these materials; N depositions were from [7].

Total N outputs were calculated as sum of N exported by agricultural products [2] and of N losses to the environment. Losses were estimated by [4] based on studies with 15N labeled organic and mineral fertilizers [8] and soil N stock changes of NON over time using N concentrations from [7] and [2].

Results

The total N inputs (kg ha^{-1} yr^{-1}) were lowest for NON (82) and highest for MINORG (250), with intermediate values for ORG (219) and MIN (184) [4]. This was due to mineral and/or manure N inputs in MINORG (155), ORG (107) and MIN (93). Symbiotic fixation made significant inputs for all treatments, ranging from 47 (NON) to 78 (ORG) kg ha^{-1} yr^{-1} or 24% (MINORG) to 57% (NON) of total N input. This underlines the contribution of legumes cropped during two to three years of the seven years lasting crop rotation. Estimated N deposition was 32 kg ha^{-1} yr^{-1} and seed N input was less than 3 kg ha^{-1} yr^{-1} for all treatments.
Total N outputs exceeded the total N inputs for all treatments. They ranged from 154 to 323 kg ha^{-1} yr-^{1} [4]. The outputs were largely determined by N withdrawal by harvested products, which on average (kg N ha-1 yr-1) were 144 in NON, 207 in ORG, 218 in MIN and 248 in MINORG. The harvested N of all fertilized

treatments clearly exceeded the N input by mineral and/or organic fertilizers, and even exceeded the sum of fertilizer and symbiotically fixed N, indicating overall high N use efficiency. Losses of N were estimated to be between 10 (NON) and 75 (ORGMIN) kg ha-1 yr-1 and were somewhat greater in systems receiving organic fertilizers [8].

The resulting balances (difference between total inputs and total outputs) were negative for all treatments [4]. Estimated values (kg N ha^{-1} yr^{-1}) were -72 (NON), -82 (MIN), -50 (ORG) and -73 (MINORG). These estimates were greater than reductions in soil N stocks (kg N ha^{-1} yr^{-1}) in the 0-50 cm soil layer of MIN (-29) and ORG (-18) deduced from soil N concentrations measured in samples taken in 1977 and 2003 [7]. This might be because some N leached to deeper layers might have been taken up by crops and thus been transferred back to the topsoil. Furthermore, symbiotically fixed N inputs might be somewhat underestimated.

The estimated budgets and measured soil N stock changes suggest that all studied cropping systems deplete soil N reserves on the long run. One explanation could be the weak stabilization of soil organic matter (SOM) in aggregates at this site [9], which sustained crops yields by mineralization of SOM. The weak stabilization could be related to the frequent soil ploughing in all treatments. Still, measured soil N concentrations were greater in ORG that regularly receives organic inputs than in MIN [2] and the decrease in measured soil N stocks was significant only for MIN but not for ORG [7]. This underlines the importance of organic matter input to maintain soil N stocks.

Conclusions

The N budgets of all studied cropping systems were negative, suggesting soil N depletion in the long run. Sustainable soil N management in addition to organic fertilizer inputs might at this site require reduced soil tillage. Symbiotic N fixation was a significant input for all cropping systems. Belowground N input by clover is currently quantified in more detail and mechanisms of legume N stabilization in soil are elucidated, which is needed to understand the loss potential of different N inputs. The significance of deep rooting crops in recovering leached N from deeper layers should as well be investigated.

References

[1] Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P.Niggli, U., 2002. Science 296, 1694-1697.
[2] Oberson, A., Frossard , E., Bühlmann, C., Mayer, J., Mäder, P.Lüscher, A., 2013. Plant and Soil 371, 237-255.
[3] Oberson, A., Nanzer, S., Bosshard, C., Dubois, D., Mäder, P.Frossard , E., 2007. Plant and Soil 290, 69-83.
[4] Frossard, E., Buchmann, N., Bünemann, E.K., Kiba, D.I., Lompo, F., Oberson, A., Tamburini, F.Traoré, O.Y.A., 2015. SOIL 2, 83-99.
[5] Unkovich, M., Baldock, J.Peoples, M., 2010. Plant and Soil 329, 75-89.
[6] Jossi, W., Gunst, L., Zihlmann, U., Mader, P.Dubois, D., 2009. Agrarforschung 16, 296-301.
[7] Bosshard, C. 2007. Diss. ETH Zurich.
[8] Bosshard, C., Sørensen, P., Frossard, E., Dubois, D., Mäder, P., Nanzer, S.Oberson, A., 2009. Nutrient Cycling in Agroecosystems 83, 271-287.
[9] Bosshard, C., Frossard , E., Dubois, D., Mäder, P., Manolov, I.Oberson, A., 2008. Soil Science Society of America Journal 72, 949-959.

DESIGNING AND EVALUATING ARABLE CROPPING SYSTEMS WITH CASH AND COVER CROP LEGUMES IN SOLE CROP AND INTERCROP TO IMPROVE NITROGEN USE EFFICIENCY

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Objectives

Increasing concern about climate change and environmental impacts requires transformation of cropping systems by for example introducing more legumes (grain legumes or cover crop forage legumes) to increase benefits from N2-fixation and break crop effects. Legumes could be grown alone or in intercropping known to use resources more efficiently when species do not compete for exactly the same niche.

For instance, correct rotational position of legumes needs to be carefully analysed to design relevant solutions maximizing their benefit. The main objective of our work was to design and evaluate prototypes of arable systems including legumes using jointly field experiments and crop modelling. This paper aimed at synthetizing: 1) impact of sole grain legume at the rotation level, 2) potential of grain legume intercrops for improving yield and cereal protein content and 3) potential of cover crops including intercropped forage legume to achieve simultaneously nitrate capture and green manuring ecosystem services.

Method

Two 6-year field experiments were initiated at INRA Toulouse (SW France) from 2003-04 to study the rotational effects of grain legumes (in sole crops and intercrops) and cover crops (green manure or catch crop function) according to N use efficiency and medium-term soil fertility. The cropping system design was based on a three-year rotation in low input system with each crop grown each year allowing climatic repetition. Six rotations were compared, differentiated by the frequency of legumes in the rotation and the presence or absence of cover crop between cash crops. Crop management was based on decision rules in order to adjust technical acts to the soil and crop status and in particular adjusting N application rates to the preceding crop. Simulations at the rotation time scale were carried out using the STICS soil-crop model. The main processes involved in the water and N dynamical budgets are taken into account at the same time [1].

Complementary experiments with intercrops were established from 2005-06 with a large range of combinations (durum wheat, bread wheat or barley intercropped with pea or faba bean) with various cultivars, sowing densities and N treatments leading to a large range magnitude and dynamics of N availability. Grain yield and cereal grain protein content as a quality criteria were used to evaluate the efficiency of the intercrops over the sole crop. The percentage of N derived from N2-fixation of legumes was estimated with 15N dilution method altogether with nitrogen content in plant and soil to determine N balance [2].

In addition others experiments were conducted in three French experimental sites with contrasted climate conditions and soil characteristics for analysing cover crops effects. Ten cover crop species (five legumes and five non-legumes) with a rapid growth rate and contrasted shoot/root architectures were evaluated in sole crops and in bispecific substitutive mixtures and compared to a bare soil as control. Biomass, N acquisition, C:N ratio and soil mineral-N were measured and ecosystem services of N management were assessed using both experimental and modelling data [3].

Results

Winter and spring legume preceding crop show positive effects on durum wheat, due to: i) higher soil mineral-N availability at wheat sowing and ii) potentially breaking of cereal diseases cycles. However, higher soil mineral-N levels both at harvest and in November after legume crops increased the potential risk of nitrate leaching which was efficiently reduced by the introduction of cover crops. Simulations of nitrate leached during the whole drainage period after autumnal destruction of cover crop mixtures did not differ significantly from those after non-legume sole crops and remained significantly lower than those under bare soil, especially for mixtures with turnip rape which benefitted greatly from being in mixtures. Legume sole crops were less efficient to reduce N leaching but their effect was still significant in comparison to bare soil which confirms that concerning nitrate leaching it is better sowing a legume cover than maintaining a bare soil. The irrigated soybean crop did not increase the risk of nitrate leaching under the present growing conditions, mostly due to: i) a late growing cycle, and ii) an efficient N uptake of mineral-N coming from soil mineralization, in complement to N2-fixation. Cover crops were particularly efficient during wet winters because the more the drainage volume, the more the reduction of nitrate leaching and nitrate concentration in leached water. N release from cover crop residues could be sufficient to compensate in a great part the pre-emptive competition for soil mineral-N when destroyed before winter. Overall, prediction of mineralized-N from cover crop residues was significantly higher for mixtures than for non-legume sole crops demonstrating the green manure ecosystem service.

Intercrops experiments showed that the total intercrop grain yield was almost always higher than that of the mean sole crop (3.3 vs. 2.7 Mg ha-1 respectively) and similar result was found with accumulated N (121 vs 101 Kg N ha-1 respectively) with a proportion of cereal at harvest higher than 50%. Our results confirmed that intercropping was more efficient than sole cropping without N fertilization or when N was applied late during cycle mainly due to dynamic complementarity: i) for light use (up to 10%) and ii) in N sources acquisition. Cereal grain protein concentration was significantly improved in intercrop compared to the respective sole crop (11.1% vs. 9,8% respectively) and the lower the sole crop value the higher the increase in the intercrop. This increase in intercropping was due to: i) a lower cereal grain yield in intercrop than in sole crop (1.9 vs. 2.9 Mg ha-1 respectively) and ii) a quite similar (ca. 90%) amount of available soil N for the cereal in both systems because of a high legume N2-fixation rate in intercrop (75% compared to 62% for the sole cropped legume).

Conclusions

Altogether with legume sole crops, intercropping a legume and a non-legume is interesting both for grain production and cover crops ecosystem services to design innovative cropping systems. This is due to the complementarity between species in improving use of N-resources especially in low available N systems. Indeed, bispecific cover crop with a legume can provide good compromises between nitrate capture and green manuring ecosystem services by recycling the soil mineral-N in good synchrony with the succeeding cash crop. In a similar way, intercropping for grain production provided compromises between grain yield improvement, cereal grain protein content increase and proportion of the two species at harvest. However, a number of factors still needs to be optimized in order to propose optimized future cropping systems including intercrops like: i) species and cultivars, ii) correct rotational position to not increase pests and diseases and also iii) sowing practice (e.g. alternate row sowing or mixture within each row, density of each component, width between rows,…). These choices depend on specific goals like for grain production the maximum total yield, the global protein production or the highest wheat grain protein content while for cover crops the choice of a mixture must be adapted according to site’s soil and climate conditions, priorities of fallow-period management and services desired.

[1] Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environnement 212, 1-12. http://dx.doi.org/10.1016/j.agee.2015.06.014

[2] Bedoussac, L. et al. 2015. Agronomy for Sustainable Development 35, 911-935. http://dx.doi.org/10.1007/s13593-014-0277-7

[3] Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364. http://dx.doi.org/10.1007/s11104-015-2734-8

NITROGEN - LOSS, SOURCE, TRANSFORMATION AND ATTENUATION WITHIN AN INTENSIVE DAIRY FARM IN SE IRELAND

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Objectives

The presence of an artificial land drainage network under an intensive grassland farm is assumed to be detrimental to water quality. This assumption automatically negates the notion of "sustainable intensification". However, on the present site drain outlet nitrate concentrations remain below European Union (EU) maximum admissible concentrations (11.3 mg NO_3- NO_3^--N/l). The objective of the present study was to understand the drivers contributing to the low nitrate occurrence through investigating the: 1) farm N balance 2) long term (10 year) spatial and temporal distribution of groundwater and drainage nitrate occurrence and 3) N source, transformations and attenuation capacity at various levels within the subsurface.

Method

The study was carried out on a derogation dairy farm (123 ha, 2.5 LU per hectare) in SE Ireland. Mean annual rainfall on site is 1037.5 mm, with maximum intensity between September and November. Field work enabled the formation of a digitised soil drainage class, in-field and open ditch drainage network and borehole network map. For the purposes of this study an existing 10 year monthly dataset incorporating groundwater biogeochemical data and a more limited subsurface drainage dataset (2 years) was combined with more in-depth data collection spanning the entire subsurface and surface system in 2014. Water samples were collected, filtered and analysed for H_2O and NO_3^--N isotopic composition, $^{2/1}$H and $^{18/16}$O and $^{15/14}$N and $^{18/16}$O respectively to elucidate provenance, N sources and N-transformational processes. Additionally, for some subsurface locations with detectable NH_4^+-N and dissolved N_2O concentrations, δ^{15}N-NH_4^+, δ^{15}N-N_2O and δ^{18}O-N_2O were examined. δ^{18}O and δD signatures for H_2O were analysed on a Los Gatos liquid water isotope analyser. Quantification of δ^{15}N and δ^{18}O of the N_2O produced from NO_3^- by *Pseudomonas chloraphis* (and from dissolved N_2O), was isotopically analysed through mass spectrometry. δ^{15}N signature for NH_4^+ was obtained through the method described by [1] while N_2O, derived by a BrO^- oxidation of NH_4^+ to NO_2^- followed by reaction with sodium azide to create N_2O, was measured on DeltaPlus IR-MS. Additional chemical analysis and dissolved gasses quantification were carried out to evaluate the extent of N-speciation.

Results

The annual N balance for total N-input was 312 kg N/ha with 106 kg N/kg of total N leached. Due to heterogeneity of the soil, NO_3^--N concentrations were both spatially and temporally variable (2004-2014), averaging 4.00 mg NO_3^--N/l with maximum concentrations of 25.31 mg NO_3^--N/l found in groundwater. Mean drainage outlet concentrations were 3.44 mg NO_3^--N/l. Three groups based on long term data were established across the site: Low, NO_3^--N concentration below significant contamination level (5.65 mg NO_3^--N/l); High, NO_3^--N concentration above a significant contamination level and Other, NH_4^+-N concentration above MAC (0.15 mg NH_4^+-N/l). Low group wells where concentrated in three main regions of the farm and corresponded with random in-field artificial drainage installation in poorly drained low permeability soils. The three groupings showed average dissolved N_2O values of 0.022, 0.037 and 0.009 mg/l respectively and excess-N_2 values of 3.69, 0.55 and 1.49 mg/l respectively. Low group wells showed a high N_2-excess ($p<0.05$) and low dissolved N_2O ($p<0.001$) concentrations suggesting a higher rate of complete denitrification in artificially drained areas. Isotopic compositions showed low spatial variability (ranging between -7.2 and -3.4‰ for H_2O-δ^{18}O and between -40.4 and -32.4‰ for H_2O-δD) and suggested drainage water consisted of both precipitation and groundwater. NO_3^- isotopic signatures were characterised by average values of 14.2‰ for δ^{15}N-NO_3^- and 9.7‰ for δ^{18}O-NO_3^-. Groundwater NO_3^- isotopic composition clustered within the nitrification box along a 1:1 slope indicating that denitrification is the main process responsible for the variation of NO_3^-

isotopic signature across the farm exhibiting an organic fertiliser signature [2]. Assuming a single source and isotope enrichment factor on the farm, the degree of enrichment in both $\delta^{15}N\text{-}NO_3^-$ and $\delta^{18}O\text{-}NO_3^-$ is directly proportional to the degree of denitrification. The importance of attenuation seemed therefore to reflect the rate of the denitrification process with group "Low" presenting higher attenuation by denitrification (19.9‰ for $\delta^{15}N\text{-}NO_3^-$ and 12.0‰ for $\delta^{18}O\text{-}NO_3^-$) when compared to group "High" ($p<0.01$). Additionally the constancy of the temporal signature points to an intrinsic denitrification ability within the poorly drained soil consistent with denitrification hot spot zones rather than rapid and sporadic processes. This highlights that the installation of random drainage systems, which are non-uniform tiles have not disrupted the natural bioremediation in these areas. This information should guide future positioning of subsurface drainage systems on landscapes with heterogeneous drainage classes. The use of a wider set of analyses uncovered distinct signatures of ammonia volatilization or atmospheric and synthetic fertilizer sources for some locations and identified NH_4^+ as a source of possible contamination. However, when these samples were analysed for conditions conducive to DNRA, non-measurable patterns for NH_4^+, N_2O and/or NO_3^- isotopes were produced that differ from the denitrificational ones.

Conclusions

Poorly drained areas of an intensive grassland farm in SE Ireland acted as "denitrification hotspots". A random in-field and drainage ditch network of 10 km was installed exclusively on these poorly drained areas. Other un-drained areas of the farm had a low attenuation capacity with a high nitrate signal. The drainage system delivered attenuated nitrate to a connected receiving water body below EU maximum admissible concentrations. During the site investigation phase of any land drainage design, determining the subsurface attenuation capacity should be as important as elucidation of soil physical and hydraulic parameters. Such systems have potential to improve surface farming conditions whilst achieving water quality targets.

[1] Zhang, L., Altabet, M.A., Wu, T.X., Hadas, O., Analytical Chemistry, 2007, 79, 5297.
[2] Kendall C., in Isotope Tracers in Catchment Hydrology (Eds.: C. Kendall, J. J. McDonnell), Elsevier Science B.V., Amsterdam, 1998.

NITROGEN USE EFFICIENCY – AN IMPORTANT INDICATOR FOR THE UTILIZATION OF NITROGEN IN CROP PRODUCTION

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Objectives

Nitrogen use efficiency is frequently proposed as a measure for the effectiveness of environmental regulations regarding nitrogen fertilizer application. Nitrogen use efficiency (NUE) should be an indicator for the quantity of fertilizer nitrogen absorbed by the crop. It can be defined as the ratio between the amount of fertilizer N applied and the amount of N removed with the harvest. However, in practice different definitions of NUE are used. Even more important than the way of calculation is the interpretation of the results. Examples from field trials show that very high as well as low NUE values may represent unsustainable crop production systems and that the interpretation of NUE values requires a sound qualification scheme.

This study examines (1) how NUE can be defined and determined, (2) how NUE depends on the period over which different fertilization schemes are tested, and (3) how these results can be interpreted and qualified

Method

NUE was defined and calculated according to the recommendations of the EU Nitrogen Expert Panel [1]. This methodology was applied to different N fertilizer experiments in which N application rates as well as N forms were investigated. The experiments were carried out with winter cereals in Germany and the UK covering different time scales ranging from annual trials during one cropping season to medium-term experiments comprising one or more rotations up to long-term field trials such as the Broadbalk Experiment in Rothamsted that started more than 150 years ago and is still running.

For estimating and presenting NUE of a crop production system, data and information are required about (1) the total N inputs into a system and the N output in harvested products, (2) the time span of the analyses, and (3) possible changes in the stock of N in the system. The NUE indicator can then be presented as a two-dimensional input - output diagram. This allows the presentation of NUE together with N output (as a proxy for yield) and N surplus (representing environment damage) in a coherent manner, together with possible reference or target values for the indicators.

Results

The data from the experiments show the usefulness of the NUE indicator concept developed by the EU N Expert Panel. Fertilization trials with different duration show clear differences in NUE which reveals the importance to consider a build-up of soil fertility in the past and of residual fertilizer N to achieve a high NUE in short term experiments. Long-term fertilization trials, however, reveal a more “realistic” picture of NUE and the accompanying indicators since the utilization of applied nitrogen is less confounded with soil derived N. Results from long-term experiments for example at Rothamsted comparing continuous cropping of winter wheat with crop rotation also show the importance of crop rotations for achieving high NUE, high N output, and low N surplus simultaneously.

The results from the long-term trials were used to propose tentative reference values for NUE, N output and N surplus, which appear achievable and realistic for ‘high input - high output’ cropping systems.

Conclusions

The proposed NUE indicator and its graphical representation is a simple, useful and flexible concept. It allows examining differences in NUE not only between fertilization schemes but also between farms, between specific systems, between countries, and between years. We have focused on fertilization trials and it can be concluded that only long-term experiments reveal the “real” NUE of mineral N fertilizer application. Nevertheless, the NUE concept is an important tool to develop and steer N fertilizer management towards a sustainable direction.

References

[1] EU Nitrogen Expert Panel. 2015. Nitrogen Use Efficiency (NUE) - an indicator for the utilization of nitrogen in
agriculture and food systems. Wageningen University, Alterra, PO Box 47, NL-6700 Wageningen, Netherlands.

IMPROVED MANURE MANAGEMENT – FROM RESEARCH RESULTS TO IMPLEMENTATION ON FARM

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Introduction

Efficient use of nutrients supplied by manures is crucial for sustainable agricultural production. However, maximising the nutrient use efficiency from manures is challenging because of the variability in nutrient content, costs associated with storage and handling, spreading accuracy, and uncertainty of crop available nutrient supply.

Manure management strategies should be based on (i) reliable information of manure nutrient content, (ii) adoption of techniques to minimise nutrient losses to the environment and (iii) integration of manure nutrient supply with inorganic fertiliser inputs. This paper summarises the research which unpins nutrient management guidance for manures in the UK.

Manure nutrient content

Accurate information on manure nutrient content is essential to help farmers to make the best use of their manures. 'Standard' or 'typical' figures are available to farmers. However, these figures are averages and the nutrient content of organic materials will vary depending on many factors, such as livestock feed composition, variable use of bedding, storage period and for slurries dilution by rainwater. Studies have derived good relationships between slurry nutrient and dry matter contents (see for example Figure 1), with similar relationships also found for poultry manures.

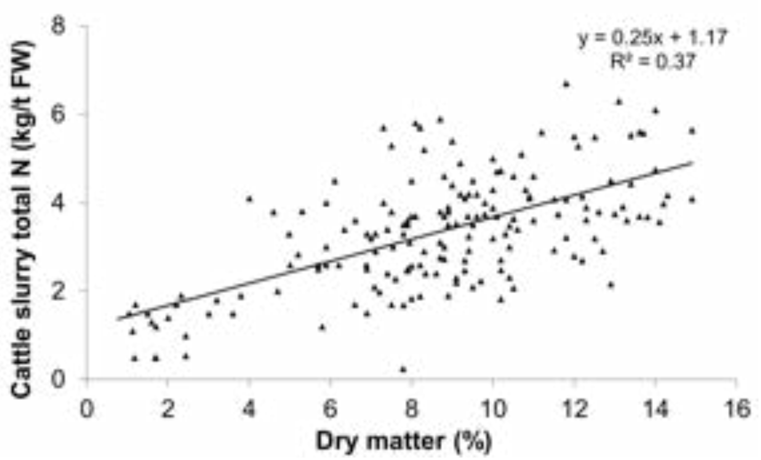

Figure 1. Relationship between cattle slurry total N content and dry matter content

It is clear that 'typical' manure analysis figures conceal significant variability and where possible more precise measurements of nutrient content at the farm level will improve the accuracy of nutrient management, therefore farmers are encouraged to analyse samples of their livestock manures. Most farmers who sample their manures will send the sample to the laboratory for wet chemistry analysis of dry matter (DM), total nitrogen (N), ammonium-N (NH_4-N), total phosphorus (P), potassium (K), magnesium (Mg) and sulphur (S). However, there are alternatives to conventional wet chemistry analysis. More recently, Near Infrared Reflectance Spectroscopy (NIRS) has been developed as a rapid, reliable and reduced cost method of analysis for organic materials [1]. Farmers with slurries can also use on farm analysis methods. Slurry N meters, such as the Agros or Quantofix meters, can be used on farm to give an accurate measurement of the slurry ammonium-N content. Slurry hydrometers can also be used on farm to measure slurry dry matter. Slurry N meters typically cost around 400 euros and slurry hydrometers are available for around 40 euros.

Minimising nutrient losses to the environment

Extensive research over the last 20 years, mainly funded by the UK Department for Environment Food and Rural Affairs (Defra), has contributed towards improved understanding of nutrient (particularly N) fluxes and losses following the land spreading of manures and the development of effective mitigation options. The main N loss pathways are via nitrate leaching, ammonia volatilisation and denitrification.

Factors controlling nitrate leaching losses include the proportion of manure N in the readily available form (i.e. NH_4-N and uric acid-N for poultry manures), application timing and the amount of manure N taken up by the crop between application and the start of drainage. [2] showed that applications of high readily available N manures (i.e. slurry and poultry manure) to winter cereals on free draining soils were greater from early autumn (up to 18% of total N applied) compared to late winter/early spring application timings (Figure 2). Nitrate leaching losses from farmyard manure applications were significantly lower (up to 7% of total N applied) than following slurry/poultry manure applications, reflecting the lower readily available N content.

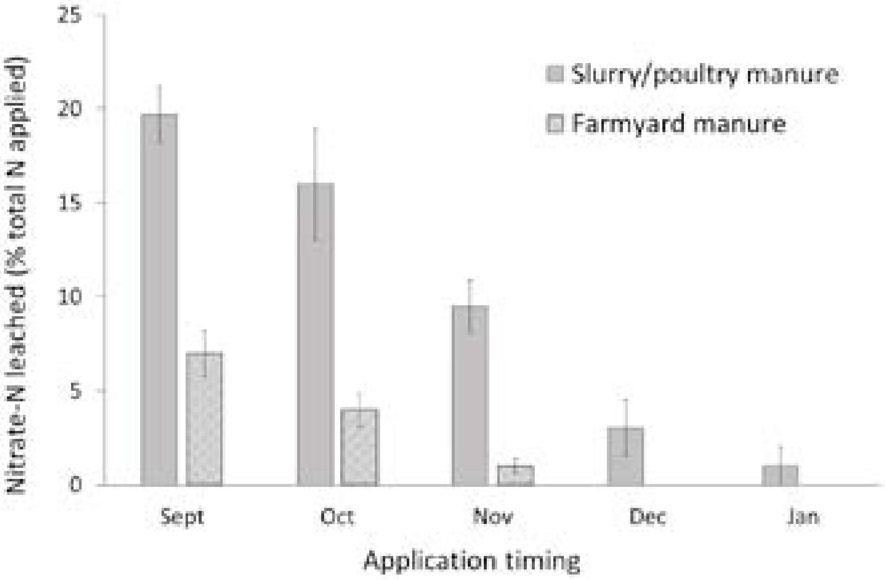

Figure 2. Nitrate leaching losses following manure applications to a free draining arable soils (Chambers et al. 2000)

This research contributed towards the evidence base for the current Nitrate Vulnerable Zone (NVZ) closed spreading periods in the UK. The UK NVZ Regulations prohibit the application of manures with a high readily available N content (i.e. more than 30% of total N in the readily available form) during defined 'closed spreading periods' during the autumn/winter [3].

Where manure is applied in the autumn, nitrate leaching losses will be lower where applications are made to crops with an autumn N requirement e.g. oilseed rape or grass. Results from a study measuring nitrate leaching losses following autumn manure applications to a clay loam soil showed that losses were significantly lower (<1% of total N applied) from pig slurry applied to oilseed rape compared to winter wheat (up to 16% of total N applied), reflecting the greater crop N uptake by the oilseed rape [4].

Ammonia emissions are influenced by many factors, including application technique, soil incorporation (method and timing), land use, application timing and environmental conditions at spreading (wind speed, rainfall and soil moisture content) [5, 6]. Typically, 65% of the ammonium-N content of pig/cattle farm yard manure, 25% of the ammonium-N content of pig/cattle slurry and 50% of the ammonium-N and uric-acid N content of poultry manures can be lost through ammonia volatilisation.

Soil incorporation of manures following land application can be effective at reducing ammonia losses, however the majority of ammonia emissions occur soon after application and therefore in order to be most effective, soil incorporation should follow soon after application (ideally within 24 hours). Slurry applications made using band spreading techniques or shallow injection, can be effective at reducing ammonia emissions following land application by *c*.30-75% compared to surface broadcasting.

Integrated planning of manure and fertiliser nutrients

Management strategies that minimise environmental N losses can be expected to maximise crop N recovery and therefore increase the fertiliser N replacement value of the manure, reducing the need for manufactured fertiliser application to meet crop requirements. In order to realise the value of manure applications, it is important to accurately predict the crop available N supply and reduce inorganic N use accordingly.

MANNER-*NPK* (MANure Nutrient Evaluation Routine) is a decision support tool to quantify manure crop available N supply [7]. MANNER-*NPK* is available to download for free from www.planet4farmers.co.uk/manner and there are currently 3300 registered users of the software. MANNER-*NPK* takes into account manure N analysis and includes algorithms to estimate ammonia volatilisation, nitrate leaching losses, denitrification and mineralisation of organic N to give an estimate of crop available N. The MANNER-*NPK* 'calculation engine' is integrated into the PLANET nutrient management software (*c*.16,000 registered users), which is in turn used by a number of the commercial providers of farm management software in the UK, facilitating the widespread use of the MANNER-*NPK* calculations to estimate manure crop available N supply.

Although much of the focus of manure management is on minimising the N losses to maximise crop available N, in the majority of cases manure phosphate and potash supply is worth more than the N value. A typical 50 m^3/ha spring application of cattle slurry will supply 46 kg/ha crop available N, 60 kg/ha P_2O_5, 160 kg/ha K_2O and 12 kg/ha crop available SO_3, and is worth 183 euros/ha in saved fertiliser costs (assuming current fertiliser prices of €0.89/kg N, €0.83/kg P_2O_5, €0.57/kg K_2O and €0.12/kg SO_3). In order to make the most of the phosphate and potash in manures, farmers are encouraged to target manure applications to fields where the soil in low in phosphate and potash and as a replacement for inorganic phosphate and potash fertiliser.

Knowledge transfer

Making correct decisions on the management and efficient utilisation of nutrients contained in organic manures is important both for the profitability of farm businesses and to minimise the risks of environmental pollution. It is important to provide clear and consistent advice to help farmers and their advisers apply best management practices in the use of organic manures. An integrated approach, using a range of technical information, from 'hard-copy' reference books such as RB209 [8] and leaflets, through to computer-based decision support systems (e.g. MANNER-*NPK*) supplemented with on-farm demonstrations, farmer and consultant meetings/workshops and one-to-one advice is required to provide the necessary support for farmers. A recent report on how advice is delivered to farmers [9] highlighted the value of trusted and credible one-to-one professional adviser-farmer interactions and concludes that professional advisers have a key role in translating R&D from the science-base in a practical way that farmers understand to encourage uptake of new technology and practices on farms.

Importantly, advice should be based on robust, scientific evidence, in order to be credible. This is particularly important as significant capital investment is often required on farms to increase manure storage capacity and to purchase improved spreading equipment, as part of the improved management practices necessary to reduce diffuse nutrient pollution [10].

References

[1] Smith, K. 2012 . Rapid analysis of manure and organic recyclables for sustainable agriculture via Near Infrared Reflectance Spectroscopy NIRS . Final Report to HGCA.

[2] Chambers, B.J., Williams, J. and Smith, K.A. 2000 . Strategies to encourage better use of nitrogen in animal manures. Soil Use and Management 15, 137-143.

[3] Statutory Instrument 2015 . The Nitrate Pollution Prevent Regulations. SI 2015 No. 668

[4] Williams, J.R. Sagoo, E., Collis, H., Cross, R., Short J., Portwood, A., Hodgkinson, R.A. and Chambers, B.J. 2010 . Pig slurry application timing to arable crops: Nitrogen losses in drainage waters. In: Crighton, K. and Audsley R. Eds. . Climate, Water and Soil: Science, Policy and Practice, 31 March – 1 April 2010. SEPA,

Edinburgh. pp. 393-398.
[5] Smith, K.A., Jackson, D.R., Misselbrook, T.H., Pain, B.F. and Johnson, R.A. 2000 reduction of ammonia emission by slurry application techniques. Journal of Agriculture Engineering Research 77 3 , 277-287.
[6] Misselbrook, T.H., Nicholson, F.A. and Chambers, B.J. 2004 . Predicting ammonia loss following the application of livestock manure to land. Bioresource Technology 96 2 , 159-168
[7] Nicholson, F.A., Bhogal, A., Chadwick, D., Gill, E., Gooday, R.D., Lord, E., Misselbrook, T., Rollett, A.J., Sagoo, E., Smith, K.A., Thorman, R.E., Williams, J.R. and Chambers, B.J. 2013 . An enhanced software tool to support better use of manure nutrients: MANNER-NPK. Soil Use and Management 29, 473-484.
[8] Defra 2010 . The Fertiliser Manual RB209 . The Stationary Office, Norwich.
[9] Agricultural Industry Confederation AIC 2013 . The value of advice report. Available from https://www.agindustries.org.uk/latest-documents/value-of-advice-project-report/
[10] Chambers B.J., Williams, J.R., Sagoo, E., Smith, K.A. and Chadwick D.R. 2006 Economic implications of minimising diffuse nitrogen pollution from livestock manures. In: Agriculture and Environment VI - Managing Rural Diffuse Pollution Eds. L. Gairns, K. Crighton and B. Jeffrey . Proceedings of the SEPA/SAC Biennial Conference. pp 84-92.

DESIGNING AN INNOVATIVE NITROGEN FERTILIZATION METHOD FOR WHEAT BASED ON THE DIAGNOSIS OF USES OF CURRENT TOOLS

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Objectives

In France, calculation of N fertilizer rates is based on the balance-sheet method. For wheat, total N rates are commonly split in three or four applications and adjusted by using monitoring tools, preventing N deficiencies. This strategy targets non-limiting N nutrition all over the crop cycle. In the last decades, progress in N fertilization mostly focused on the estimation of total N rates through refining the estimation of the balance-sheet equation parameters and the development of monitoring tools. However, these fertilization strategies, although based on scientific knowledge and representative of technical progress, lead to negative environmental impacts, and in 40 % of the situations, to non-optimal economical results. We assumed that these results are linked to a mismatch between the theoretical principles of the balance-sheet and the way farmers and advisors use it. We analyzed this mismatch to identify key points then used to design a new decision support method.

Method

As proposed by Cerf et al. [1] to design decision support tools with their users, we combined a diagnosis of the uses of existing tools, participatory workshops to design new concepts of fertilization method, a simulation model to implement this concept in a prototype and an on-farm test of the prototype.The diagnostic of uses consists of an analysis of the limits and constraints encountered by users when implementing current methods and tools. It was carried out based on two complementary sources of information. First, official reports from French regional working groups on the implementation of the balance-sheet method, mandated by the Ministry of Agriculture: within the fifth Action Program of the Nitrates Directive, twenty regional groups of experts (GREN) have been created to agree on an equation for the calculation of the fertilizer rate and its parameterization in each region. Second, interviews with experts from some GREN and with farmers and technical advisors in various regions of France. Interviews focused on their practical use of the balance sheet method.We organized two participatory workshops with fertilization experts from Research and Development. In those workshops (September 2014, June 2015), we shared the results of the diagnosis of uses and existing knowledge that experts suggested to consider. Following the C-K theory [2], the participants formulated new concepts to explore. Based on a dual expansion of concepts (C) space and knowledge (K) space, this theory helps overcoming fixation effects in design [3]. To perform a collective and participatory exploration, the C-K framework was a practical guideline to structure exchanges and to highlight knowledge that should be produced to achieve a prototype from the ideas shared by the group of experts. To operationalize the concept, we used crop model simulations to define decision rules for fertilizer application.Finally, the implementation of the prototype was proposed to farmers in two different locations.

Results

The diagnosis of uses showed the difficulties to implement the balance-sheet method. The GREN reports' analysis highlighted controversies occurring when stakeholders confronted their perceptions. Interviews confirmed that those controversies were sources of doubts and errors when implementing the method. The first controversy concerned the target yield. While there is a rule to estimate it the GREN reports highlighted arguments against it: the failure to achieve the potential yield in favorable years or to value the genetic progress, the risk of strengthening the trend of yield stagnation or of low grain protein content. Moreover, interviews revealed that farmers tend to estimate the target yield as the desired yield, close to the highest value ever reached. The second controversy was linked to measurement of soil N mineral content at the end of winter. From farmers and advisors, it is time consuming and results in several sources of uncertainties (i.e., sampling procedure or extrapolation of measures to other fields). These controversies illustrate the mismatch between scientific thinking that lead to emphasize concepts such as target yield and soil analysis, and users' ways of implementing the method, where those concepts are sources of doubts and errors.

During participatory workshops, we explored “a fertilization strategy without a target yield, without measurement of soil N availability, including periods of N deficiency, and that aims at maximizing Nitrogen Use Efficiency”. Those ideas were formulated from both the diagnosis and the willingness to integrate recent knowledge not yet taken into account. The exploration led the concept: “Following optimal plant Nitrogen nutrition by regular monitoring and fertilization rates calculated based on anticipation of soil N supply”. To make it concretes, knowledge was discussed to provide a triggering threshold to apply N fertilizer (i.e., early monitoring based on Nitrogen Nutrition Index (NNI) and crop biomass, weather forecast, plants’ N uptake capacity and soil water content at the moment of N application). Some knowledge was already available, however some had to be produced. To achieve a prototype of a tool we did a specific study on the minimum NNI pathways including N deficiencies that is not detrimental to wheat. We used the Azodyn soil-crop model [4] to build decision rules for N rates based on the aforementioned principles. Rate and timing are defined during the crop cycle, depending on, N status (weekly estimated), soil types and climate conditions. The test of the feasibility of the method in on-farm conditions is on-going and its results will be available in June 2016.This prototype relies on an estimation of NNI based on a chlorophyll meter measurement. However, the same principle could be applied through other tools and technologies making it possible to take into account field variability.

Conclusions

From an analysis of the limits expressed by stakeholders regarding current decision support tools, we designed an innovative method to manage N fertilizer. The diagnostic of uses was useful to enter the process of designing the innovative method. It enabled to highlight and show how the current paradigm was flawed regarding the objective to achieve both environmental and agronomical issues. This analysis finally showed a conceptual gap between a model based on scientific knowledge and the operational capability of a tool. Introducing the workshops with the diagnosis of uses created good conditions to explore concepts for innovative management strategies. The designing process required producing new knowledge (in particular, on the interest of periods of nitrogen deficiencies, that are prohibited in the current method) in order to unlock the current paradigm.

References

[1] Cerf, M., Jeuffroy, M.H., Prost, L. & Meynard, J.M. (2012). Participatory design of agricultural decision support tools: taking account of the use of situations. Agronomy for sustainable development. 32(4):899-910.

[2] Hatchuel, A. & Weil, B. (2009). C-K Design Theory: An Advanced Formulation. Research in Engineering Design, 19:181-192.

[3] Le Masson, P., Hatchuel, A. & Weil, B. (2011). The interplay between creativity issues and design theories: A new perspective for design management studies? Creativity and Innovation management, 20(4):217-237.

[4] Jeuffroy, M.H, & Recous, S (1999). Azodyn: A simple model simulating the date of nitrogen deficiency for decision support in wheat fertilization. European Journal of Agronomy. 10: 129-144.

CropSAT - A SATELLITE-BASED SUPPORT SYSTEM FOR VARIABLE-RATE SUPPLEMENTARY FERTILIZATION OF NITROGEN IN SMALL GRAINS PRODUCTION IN SCANDINAVIA

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Objectives

The use of support systems for crop production based on optical satellite remote sensing is a challenge in temperate regions frequently covered by clouds. Winter wheat (*Triticum aestivum* L.) is the most common crop in Scandinavia. Split nitrogen (N) fertilization is commonly adopted to achieve desired crop quality and yield, while expected to reduce the risk for N leaching. Tractor-mounted crop sensors are increasingly used for variable-rate on-the-go scanning and supplementary N fertilization, but still most of the winter wheat is managed without such sensors. In an effort to provide most Swedish farmers with a support system based on satellite data for supplementary N fertilization in winter wheat and other small grain crops, a web-based free service (CropSAT.se) was developed. The system will also be used in Denmark in 2016. This paper summarizes the experiences of functionality and usage, image delivery, and comparisons with ground-based sensor measurements.

Method

The CropSAT development started in 2013 led by the Swedish University of Agricultural Sciences (SLU) in collaboration with the Rural Economy and Agricultural Societies (Hushållningssällskapet) and Lantmännen Farmers' Cooperative. The first web application was developed in 2014 with a simple user interface, allowing the users to: locate and select fields using Google maps and field boundaries from the Swedish Board of Agriculture; split fields if necessary; select satellite image; manually reclassify a vegetation index map into a N application map; and download a variable-rate application file. The system was improved in 2015 and was run with support from Agroväst Livsmedel AB (administration) and DataVäxt AB (programming and management of web application) under the management of Focus-on-Nutrients, a national undertaking for improved nutrient use efficiency administered by the Swedish Board of Agriculture.

Satellite data from DMC satellites (DMCii Ltd, UK) with 22-m spatial resolution, combined with Landsat 8 data, was used in the system. Our intent was to cover ~ 2.4 million ha or >90 % of the arable land in the country with as much useful satellite data as possible during the period for supplementary fertilization, 21 April to 12 June. There is a daily revisit time of the DMC 22-m satellites, while Landsat-8 has a weekly revisit. The vegetation index that we chose to use in the system, after initial performance tests, was the modified soil adjusted vegetation index (MSAVI). Other indices we tried were normalized difference vegetation index (NDVI) and soil adjusted vegetation index (SAVI). Pixels with clouds or cloud shadows, and pixels within 15 m of the field borders were removed.

Comparisons were made between the MSAVI and N uptake in winter wheat calculated from the handheld N-Sensor (here considered ground-truth; Yara AB, Sweden). Weekly field measurements were conducted in one part of each of 26 fields in southwest and south Sweden. These were paired with the average satellite index of the pixels within a distance of 15-30 m from the coordinate of the sensor measurement, if sensor measurement dates corresponded to acquisition date of satellite imagery (± 2 days).

Results

May 2015 was unusually cloudy and rainy in southern Sweden, which limited the number of cloudless satellite scenes. Despite this, it was possible to acquire at least three cloud-free images for 2/3 of the region of interest during the time window. In some areas, up to eight images were acquired. Among the most intensively cultivated districts, it was only one region (in the southwest) in which there were only two useful images. There were more than 1500 users of the CropSAT service and about 4000 variable-rate N application maps were downloaded.

Comparisons between vegetation indices calculated in the satellite imagery and N-uptake as estimated from measurements done by the handheld N-Sensor showed that SAVI and MSAVI performed best and was linearly correlated with N uptake ($r^2 = 0.77$ in both cases), whereas for NDVI, the proclivity to become saturated were obvious (index values stabilizes around 0.9) already at an uptake of 50 kg N ha^{-1}. In total there were five winter wheat varieties and there was a tendency that different varieties of winter wheat had different reflectance characteristics, even though the dataset used in this study was too limited to draw final conclusions.

In the current version of CropSAT, it is the user who interprets the vegetation index maps and interactively creates maps of N fertilization. An issue for future developments of the concept is to aid the farmer with the conversion from vegetation index to fertilization rate. One possible approach is to use ground-based sensors to estimate N uptake during the season for supplementary fertilization and translate satellite images to N uptake using the ground-based reference measurements collected to date. A first attempt was made with the present dataset. By cross-validating (leave-one-field-out) regression models between satellite MSAVI and the N uptake from handheld N-sensor measurements, we could asses the general performance of MSAVI for predictions of N uptake during the season 2015. Parameterized relationships were based on data up to the date of a satellite image, so the results simulated a possible practical application with a continuous data collection and calibration. In this test we used only fields with the two most common winter wheat varieties in our dataset (Julius and Brons; both SW Seed, Sweden). The validation statistics indicated once more that there may be a difference between varieties, but also a model based on both cultivar performed well. Determination coefficients (r^2) and mean absolute errors (MAE) were as follows: Julius: 0.82, 8.9 kg N ha^{-1}; Bronze: 0.94, 5.3 kg N ha^{-1}; and the combined model: 0.83, 9.5 kg N ha^{-1}.

Conclusions

It is possible to use satellite data for applied N status assessment also in cloud-infested areas such as Scandinavia. The CropSAT vegetation index maps from satellites can be used for site-specific adjustment of N fertilizer in the fields. Due to risk for early saturation of NDVI, other indices such as SAVI or MSAVI seemed to be more useful. It is likely that there is a need for near daily revisit time of satellites order to be able to acquire enough useful images for operational systems. Satellite images are very cost-effective in providing crop status data to farmers (for CropSAT in 2015 about 0.02 Euro ha^{-1}, estimated for the area covered by at least three images). Consecutive ground-calibrations by handheld sensors might be a viable approach to provide not only index maps but also N uptake maps. In a fist test the prediction error estimated (MAE) was < 10 kg N ha^{-1}.

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FARMER ATTITUDES AND POTENTIAL BARRIERS TO THE USE OF PROCESSED ORGANIC FERTILISERS

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Objectives

A number of European regions have a surplus of nutrients from animal manures, including Denmark, which has led to nitrogen overload of soils and subsequent pollution of the aquatic environment [1]. To reduce nutrient input to agricultural soils near animal farms, more organic waste processing (e.g. manure and urban organic waste separation, anaerobic digestion, composting) is needed to create products that can be exported to regions without a surplus. Processing of organic wastes will result in novel organic fertiliser products that farmers may or may not be willing to apply to their fields. To increase farmers' acceptance of processed organic wastes, it is important to understand farmer attitudes towards their use. The objective of this survey-based study was to identify farmers' perceptions of organic fertiliser use, and advantages and potential barriers to their use. Here we report on the results from farmers in Denmark.

Method

The survey consisted of 24 questions and was designed to take approximately 10 minutes to complete. The questionnaire focused on a number of organic fertiliser types, including unprocessed and processed manures, as well as urban organic wastes. Farmers were asked about their current use of these fertilisers, their interest in their use three years from now, the barriers that may prevent them from using organic fertilisers, and also the most important advantages to or reasons for them to be using organic fertilisers.

Farmer addresses were obtained from the 2011 Danish fertiliser accounts registry (the most recent publically available), covering all farms in Denmark using N fertilisers (around 43 000 commercial operations). Farmers with more than 10 ha of agriculturally farmed land were selected, in order to exclude non-commercial operations. 1 800 farmers were randomly selected from the list that remained, and their records checked against the 2014 business registry records to ensure that their business number (CVR) was still active. 1 585 farmers remained after this selection process, and this population was checked against the full fertiliser accounts registry to ensure it was representative of the entire population.

Farmers selected for the survey were sent a cover letter, survey form and a pre-paid return envelope inside. Participants were also given the option to fill out the survey online instead of returning the paper survey. Respondents that replied within one month of the date that the survey was sent out had the opportunity to enter in a prize draw.

Results

Out of 1 585 letters sent, 448 farmers responded (425 by letter, 23 online), a response rate of 28%. The respondents were found to be generally representative of Danish agriculture; the primary farming activity of respondents matched the Danish farming statistics closely [2], with 62% primarily farming field crops, 12 and 9% dairy or cattle farmers respectively, 6% pig farmers, with other land uses being less important.

The majority (72%) of farmers who responded used at least one type of organic fertiliser, indicating that a major proportion of the field crop farms are receiving smaller or larger amounts of manure from neighbouring animal farms, a practice which is stimulated by the Danish environmental regulations implementing the EU Nitrates directive, requiring export of manure N in excess of 170 kg N ha-1 from the animal farm. When asked about future plans, 79% of respondents expected to use the same amount of organic fertilisers three years from now as they do today.

Almost half (47%) responded that they would be interested in using an organic fertiliser three years from now which is not currently available to them (most interest for unprocessed manures, then processed manures, then urban organic wastes). These results indicated that although the majority of farmers did not expect to change organic fertiliser use in the near future, almost half of them were interested in using a new type of organic fertiliser if it were available. These results showed that there is an unmet demand for organic fertilisers amongst farmers in Denmark.

Farmers ranked the three most important advantages or reasons for wanting to use organic fertilisers and ranked the following most highly: 1. improvement of soil structure with organic fertiliser, 2. low cost to buy or produce (e.g. own animal manure), 3. certainty of NPK content. Respondents also ranked the three most important barriers to the use of organic fertilisers, and they selected: 1. difficulty in planning for organic fertiliser use compared to mineral fertiliser, 2. uncertainty of NPK content, and 3. the machinery to produce/handle organic fertilisers is expensive. The certainty or uncertainty of NPK content was ranked highly as both an advantage and a disadvantage. Farmers who currently use organic fertilisers ranked “uncertainty of NPK content” as a more important barrier. This may have indicated that experience with the use of organic fertilisers may be linked to perceptions of the product, i.e. with experience comes greater awareness of the uncertainty of nutrient contents. Other question responses were compared to identify differences in farmer perceptions based on farm practice and farmer demographic criteria.

Conclusions

A majority of Danish farmers use at least one type of organic fertiliser. Although farmers generally did not intend on using more organic fertilisers in three years than they do today, there was a significant interest in organic fertilisers that are currently not available to these farmers, particularly processed manures. This indicated that in Denmark there is an unmet need for access to organic fertiliser processing technology and the resulting fertiliser products. Farmers considered the difficulty of use, uncertainty in NPK content, and cost of use to be main barriers to using organic fertilisers. Improvement in soil structure was considered the biggest advantage to using organic fertilisers.

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References

[1] Sutton, M.A.; Billen, G., 2011. In: Sutton, Mark A., Clare M. Howard, Jan Willem Erisman, Giles Billen, Albert Bleeker, Peringe Grennfelt, Hans van Grinsven, and Bruna Grizzetti (eds), Technical summary, The European Nitrogen Assessment: Sources, Effects and Policy Perspectives. Cambridge University Press, Cambridge, UK.
[2] Statistics Denmark 2014. Agriculture, horticulture and forestry, website accessed 01/06/2015, URL: http://www.dst.dk/en/Statistik/emner/landbrug-gartneri-og-skovbrug

NITROGEN USE EFFICIENCY WITHIN THE VITTEL MINERAL WATERSHEDS: A PARTICIPATORY INVESTIGATION AIMING AT SETTING BEST MANAGEMENT PRACTICES AT DIFFERENT SCALES

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Objectives

AGREV 3 (Agriculture Environment Vittel), considered as a research-action project, consists in preserving a mineral watershed of 6200 ha of agricultural land within 104 000 ha. To be labelled 'Vittel', the water cannot contain more than 10 mg of nitrates per litre and must not contain pesticides traces. In order to reach these goals, Agrivair (a Nestlé Waters entity) challenged INRA (French National Agronomic Institute), to imagine, implement and evaluate redesigned agricultural practices allowing a viable farming system and a long term mineral water protection.

The AGREV3 goals are threefold: (i) to understand the relationship between farming practices the ground water nitrate rate; (ii) to identify and test practices enabling to reduce or maintain the nitrate rate under a desired level ; (iii) to build the nitrogen cycle at different scales (field, farm and watershed) and optimise the nitrogen use efficiency.

Method

A three steps methodology was developed:

1. Understanding the farming systems dynamics: How farmers are driving their system at different spaces and time scales?

The 6 200 ha are studied in order to list all the land-use successions and the farming practices. This gives valuable informations on the spatial and time dynamics of the cropping systems implemented. The landscape designed by farmers reveal at various scales logical processes and driving forces related to soil, climate, cropping system, and economical pressure whose understanding is a major challenge [3]. Thanks to this landscape agronomists vision, we deliver operative knowledge to the landscape managers: the farmers and the actors in interaction with them [13][11][7].

2. Identifying, testing, and validating the management practices necessary to reduce the nitrate threat through on farm innovation

With the collaboration of these actors, we design an experiment in order to evaluate water quality induced by farmer's practices. This is realised by placing 170 ceramics cups within 24 farmers' fields. To complete this experiment, we measured nitrate lost under several manures heaps and water quality from a net of 20 spring and several relevant data of the nitrogen cycle.

To create innovation, the methods and results are continuously discussed in a way of participatory research, so a "learning by doing" research action program that took into account farmers' livelihood strategies [12][19][16][18][1]. Scientists and Agrivair involved farmers in the research action program on identifying acceptable conditions for new production systems compatible with Vittel's goals of low nitrate rate as well as enabling long term evolution of farming systems.

3. Building the Nitrogen processes at different scales using the collected information to target efficient scale at which solutions may be constructed

The data collected at the field scale and the farming system observations allow us to study the nitrogen flows at different scales. The primary step was to determine the nitrogen balance of each cropping system of the watersheds which is dynamic, spatialised, and easily understood by farmers [2][3][17]. Afterwards, all the collected informations are used to formalise a detailed nitrogen cycle at the field, farm and watershed scales [8][15][14][10][9][20].

Results

The evolution of nitrogen leaching has been measured since 1988 with ceramic cups collecting system in the Vittel watershed. All of these trials give us more than 4000 measurements points on 10 different crops. A classification of nitrate leaching level was done based on the crops and on the amounts of farmyard manure applied [3]. We conclude that maintaining a rate of 10 mg/l of $N\text{-}NO_3^-$ under the root zone can be achieved by reducing fertilizer use and manure application as well as changing crop successions and grassland surface area in the farmland.

All the measurements on plots, crop rotations, and precise observatories of agricultural practices build a territory agronomically well informed through a global farmland observatory. This allows to understand the water quality evolution and to contribute to changes in the use of the lands in the watershed. Following eighteen years of on-farm's innovation trials aimed at adapting farming systems in collaboration with the farmers to protect the water resources, we now offer a new approach to the diagnosis of farming systems in watershed, which take into accounts for spatial and functional dimensions of the farming activity.

This methodological process is based on crop rotation and observations of fertilising practices, used as an indicator of the farming organisation though space and time [21]. One of our previous researches led to the following prescriptions which are currently respected by the 30 farmers on the watershed:

- Giving up maize cultivation for animal feed
- Maintaining producing pastures
- Reducing stacking rates to a maximum of one livestock unit per hectare.
- Composting animal manure to achieve an optimal application in quantity and time within the fields, and mainly on grassland.
- Giving up agrochemicals (no pesticides)
- Modernising farm equipments for optimal manure management and storing
- Promoting technical solutions to optimized nitrogen use within the territory

Conclusions

All of these prescriptions have to be improved by our current new results. Our presentation aims at showing a methodology to be applied in order to monitor nitrogen flows and the leaching risks associated with a diversity of agricultural practices implemented at different temporal and spatial scales on the Vittel watershed.

We have three main goals in this participatory research:

- to validate nitrogen pressure indicators (BASCULE, crop rotation, practices, etc.) with our specific measurements (ceramic cups, nutrient flux under farmyard, springs measured, etc.) with the involved farmers

- to extrapolate known data at the watershed scale

- to adapt and optimise models of nitrogen fluxes too such very low nitrate values (under 10 mg NO_3^-/L)

Thanks to the works with all farmers of the watershed, technical systems which promote the best nitrogen efficiency are continuously set up. To encourage the best agronomic management practices, we work on establishing several different scenarios at the watershed scale to validate, with both farmers and watershed managers, the best global solutions leading to a win-win situation.

[1] Barataud 2014, [2] Barry 1993 [3] Benoît M. 1992 [4] Benoît M. 1994, [5] Benoît 1995 [6] Benoît 2012, [7] Benoît 2007, [8] Billen 2005, [9] Billen 2013, [10] Bouwman 2013, [11] Cavazza 1996, [12] Darré 2004, [13] Deffontaines 1995, [14] Fowler D 2013, [15] Ledoux 2007, [17] Puckett 1999, [18] Reau 2012, [19] Ruault 1996, [20] Soussana 2014, [21] Xiao 2014

ECOLOGY OF MICROBES CAUSING N LOSS AND RETENTION IN ARABLE SOILS

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Introduction

Soil microbial communities are the principal drivers of N-cycling in arable soils, with distinct functional guilds regulating retention or loss of N. Inorganic N, derived from decomposition or applied as fertilizer, may be lost due to nitrification, a process in which ammonia is oxidized to nitrate that can leach into nearby waterways. Instead of leaching, nitrate can either be converted back to ammonium through the process dissimilatory nitrate reduction to ammonium (DNRA) or lost by denitrification. The communities of each of the functional guilds are typically very diverse and both between and within these guilds members are differently affected by environmental factors. For example, microorganisms involved in the anaerobic processes denitrification and DNRA were favored in the vicinity of roots, whereas the ammonia oxidizers performing the first step of nitrification were more abundant in the bulk soil in an experiment with forage crops (unpublished).

Nitrifying microbes

The nitrification process is either a two-step process shared between ammonia and nitrite oxidizers, or is performed by complete nitrifying bacteria as in the newly discovered complete ammonia oxidizers (comammox) [1, 2]. The ammonia-oxidizing archaea (AOA) and ammonia-oxidizing bacteria (AOB) have been extensively studied and several studies have shown niche separation between AOA and AOB [e.g. 3]. Even though AOA most often outnumber AOB, both groups play an important role in nitrification in terrestrial environments. In grassland soils, we have shown that AOA are important drivers of nitrification under nitrogen-poor conditions, but that input of easily available nitrogen results in increased abundance, activity, and relative importance of AOB for gross nitrification [4]. Less is known about the ecology of nitrite oxidizing bacterial communities (NOB), and the significance of interactions between AO and NOB communities in determining nitrifier community structure. We have explored the interaction between these communities across a 44-hectare farm. Variance partitioning revealed that NOB and AOB community structures were significantly influenced by the abundance and diversity of the other nitrifiers. By contrast, the majority of variation in AOA community structure was explained by spatial and edaphic factors. Network analysis showed distinct modules of co-occurring AO and NOB groups occupying disparate regions of the field site, with each module dominated by different AO and NOB lineages (unpublished). Our results suggest that the AOA, not the AOB, were contributing to nitrate leaching at the site by providing substrate for the nitrite oxidizers [3]. These results demonstrate the importance of accounting for both abiotic and biotic interactions in defining the niche space of functional communities at scales compatible to management strategies.

Microbes determining the fate of nitrate

Denitrification, a facultative anaerobic respiratory pathway in which nitrate is sequentially reduced to N_2O or N_2. The pathway is modular and by analyzing sequenced genomes of denitrifiers, we have shown that about half of the genetically characterized denitrifiers lack the capacity of complete denitrification [5]. This means that the greenhouse gas N_2O is the end-product. Experimentally, we also confirmed that the N_2O:N_2 ratio from denitrification in soil increases when the proportion of bacteria lacking the N_2O reduction step increase in soil [6]. This shows a direct causal link between the denitrifier community composition and potential N_2O emissions. In soil, the rhizosphere is a hot spot for denitrification. However, the soil type is more important than the plant for genetic and enzymatic potential for denitrification in the rhizospheres of forage as well as annual crops [7]. In the bulk soil, the plant had no effect and the denitrification rates were only affected by the soil type.

While denitrification is a major route for N loss, DNRA retains mineral N in the ecosystem. To compare the importance of denitrification and DNRA, we compared a long-term annual crop rotation with cereals and a grassland rotation system ('ley') with perennial forage crops with different fertilization levels at a field experiment. Preliminary results indicate that increased denitrification produced larger amounts of nitrous oxide in the crop soil, whereas relatively more mineral N was conserved in the ley soil (unpublished). The denitrifiers were more abundant than DNRA bacteria in the fertilized treatments indicating that N limited ecosystems, here represented by lower fertilization levels and higher $C:NO_3^-$ ratios, conserve and re-cycle mineral N through DNRA. Our results suggest that different long-term agricultural management practices can shift the importance of denitrification and DNRA due to altered soil conditions.

Nitrous oxide reduction

Arable soils are the major source of N_2O. However, negative net N_2O fluxes have been reported [11] and the capacity of soils to act as N_2O sinks is gaining increased attention in the context of climate change [10]. The only known sink of N_2O in the biosphere is the microbial reduction of N_2O to N_2, which is catalyzed by the N_2O reductase encoded by the *nosZ* gene. Recently, we showed that the phylogeny of the N_2O reductase is split into two major clades [10], with the previously undetected Clade II being equally or more abundant than Clade I in different environments [10, 11, 12]. Clade II harbors a diverse range of denitrifying taxa and a substantial number of non-denitrifying bacterial taxa. The latter have the potential to be N_2O sinks since they do not have the genetic capacity to produce N_2O, only reduce it. A comparison of 652 microbial genomes across 18 phyla illustrated the modularity of the denitrification pathway, as organisms with *nosZ* Clade II were mostly non-denitrifying N_2O reducers, whereas canonical denitrifiers that use N_2O as an intermediate were dominant in clade I. Further, co-occurrence patterns of key denitrification genes were not randomly distributed across taxa or amongst preferred habitats, with *nosZ* occurring more frequently than expected among aquatic organisms. These results underpin the importance of community structure for N_2O emissions and that it may vary across habitats. Identifying the fundamental ecological niches of N_2O reducing microorganisms as well as processes affecting the assembly of N_2O reducing communities and their activity are essential for understanding their importance for climate regulation. Recent findings based on experimental work and field studies indicating niche differentiation between the two clades and the crucial role for Clade II in regulating N_2O emissions are presented**.**

The impact of N-fertilization on N_2O reducers was determined using 14 geographically diverse Swedish long-term field trials including both fertilized and non-fertilized treatments. Fertilization affected the highly diverse *nosZ* Clade II community as it changed the community composition and decreased the phylogenetic diversity, which was negatively correlated with the $N_2O:N_2$ emission ratio. The more abundant clade I correlated positively with the potential denitrification activity and influenced the proportion of N_2O produced only in the fertilized samples. However, the clade I community was not significantly affected by fertilization. Analysis of N_2O reducing communities in 47 different arable and grassland soils across Europe showed that the soil N_2O sink capacity was mostly explained by the abundance and diversity of Clade II, and that niche differentiation or even competitive interactions existed between organisms with either type of N_2O reductase [12]. In the rhizospheres of lucern, cocksfoot, barley and sunflower, we demonstrated niche differentiation between the nitrous oxide reductase genes *nosZ*I and *nosZ*II, with Clade I dominating in the root-associated communities and Clade II in the soil [7]. The structure of the root-associated N_2O reducers of differed from those in the bulk soils and was mainly driven by edaphic factors. Thus, each soil constituted a unique pool of microorganisms from which a selection was recruited to the root environment and there was no plant species effect. The structures of the root-associated N_2O reducing communities were more variable than those of the soil communities, indicating that priority effects played a role in the assembly process of root-associated N_2O reducing communities. In coastal sediments, specific lineages between and within each *nosZ* clade were associated with different oxygen regimes [13], again suggesting niche partitioning between the two communities that could be relevant also in the root-soil interface. Altogether, the results indicate that non-denitrifying N_2O reducers are important N_2O sinks and are favored by other environmental factors than N_2O reducers known as denitrifiers within clade I.

References

[1] Daims, H., Lebedeva, E.V., Pjevac, P., Han, P., Herbold, C., Albertsen, M., Jehmlich, N., Palatinszky, M., Vierheilig, J., Bulaev, A., Kirkegaard, R.H., Bergen, M.V., Rattei, T., Bendinger, B., Nielsen, P.H., Wagner M. 2015. Nature 528, 504-509.
[2] van Kessel, M.A.H.J., Speth, D.R., Albertsen, M., Nielsen P.H., Op den Camp, H.J.M., Kartal, B., Jetten, M.S.M., Lücker S. 2015. Nature 528, 555-559.
[3] Wessén, E., Söderström, M., Stenberg, M., Bru, D., Hellman, M., Welsh, A., Thomson, F., Klemedtsson, L., Philippot, L. and Hallin, S. 2011. ISME J, 5:1213-1225.
[4] Sterngren, A.E., Hallin, S. and Bengtson, P. 2015. Frontiers in microbiology, 6:1350.
[5] Graf, D.R.H, Jones, C.M. and Hallin, S. 2014. PLoS ONE, 9(12):e114118.
[6] Philippot, L., Andert, J., Jones, C.M. and Hallin, S. 2011. Global Change Biology, 17: 1497-1504.
[7] Graf, DRH. 2015. *Ecology and genomics of microorganisms reducing the greenhouse gas* N_2O. Thesis. Uppsala: Swedish University of Agricultural Sciences, Acta Universitatis agriculturae Sueciae, 1652-6880; 2015:109.
[8] Richardson, D., Felgate, H., Watmough, N., Thomson, A., Baggs, E., 2009. Trends in Biotechnology, 27, 388–397.
[9] Chapuis-Lardy, L., Wrage, N., Metay, A., Chottes, J. L., and Bernouxs, M. 2007. Global Change Biology, 13, 1–17.
[10] Jones, C.M., Graf, D.R.H, Bru, D., Philippot, L. and Hallin, S. 2013. ISME J, 7:417-426.
[11] Orellana, LH, Rodrigues, LM, Higgins, S, et al, 2014. mBio, 5: e01193-14.
[12] Jones, C. M., Spor, A., Brennan, F. P., Breuil, M.-C., Bru, D., Lemanceau, P., Griffiths, B., Hallin, S. and Philippot, L. 2014. Nature Climate Change, 4:801-805.
[13] Wittorf, L., Bonilla-Rosso, G., Jones, C.M., Bäckman, O., Hulth, S. and Hallin, S. Environmental Microbiology Reports, in press doi:10.1111/1758-2229.

COVER CROPS TRIGGER NITROGEN UPTAKE BY SOIL MICROORGANISMS

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Objectives

In many parts of Europe and especially in some regions in Germany, for example the lower Rhine, groundwater pollution with nitrate is still a problem. It is caused by excessive nitrogen (N) use and inefficient N uptake by crops. As a consequence, cover crops (CC) are promoted aiming at immobilization of excess residual N in plants after the harvest of the cash crop in autumn. The N uptake efficiency of CC, however, varies between different CC species due to differences in plant-soil feedback reactions, such as different rooting patterns. The objective of our study was to investigate the relationship between root distribution and residual nitrogen immobilization by CC. Moreover, we studied the effect of N addition to stimulate plant growth and their N uptake, as well as soil microbial biomass which competes with plants for N.

Method

Three CC, *Raphanus sativus oleiformis* L., *Brassica rapa oleifera* L. and *Phacelia tanacetifolia* Benth. were grown in the greenhouse for 39 days. The loamy sand soil was kept at 60-70 % of its water holding capacity by watering the pots according to their weight loss every 2-3 d and at three fertilizer levels: 0, 40 and 80 kg N ha^{-1} applied as calcium ammonium nitrate (CAN) in a pot experiment. In addition, pots without plants (fallow) were used as controls. At harvest plants were separated into above-ground biomass (AGB) and roots to determine dry matter. Soil columns were separated into top and bottom soil layer (each about 11 cm). Approximately 300 g of soil was sampled from the inside of the lower half of the top soil layer, and around 15 g of soil was sampled from the inside of the lower half of the bottom soil layer. These samples were stored in closed plastic bags at 4 ˚C until further analysis. Roots were washed out from the two soil halves using tap water and stained for at least 24 h in a 0.035% neutral red solution with 70% ethanol. Taproots from *Raphanus* and *Brassica* were removed from the root samples, after which root length and root diameter of all three plant species was determined as described by [1]. In short, a subsample was taken, spread out in water in a tray, and scanned at 400 dpi on a scanner with a two-sided lightning system (EPSON Expression 11000XL). Root length and average root diameter were determined using an image analysis software (Win-Rhizo, Régent Instruments Inc.), and dry weight of both the root subsample and the rest of the roots was determined after which specific root length (SRL) and total root length were calculated per pot. Soil samples were analysed for soil microbial biomass carbon (C) and N using fumigation extraction as described by [2, 3]. In addition, NO_3^--N and NH_4^+-N concentrations in the soil extracts of the non-fumigated samples was estimated using an AutoAnalyzer 3 HR (SEAL).

Results

As expected, CC decreased inorganic N concentrations in the soil up to tenfold compared to soils without vegetation, as indicated by low nitrate levels, which were equally low in both soil layers. Interestingly, *Brassica* produced almost twice as much root biomass compared to *Raphanus*, but recovered comparable amounts of N. *Phacelia*, on the other hand, captured a smaller amount of N as indicated by substantially lower plant biomass. This was consistent with a decrease in root length and an increase in root diameter. For both, *Brassica* and *Raphanus*, residual N was comparable between all three fertilizer levels, indicating that these plants respond to higher N availability by increasing their N uptake. *Phacelia* on the other hand was not able to make use of larger N availability, as shown by higher nitrate levels at 80 kg N ha^{-1} in both soil layers accompanied by a decreased root biomass. This suggests that *Phacelia* is well suited to immobilize N in agricultural soils with relatively low N concentrations, which may be related to the bigger root diameter of this species. *Raphanus*, on the other hand, is suggested to be an 'all-rounder' that can cope well with a varying level of N in the soil, while *Brassica* left slightly less nitrate with the addition of 40 kg ha^{-1} N although shoot biomass did not increase. Boosting plant performance by adding N appeared to be species dependent. Consequently, practical recommendations for CC fertilization have to be more species specific.

For none of the investigated CC, a consistent effect of fertilization on the root-to-shoot ratio could be observed. This is probably due to the fact that the nutrient content in agricultural soils and especially those equipped with CC, is often larger than in natural ecosystems, where effects of N levels on the root-to-shoot ratio could be observed. Species-specific differences in root morphology and physiology might also explain part of the observed rather species specific reaction to increased N levels. This is partly reflected by the root diameter, which was not affected by fertilization but rather showed strong species specificity.
Microbial biomass C slightly increased with increasing N fertilization but was not consistently affected by CC presence. However, microbial N was increased by CC cultivation independent of fertilization status, indicating increased N immobilization by soil microorganisms when CC are present. This is probably caused by an increased metabolic activity of the microbial biomass triggered by root exudates and rhizodeposits, which provide easily available carbon as an energy source. N might therefore be temporarily accumulated in the biomass and end up in microbial residues. As a consequence, CC contribute two-fold to the decrease of residual N levels in the soil: (1) plant uptake and (2) triggering microbial N immobilization.

Conclusions

In conclusion, CC did not only contribute to reduced N losses by N uptake, but also by substantially stimulating microbial N immobilization. Consequently, CC store more N than previously assumed and stimulate N immobilization by soil microorganisms. Future studies have to verify these findings and investigate the N release from CC residues in different cropping systems and under different environmental conditions. Moreover, the availability of N mineralised from catch crops for subsequent crops has to be assessed as well as the possible risks of nitrate leaching.

References

[1] Bouma TJ, Nielsen KL and Koutstaal B 2000. Plant and Soil 218, 185-196.
[2] Brookes PC, Landman A, Pruden G andJenkinson DS 1985. Soil Biology and Biochemistry 17, 837 - 842.
[3] Vance ED, Brookes PC and Jenkinson DS 1987. Soil Biology and Biochemistry 19, 703-707.

DINITROGEN EMISSIONS FROM CODENITRIFICATION IS THE MAIN LOSS PATHWAY FROM URINE AMENDED GRASSLAND SOIL

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Objectives

Grazed grassland livestock systems are often associated with considerable losses of reactive forms of nitrogen (N) to the environment such as nitrate leaching, ammonia and nitrous oxide (N_2O) emissions. Previous research has focused on losses to air and water due to the health, economic and environmental impacts of reactive N. Di-nitrogen (N_2) emissions from soils are still poorly characterized, both in terms of the processes involved and their magnitude, due to methodological constraints. There have been relatively few studies on N_2 losses in vivo and even fewer have examined the relative contribution of the different N_2 emission pathways. The objectives of this recently published study were 1. To quantify N_2 fluxes from urine amended soil and 2. To quantify the contributions from conventional denitrification and codenitrification pathways [1].

Method

Cow urine was amended with 98 atom% ^{15}N-labelled urea resulting in a urine N concentration of 10 g N L^{-1} and a ^{15}N enrichment of 45 atom% excess. Two litres of urine was applied to replicated (n=4) monolith lysimeters at a rate of 1000 g N ha^{-1}. To understand the role of nitrification on nitrogen fluxes, dicyandiamide (DCD) was used to inhibit nitrification. DCD was sprayed onto the lysimeter surface in two split applications of 15 kg DCD ha^{-1} at 0 and 60 days after urine application. There were two treatments: (1) ^{15}N-labelled urine (“no DCD”) and (2) ^{15}N-labelled urine with DCD (“DCD”).

The static chamber method was used to quantify N_2O and N_2 fluxes. Headspace N_2O concentration was quantified using gas chromatography. N_2 and N_2O samples were analyzed for ^{15}N by isotope ratio mass spectrometry in the UC Davis Stable Isotope Facility. True denitrification and co-denitrification to N_2 were calculated using the ^{15}N flux method [2]. In brief, for N_2O the ion currents (I) at *m/z* 44, 45, and 46 enabled concentrations and molecular ratios ^{45}R ($^{45}I/^{44}I$) and ^{46}R ($^{46}I/^{44}I$) to be calculated. The sources of N_2O were then apportioned into the fraction (d'_D) derived from the denitrifying pool of enrichment N_2O_{aD} and the fraction $d'_N = (1 - d'_D)$ derived from the pool or pools at natural abundance. For N_2, the ion currents at *m/z* 28, 29 and 30 enabled molecular ratios ^{29}R ($^{29}I/^{28}I$) and ^{30}R ($^{30}I/^{28}I$) to be determined. Differences between the molecular ratios of enriched and ambient atmospheres were expressed as $D^{29}R$ and $D^{30}R$. The flux of N_2 was calculated using three different methods:

(1) $D^{29}R$ and $D^{30}R$ were used to calculate the enrichment of the denitrifying pool ($^{15}X_N$) and then the N_2 flux

(2) using $D^{30}R$ data only assuming that the enrichment of the denitrifying pool was N_2O_{aD}

(3) using $D^{29}R$ and $D^{30}R$ to calculate a separate contribution due to co-denitrification (N_{2CO}) and true denitrification (N_{2TRUE}) calculated by Method 2.

Results

Denitrification of ^{15}N-labelled N sources resulted in the generation of N_2 gas with either one or both N atoms ^{15}N-labelled, giving a mass number of either 29 or 30, respectively. As co-denitrification results in the formation of hybrid N_2, the isotopic composition of that hybrid N_2 will contain a large proportion of ^{29}N relative to ^{30}N and the ratio of $D^{29}R$ to $D^{30}R$ derived solely from co-denitrification will be 272. The observed ratio of $D^{29}R$ / $D^{30}R$ in this study was 214 indicating a substantial contribution of co-denitrification to the total N_2

efflux. Temporal profiles of gaseous N emissions revealed substantial losses associated with N_{2CO}, with mean daily fluxes of 4.4 kg N ha^{-1} d^{-1} observed over the four-month experiment. In contrast, emissions associated with true denitrification were an order of magnitude lower; with mean daily fluxes of 0.1 and 0.05 kg N ha^{-1} d^{-1} observed for N_{2TRUE} and N_2O_{TRUE}, respectively. Although N_{2CO} was the predominant loss pathway there was no detectable N_2O_{CO} during the course of the experiment. The cumulative gaseous N loss associated with true denitrification was 11.0 and 6.6 kg N ha^{-1} for N_{2TRUE} and N_2O_{TRUE}, respectively. Cumulative N_{2CO} was estimated at 558 kg N ha^{-1}, which accounts for 97% of the measured gaseous N loss or 56% of the N applied. Nitrification contributes to the high N_2 rates observed, over the first 30 days of the experiment, when the nitrification inhibition was effective, cumulative emissions were reduced by 55% ($P < 0.05$) for N_{2CO} and 59% ($P = 0.22$) N_{2TRUE}.

We hypothesise that urine N deposition on grassland soils may provide the optimal conditions for co-denitrification, principally due to the combination of high N inputs of both labile soil organic N and C. The formation of both hybrid N_2 and N_2O has been shown to be promoted by increases in pH. Urine patches cause localized areas of high pH (circa. 8 - 10) due to the formation of NH_3, NH_4^+ and hydroxide ions following urea hydrolysis. The second stage of nitrification, the oxidation of NO_2^- to NO_3^-, can be inhibited by high NH_3 concentrations in soils due to the elevated soil pH and resulting in elevated NO_2 concentrations. High soil NO_2^- levels of 70 mg kg^{-1} have been observed after urine application with no measurable NO_3^- accumulation [3]. We suggest that the high rates of codenitrification observed in this study result from the physiochemical conditions after the nitrogen cascade from urine application. This seldom studied process in soil requires further investigation in grazed grassland systems to improve estimation of nutrient balances and greenhouse gas emissions.

Conclusions

Co-denitrification was the dominant process producing N_2 beneath urine patches, accounting for 97% of all denitrification-derived gaseous N_2 loss. The quantification of significant N loss via co-denitrification has major environmental and economic implications. These high N_2losses represent a considerable economic loss of soil N required for production of agricultural goods. Further studies on co-denitrification in grazed grasslands and the factors affecting its magnitude are needed.

Acknowledgements

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References

[1] Selbie D.R. et al. 2015. Scientific Reports 5,17361, 1-5

[2] Laughlin, R.J., Stevens, R.J. 2002 Soil Science Society of America Journal 66,1540-1548

[3] Clough, T.J., et al. 2003 Australian Journal of Soil Research 41(3):421-438.

OPPOSING EFFECTS OF NITROGEN AND PHOSPHORUS ON SOIL MICROBIAL METABOLISM AND SOIL CARBON STORAGE

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Objectives

Due to its positive effect on net primary production (NPP), nitrogen (N) fertilization increases soil organic carbon (SOC) storage in agricultural systems 1. However, the effect of fertilization with N and other macro-nutrients on carbon (C) outputs such as heterotrophic respiration and the mechanisms involved are still difficult to predict. Cleveland and Liptzin 2 reported a globally well constrained microbial biomass C:N:-Phosphorus (P) ratio of 60:7:1, which indicates stoichiometric constrains for microbial growth and suggests that nutrient availability may impact on microbial resource use efficiency. Our objectives were to quantify the long-term effects of N and P fertilization on SOC stocks in ten meta-replicated long-term field experiments in Sweden. In addition, short- and long-term effects of contrasting N and P availability on CO2 and heat production were determined in three experiments to advance our understanding on how major soil nutrients influence microbial metabolism and SOC cycling.

Method

The Swedish Long-term Soil Fertility Experiments (LTEs) were established between 1957 and 1966. These experiments are meta-replicated across Sweden and cover a wide range of climatic and pedological conditions. They are unique because all of them have an almost identical experimental design consisting of a combination of different N and PK levels.

Previous investigations in Swedish LTEs revealed that SOC stocks increased with N fertilization 1,3. On the contrary, in treatments with no N, but only PK addition, SOC stocks decreased in nine out of ten soils from the LTEs with increasing PK-application rates despite higher NPP as compared to the unfertilized reference 4. It has been established that P rather than potassium (K) is the element affecting ecosystem C fluxes. For further evaluating the effect of N and P on heterotrophic respiration, we incubated soil samples with and without mineral N and P and/or glucose.

Soils were sampled in March 2015 in three of these LTEs representing a large gradient in soil texture (7-30% clay) from the following three field treatments: i) no NPK (0NPK), ii) no PK but highest N level (N0PK) and iii) no N but highest PK level (PK0N).

We combined each field-treatment (n=3) at each field site (n=3) with 8 laboratory-treatments, which were no nutrient addition (Con), as well as +N, +P, +NP, Glucose, Glucose+N, Glucose+P and Glucose+NP additions. Five grams of soil were filled into 20 ml glass reaction vials with an indicator dye in their headspace as CO2 trap. Heat production was recorded during five hours in an isothermal calorimeter (TAM Air, Sollentuna, Sweden) set to a temperature of 25°C. The trapped CO2 was measured in a spectrophotometer.

To investigate the short-term effect of nutrient addition on heat and CO2 production, we used linear mixed effect models with (nested) random effects to test the difference between laboratory-treatments for significance.

Results

In the glucose-amended samples, we found 14% lower CO_2 and heat production when N was added (Glucose+N) in comparison with Glucose alone. Interestingly, this was observed in all six soils with a long-term history of no fertilizer N addition, while in the field-treatments with N addition (N0PK), we found an increase in CO_2 production at all three sites in comparison to Glucose addition alone. This indicates that under N deficiency CO_2 production was lowered with N addition, while the opposite was true when soil N was more abundant.

Both stimulating and retarding effects of N on soil respiration have been reported in the literature. The "microbial nutrient mining"- theory predicts that under nutrient limiting conditions, nutrients needed for biosynthesis are acquired by decomposing more recalcitrant organic matter by using energy from labile, but nutrient-poor C sources 5. In contrary, a stimulating effect of N on microbial activity has also been reported from decomposition studies under nutrient-poor conditions 6. In our study, we were able to show that the response of heterotrophic respiration to N additions depends upon prevailing N availability in the soil, thus providing support to both theories mentioned above. The convergence of the two theories adds to our understanding and ability to predict ecosystem responses to altered N availability.

While Glucose+N addition reduced CO_2 and heat production, Glucose+P addition increased CO_2 and heat production by 17% and 9%, respectively. Similar results were found when comparing the contrasting long-term field-treatments: PK0N had a higher Glucose-induced CO_2 and heat production per unit SOC as compared to 0NPK, while both were suppressed in N0PK fertilised soils. We were able to link basal respiration per unit SOC to long-term losses in SOC stocks, which were highest in the PK0N-fertilised plots at all investigated sites.

Conclusions

In conclusion, N and P showed opposing effects on the balance of microbial metabolic processes including respiration. The results suggest that SOC dynamics are more output-driven in PK fertilized systems but more input-driven in N fertilized systems due to the more pronounced response of NPP to N than to PK fertilization. Our findings are of specific importance for nutrient poor but C rich ecosystems exposed to nutrient inputs.

[1] Kätterer, T., Bolinder, M., Berglund, K. & Kirchmann, H. 2012. Acta Agriculturae Scandinavica, Section A-Animal Science 62, 181-198
[2] Cleveland, C. C. & Liptzin, D. 2007, Biogeochemistry 85, 235-252
[3] Kätterer, T., Börjesson, G. & Kirchmann, H. 2014, Agriculture, Ecosystems & Environment 189, 110-118
[4] Poeplau, C., Bolinder, M. A., Kirchmann, H. & Kätterer, T. 2015, Biogeosciences Discuss. 12, 16527-16551
[5] Craine, J. M., Morrow, C. & Fierer, N. 2007, Ecology 88, 2105-2113
[6] Allen, A. S. & Schlesinger, W. H. 2004, Soil Biology and Biochemistry 36, 581-589

NITRIFICATION, DENITRIFICATION AND NITROUS OXIDE EMISSION AS AFFECTED BY SOIL pH MANAGEMENT

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Objectives

Amelioration of soil pH by liming is a common practice in vast areas of crop production. It is well known that rates and product stoichiometries of microbial N transformations can be affected by pH. While liming of acid soils appears to increase N_2O reductase activity in denitrification (resulting in less N_2O relative to N_2), sudden pH increase may boost mineralization and nitrification and hence N_2O emission. The goal of the present study was to evaluate nitrification and denitrification potentials and their gaseous product stoichiometries (NO, N_2O, N_2) in soils one year after incorporating different calcareous and siliceous minerals in a field experiment, resulting in more or less strong increase in soil pH.

Method

Soils were retrieved from a field trial established in 2014 on the research farm of the Norwegian University of Life Sciences (NMBU) at Ås (59° 49' N, 10° 47' E, 75 m a.s.l) in southeast Norway. The experiment consists of seven treatments, comparing calcareous limes (calcite, dolomite) with siliceous minerals (olivine, norite, larvikite, nepheline) and an untreated soil in a randomized complete block design on an acid loam soil (pH_{H2O}= 5.4) after 60 years of various crop rotations (C_{tot}= 2.9 % ; N_{tot}= 0.28 %). The experiment was designed to compare fast liming materials (calcareous limes) with slow liming materials (siliceous minerals) as a strategy to reduce N_2O emissions from soil. Minerals were applied in autumn 2014 at a dose of 30 t ha^{-1} (siliceous rock powders and calcite) and 23 t ha^{-1} (dolomite) and the area was sown with grass in spring 2015. Since June 2015, N_2O *in situ* emissions are monitored by an autonomous field flux robot(https://www.youtube.com/watch?v=NAtl-2ONuKI&feature=youtu.be) at high temporal resolution. To determine the trajectories of N transformations in response to the various treatments, we determined potential nitrification and denitrification and their N_2O product stoichiometries, $N_2O/(NO_2^- + NO_3^-)$ and $N_2O/(N_2O+N_2)$, respectively, in laboratory experiments one year after initiation of the field experiment. Soils were incubated as 1:10 oxic or anoxic slurries with 1 mM NH_4Cl or KNO_3 for nitrification and denitrification, respectively. Headspace concentrations of O_2, CO_2, NO, N_2O and N_2 were monitored by a temperature controlled, robotized incubation system [1]. Nitrate and nitrite accumulation was analyzed throughout the incubations. To evaluate the potential overall N_2O emission response to liming, we compared N_2O emission potentials of nitrification and denitrification as the product of increase in rate as well as change in N_2O yield in each process.

Results

The field experiment is in its second year and shows strong pH increase (0.7-1.5, units) in plots with calcareous limes, a weak pH increase (~ 0.2, units) in the olivine treatment and no measurable pH increase in other mineral treatments. Oxygen consumption and nitrification rates in the aerobic laboratory incubations were correlated positively with soil pH, suggesting that liming could increase N_2O emissions and NO_3^- leaching. The stimulation of nitrification was substantial with a nearly 4 times higher rate in the calcite treated soil as compared to the untreated control. N_2O accumulation relative to nitrification, $N_2O/(NO_2^- +NO_3^-)$,was $9\text{-}17*10^{-4}$, thus 0.09 - 0.17% of the oxidized NH_4^+ was emitted as N_2O. This ratio ("nitrification N_2O yield") increased with soil pH in the order control, larvikite < norite, olivine < nepheline < dolomite < calcite and was significantly higher for calcite and dolomite treated soils. Higher N_2O yield at higher pH appeared to be associated with transient NO_2^- accumulation in the oxic soil slurries, suggesting that nitrifier denitrification of NO_2^- or chemical reactions between NO_2^- and H_2NOH supported the inherently high N_2O yields in calcite and dolomite treated soils.

Potential denitrification rates showed little response to pH increase. In contrast, N_2O product ratios were strongly reduced in the order calcite < nepheline < dolomite < larvikite < olivine < norite = control. Calcite treatments showed almost no N_2O accumulation (0.08% of added NO_3^-), whereas the untreated control soil accumulated up to 14.2 % of the added NO_3^- as N_2O. The corresponding number for the dolomite treatment was 2.1% and for nepheline 6% which corresponds to a ~50% reduction in denitrification N_2O yield. All other silicate treatments showed no significant reduction in relative N_2O accumulation, consistent with the lack of pH change in these treatments at the time the soils were sampled.

In summary, calcite treatment stimulated nitrification rates by a factor of four and nitrification N_2O yield by a factor of two. In comparison, the effect of pH increase on denitrification rates was negligible, while the "N_2O yield" of denitrification was almost zeroed within 1 year after calcite application. Balancing the converse effects of soil pH increase on the N_2O production potential in the two processes suggests that liming should decrease N_2O emissions in soils prone to intermittent denitrification, particularly since N_2O yields are typically much higher in denitrification than in nitrification.

Conclusions

Given the overall low N_2O yield of nitrification (0.1 - 1%) as compared to that of denitrification (10 - 100%), the observed increases in N_2O yields of nitrification after liming are unlikely to override a significant reduction in N_2O production by denitrification under fluctuating oxic-anoxic conditions. The results will be discussed relative to high-resolution N_2O fluxes measured by an automated field flux robot in the same liming experiment.

[1] Molstad, L., Dörsch, P., Bakken, L.R. 2007. *Journal of Microbiological Methods* 71, 202-211

DEVELOPMENT TRENDS AND SOLUTION SCENARIOS FOR IMPROVED N EFFICIENCY

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Objectives

The overall Nitrogen Use Efficiency (NUE) for Danish agriculture has more than doubled, from less than 20% in 1930, to about 20% in 1970, and up to between 40-50% today [1]. Similar trends have been observed in other OECD countries. However, there is room for significant further improvements of the NUE, and there are urgent needs to investigate how different pathways towards increased NUE may interfere with types of N losses to the environment, or soil-pooling, as well as the yield and the economy [2]. Otherwise, suboptimal development trends maybe promoted, with adverse pollution swapping effects, and severe economic losses as a result.

The objectives of the present paper are: (i) based on the Danish case, to document these development trends, including links to the distribution between different types of N-losses, greenhouse gas (GHG) emissions, soil pooling, and (ii) to illustrate the effects of selected solution scenarios for improved N efficiency.

Method

Based on concepts developed during the European Nitrogen Assessment, the national N balance, including new methods to synthesize major N flows in Danish agriculture and the surrounding Society, has been accounted [3]. From this, it is possible to calculate the NEU (N output divided by N input), and split surplus N (N input to agriculture minus N output from agriculture) into types of losses (especially in the form of reactive Nitrogen (Nr) compounds like nitrate, ammonia, nitrous oxide and nitrogen dioxide).

In the present study, similar techniques is used to assess decadal trends in the Danish NEU, as well as the development in N-surpluses and types of N losses, also including estimated soil N pool changes. Farming systems modelling techniques are implemented, distinguishing between sets of official emission factors for different types of crop- and livestock production systems as well as livestock housing, manure handling, -spreading and -storage systems [4].

In addition, the study includes the assessment of selected so-called solution scenarios, defined during the www.dNmark.org Nitrogen Research Alliance. In this context, the types of solution scenarios include examples on the effect of: 1) New production chains with more efficient nitrogen utilization and recirculation (for example extensive implementation of biogas production, both from manures and green biomass, and in combination with biorefinery systems and the recycling of waste streams). 2) Geographically targeted measures based on locally adapted management and planning (geographically differentiated land use), and 3) New consumption patterns leading to land use changes and changes in nitrogen cycles (for example more organic food consumption).

Results

The main cause for the doubled N-efficiency during the proceeded four decades is the ongoing better utilization of livestock manures, and a higher efficiency in the livestock production. Until the mid-1980es increased crop yields per N input, with extensive conversion from spring cereals to higher yielding winter cereals, added significantly to the higher NEU. However, especially with the implementation of the series of action plans for the aquatic environment, including statutory maximum N fertilizer norms for each crop, the obligatory substitution rate between livestock manure and synthetic fertilizers was tightened, and efficient techniques to increase the NUE of manures was so successful that the fertilizer import dropped significantly. From more than 400 kt N imported in the form of synthetic fertilizers in the beginning of the 1980es to below 200 kt N today.

Over the years, the national N action plans especially focused on measures to reduce the nitrate leaching to the aquatic environment; both groundwater and surface waters (for instance extensive use of catch crops, more winter green fields, and a more effective utilization of fertilizers). This has been very successful, and has more than halved the total nitrate leaching, whereas the total N-surplus also have been reduced significantly (by 43% over the same period), but relatively less than the nitrate leaching. Thereby, relatively speaking the strong focus on leaching have led to pollution swapping, where the other types of N-losses have been reduced less, and moreover the soil pools and thereby the long term effect on N-losses has been affected.

With the major reform of Danish agri-environmental policies from December 2015, the focus on targeted reduction in N leaching, in order to meet requirements of the EU Water Framework Directive (WFD) increased, whereas the general regulation with fertilizer norms has been loosened (from a level 15-20% below the economic optimal crop fertilizer norms, back to the production economical optimum). This adds further to the pollution swapping, assessed as a baseline for the expected NEU developments until 2030.

Finally, the overall national NEU of selected solution scenarios is accounted using the techniques defined above, and compared to the 2030 baseline mentioned. For comparison, each solution scenario is defined in order to meet the Danish WFD goals, and it is assessed how this equal effect on nitrate leaching for each scenario will interfere with the other types of reactive N losses simulated. These results on side effects in the form of pollution swapping will be relevant to any country in the process of revising agri-environmental policies to meet multiple targets for reduced pollution of the aquatic environment as well as other N pollutants, and in combination with development of a viable agricultural business sector.

Conclusions

Significant pollution swapping effects of the decadal measures to reduce N leaching from Danish agriculture were identified from the study of national trends in the N balance, and is an important part of the story about the effect of increased Nitrogen Use Efficiency (NUE) induced by agri-environmental policies.

The same methods are useful to compare different solution scenarios to further increase the NUE and achieve defined N pollution goals, as for instance those set out in the EU Water Framework Directive, while being aware of the side effect in the form of other types of reactive nitrogen losses and space for the further development of farming.

Acknowledgements

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References

[1] Dalgaard, T. et al. 2014 Policies for agricultural nitrogen management - trends, challenges and prospects for improved efficiency in Denmark. Environmental Research Letters 9 115002 16 pp .
[2] Zhang X. et al. 2015 Managing nitrogen for sustainable development. Nature 528 51-59.
[3] Hutchings, N. et al. 2014 A nitrogen budget for Denmark; developments between 1990 and 2010, and prospects for the future. Environmental Research Letters 9 115012 8 pp .
[4] Happe, K. et al. 2011 Modelling the interactions between regional farming structure, nitrogen losses and environmental regulation. Agricultural Systems 104 3 281-291.

NITROGEN CASCADE AT THE LANDSCAPE SCALE: MODELLING THE EFFECT OF CLIMATE, SOILS AND AGRICULTURE ON DIRECT AND INDIRECT N EMISSIONS IN CONTRASTED RURAL SITES

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Objectives

In rural landscapes, the way reactive nitrogen transforms and transfers in the agro-ecosystem depends on farm management, landscape structure and their interactions with the environment. While NO_3^- emissions are frequently measured and modeled at the catchment level, this is rarely the case for NH_3 and N_2O emissions, although (1) in intensive livestock production areas, NH_3 emissions to atmosphere can be as high as NO_3^- emissions to water; (2) N_2O indirect emissions after lateral transport of NO_3^- and/or NH_4^+ can be as high as direct emissions in the field. Within the ESCAPADE project (ANR-12-AGRO-0003http://www.n-escapade.fr), N emissions to air and water in three contrasted sites in France are assessed using spatially distributed models, calibrated using landscape-wide monitoring schemes. The main objectives are to (1) evaluate the ability of these models to simulate observed spatial-temporal patterns of N emissions (2) discuss the relative importance and main controlling factors of these emissions.

Method

Study sites are headwater catchments located in Brittany (Western France) in Gascogne (South-West of France) and in Ile-de-France (Paris region). They are contrasted in terms of landscape structures, agriculture type (mix farming with high livestock density in Brittany, and cereal cropping in Gascogne and Ile-de-France), bedrock, soil, and climate (mild and humid in Brittany, temperate with continental influence in Ile-de-France, temperate with mediterranean influence in Gascogne). Surveys were carried out to describe exhaustively agricultural practices. Measurements and monitoring of discharge, NO_3^- concentration, atmospheric NH_3 concentrations and field-scale N_2O emissions, were conducted in the three sites.. Two integrated and spatially distributed models are used complementarily. TNT2 is a spatially distributed agro-hydrological model focusing on nitrate transfer, hedgerows and riparian zone functioning [1, 2]. NitroScape is a model designed to quantify the contribution of both atmospheric and hydrological transfers to Nr fluxes, budgets and indirect Nr emissions [3].

Results

The application of the models to the sites is being performed using similar calibration procedures. The results of these simulations will be presented and discussed during the workshop. Preliminary results show the ability of the models to simulate fluxes and losses of reactive nitrogen (NO_3^-, NH_4^+, NH_3) and greenhouse gases (N_2O) in the coupled compartments of the sites: atmosphere, hydrosphere, pedosphere and agroecosystems including farm buildings, croplands, grasslands, semi-natural zones such as hedgerows or riparian zones. The models show the spatial (i.e., within the sites represented by spatial resolutions of a few meters) and temporal (i.e., within one year and between years) variability of nitrogen fluxes and losses. This variability results from the relative position of nitrogen sources and sinks within the landscape, as well as their intensity (i.e., potential of emission and recapture) which is related to nitrogen management. It also results from differences between the sites in terms of soil characteristics and climatic conditions. The models are able to quantify the indirect emissions of nitrogen resulting from lateral transfers in water or in the air as well as the interactions between these two pathways at the soil and vegetation interface.

Conclusions

Both models are complementary to quantify nitrogen fluxes and losses at a landscape scale. They are innovative since they integrate simultaneously lateral transfers of nitrogen through both the atmosphere and the water pathways. They provide relevant results on nitrogen losses on sites characterized by contrasted management, soil and climate conditions. This ensemble of coupled models forms a powerful tool to assess the impact of mitigation and adaptation scenarios related to farm management, changes in landscape structure and agricultural policies on nitrogen losses, environmental impact of agroecosystems and greenhouse gas balance.

References

[1] Beaujouan, V., Durand, P., Ruiz, L., Aurousseau, P., and Cotteret, G. (2002). A hydrological model dedicated to topography-based simulation of nitrogen transfer and transformation: rationale and application to the geomorphology-denitrification relationship. *Hydrological Processes* 16, 493-507.

[2] Oehler, F., Durand, P., Bordenave, P., Saadi, Z., and Salmon-Monviola, J. (2009). Modelling denitrification at the catchment scale. . *Science of the Total Environment* 407, 1726-1737.

3] Drouet, J. L., Duretz, S., Durand, P., and Cellier, P. (2012). Modelling the contribution of short-range atmospheric and hydrological transfers to nitrogen fluxes, budgets and indirect emissions in rural landscapes. *Biogeosciences* 9, 1647-1660.

USING FIELD NITROGEN BALANCES AS AN INDICATION OF NITROGEN SOURCE PRESSURE CHANGE ON WATER QUALITY

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Objectives

The European Union Nitrates Directive constrains the magnitude and timing of nutrient management and is legislated to improve and protect water quality in agricultural catchments. Specific action programme meaures are peridocally reviewed and, in the Republic of Ireland, these are evaluated at the catchment scale across and the nutrient transfer continuum. As part of this larger programme, the objectives of this specific study were to (i) assess the N balances at field scale in an intensive arable catchment over a 4 year period (2010-2013), and (ii) identify if total oxidized N (TON) concentrations at the catchment outlet reflected changes in field N balances during the study period.

Method

The catchment is 11 km^2, located in the south-east of Ireland and mostly on well-drained cambisol soils on slate and siltstone bedrock. The aquifer is shallow with flow largely occurring in permeable layers of subsoil and highly weathered bedrock. The stream is largely groundwater fed and due to the high soil and bedrock permeability the discharge responds relatively quickly to rainfall and nitrate-N attenuation along pathways are assumed to be small. Between 2010 and 2013 catchment annual nutrient (chemical and organic) inputs, land-use (crop types) and yield data for fields were collected from landowners. The N off-takes for each crop yield recorded were calculated using standardized figures based on the crops N content. Field balances were calculated as the difference between the total N inputs and total N off-takes expressed as kg N ha^{-1}. Concurrently, high temporal resolution monitoring of water discharge and TON concentration was conducted at the catchment outlet across four hydrological years (April 2010 to March 2014). In stream ecological surveys of macro-invertebrate and diatom quality were carried out at the catchment outlet every May and September from 2010 to 2013.

Results

Land-use in this catchment included grassland (28%) and a range of other annual tillage crops (cereals and root crops). However, across the 4 year study period, spring barley dominated land-use (49.5%) and occupied on average 1,322 ha. The average N applied to the tillage crops in the catchment increased from 144 kg N ha^{-1} in 2010 to 162 kg N ha^{-1} in 2012, with a slight reduction to 161 kg N ha^{-1} in 2013. For spring barley specifically, the average N input rate increased annually from 136 kg N ha^{-1} in 2010 to 154 kg N ha^{-1} in 2013. These rates were below the recommended maximum allowance of 155 kg N ha^{-1} for expected spring barley yields of 7.5 t ha^{-1} as the average yields ranged from; 7.3 t ha^{-1} (2010) to 7.7 t ha^{-1} (2013). Consequently, an average N surplus was calculated from all tillage fields increasing from 12.0 kg ha^{-1}, 22.6 kg ha^{-1} and 26.3 kg ha^{-1}, including spring barley fields of 14.4 kg ha^{-1}, 25.1 kg ha^{-1} and 25.0 kg ha^{-1} across the observed years of 2010, 2011 and 2013, respectively. The highest average N surpluses were in 2012, calculated as 35.5 kg N ha^{-1} for the tillage fields in this catchment and of 33.0 kg N ha^{-1} for spring barley. Although N inputs in 2012 were slightly higher compared to the other observed years, an exceptionally high and intense period of summer rainfall (533 mm) in this year damaged crops, and resulted in slightly lower than expected yields, including 7.0 t ha^{-1} yields for spring barley.

At the catchment outlet, the average TON concentrations increased from 6.3mg l^{-1} in 2010/2011 to 6.7mg l^{-1} in 2011/2012 and remained at 7.2mg l^{-1} in 2012/2013 and 2013/2014. Over this same period, there were no clear trends of improving or declining stream biological quality. However there were early indications of a decline in the September macro-invertebrate quality from ‘good’ (2010 and 2011) to ‘moderate’ status (2012 and 2013) and of improvements in the May diatom quality from ‘poor’ (2010 and 2011) to ‘good’ (2012) and ‘moderate’ (2013) status.

Mobilisation, transformations and transport time of N (lag-time) via groundwater pathways and ultimately monitored at the catchment outlet is influenced by soil type and the seasonal climatic systems within the catchment. Considering some of these influencing factors, these field N balances that are based on production values alone need to also account for other gains and losses of N within the biosphere (e.g. soil), particularly when providing a better assessment that changes in N sources pressures may have within different catchment and climates.

Conclusions

The field N balances from this intensive arable catchment indicate that the N source pressure has increased across the observed period. With an expected lag time effect from source to stream, given the highly permeable nature of this catchment, lag time was short and N losses increased. With changing cropping patterns field N balances need to account for the native N supplied from the soil, along with critical factors such as climate and processes that contribute to its mobilisation. This could provide a clearer indication of the levels of N source pressure change and the confounding factors that drive their losses in this catchment at risk to N loss. Factors which will become more crucial as N inputs continue to increase to achieve expected higher yields under increasingly unpredictable and variable climate systems.

IMPACT OF NITROGEN USE IN AGRICULTURE ON GLOBAL EMISSIONS OF NITROUS OXIDE (N2O) AND CARBON DIOXIDE (CO2)

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Objectives

Nitrogen (N) use in agriculture benefits crop production, but also leads to nitrous oxide (N_2O) emissions, which contribute to climate change [1]. N_2O is emitted directly from agricultural soils, as well as indirectly from water bodies and terrestrial systems due to elevated N deposition and N runoff to water. However, elevated N deposition may also increase net primary productivity in N-limited terrestrial ecosystems and thus carbon dioxide (CO_2) uptake from the atmosphere [2]. This indirect effect can lead to a considerable reduction of the overall climate impact of N use in agriculture. This research derives a quantitative estimate of the global impact of N use in agriculture on net greenhouse gas emissions, by assessing the effect of N deposition on carbon (C) sequestration in forests (based on a meta-analysis of forest fertilization experiments) and comparing it with available estimates of global direct and indirect N_2O emission from agriculture.

Method

(Description in this and the following section is based on preliminary analysis of ca. 50% of the data).

As forests currently account for about 90% of the terrestrial C sink, the size of the nitrogen-induced C sink is largely determined by forests' response to N deposition, in interaction with other environmental drivers, such as CO_2 concentration, temperature, and phosphorus availability. In order to assess additional C sequestration per unit N deposition (C-N response) in forests, as well as factors influencing this response, we performed a meta-analysis on data from forest fertilization experiments around the globe. We focused on studies reporting changes in aboveground woody biomass (AGWB), a relatively stable carbon pool with long turnover times, in response to N addition. We hypothesize that the C-N response differs among forest biomes (boreal, temperate, sub-tropical and tropical forests).
We performed an extensive literature search to identify relevant studies and selected articles based on pre-defined criteria. In total, we identified 20 relevant studies with 63 observations. Effect sizes (kg C sequestered in AGWB per kg N added) were extracted from individual studies. Summary effect sizes were calculated as the weighted average of individual effect sizes using a random-effects meta-analytical model.

To calculate total C sequestration in forests' AGWB resulting from agriculture-related N deposition, we multiplied average C-N responses of tropical, sub-tropical, temperate and boreal forests with the amount of ammonia (NH_3) deposited on these forest types. We assume that NH_3 deposition presents a reasonable estimate of total N deposition caused by N use in agriculture - in fact, a small part of NH_3 emissions stems from other sources, however, this is compensated by neglecting agricultural nitrogen oxide (NO_x) emissions, which are in the same order of magnitude. NH_3 deposition per forest biome was estimated by overlaying a land cover map (GLC 2000) and spatially explicit TM5 model estimates of total NH_3 deposition for the year 2000 [3].

Finally, we reviewed published estimates of agricultural N_2O emissions and compared the climatic effect of these emissions to those of enhanced forest C sequestration by converting both fluxes to CO_2-equivalents (CO_{2eq}).

Results

Results from the meta-analysis showed N-induced C sequestration in AGWB of:

- 23.1 (18.9-27.2) kg C per kg N for boreal forests (n=12);
- 20.7 (13.5-27.9) kg C per kg N for temperate forests (n=33);
- 5.5 (-4.0-15.0) kg C per kg N for sub-tropical forests (n=9); and

- 2.2 (0.2-4.3) kg C per kg N for tropical forests (n=10).

These estimates agree reasonably well with results from stoichiometric scaling [2]. In this approach, N-induced C sequestration is estimated by multiplying N deposition with the fraction of N retained in ecosystems, N allocation to ecosystem compartments, and C:N ratios of these compartments. Results thus obtained for AGWB are 21.3 (17.0-25.5) kg C per kg N for boreal forests, 14.4 (11.6-17.3) kg C per kg N for temperate forests and 5.0 (3.3-6.6) kg C per kg N for tropical forests [2]. Estimates of C-N responses for *total* plant biomass obtained by a global process-based dynamic vegetation model [4]are also similar for boreal (17.5±10.2 kg C per kg N) and temperate (24.0±4.7 kg C per kg N) forests. For tropical forests, the model estimates a much higher response (25.9±20.9 kg C per kg N), however, the authors acknowledge that this estimate is highly uncertain due to (among others) the lack of P cycle representation in the model.

By multiplying the C-N responses obtained by our meta-analysis with estimates for NH_3-N deposition per forest biome, we derive a global C sink in forest AGWB of about 113 (49-178) Tg C/year. In order to derive an estimate of total N-induced forest ecosystem C sequestration, we multiply C-N responses in soils and belowground woody biomass obtained by stoichiometric scaling [2] with NH_3 deposition. We estimate an additional global annual C sequestration of 100 (80-133) Tg C in soils and 23 (18-30) Tg C in BGWB (mainly in temperate forests due to a combination of high N deposition and high C-N responses). Total ecosystem C sequestration caused by agricultural N use thus amounts to ca. 236 (147-341) Tg C/year, or 865 (539-1,250) Tg CO_2/year.

Estimates for global N_2O emissions from agriculture published in the scientific literature vary mostly between 6.0 and 11.2 Tg N_2O/year [1],[5]. This corresponds to CO_2-equivalent emissions of 1,780 to 3,320 Tg CO_2eq/year (based on a 100-year global warming potential of 298). Using our central estimate for N-induced C sequestration, we estimate that 26-49% of agricultural N_2O emissions are compensated by agricultural N use-induced C sequestration in forests.

Future analysis of the dataset will allow a refinement of this estimate by determining variables that influence C-N responses, such as foliar nutrient status, soil quality, or dominant mycorrhizal associations.

Conclusions

This study is the first to obtain an estimate of agriculture N-related C sequestration in forest aboveground woody biomass using on meta-analysis. Based on a meta-analysis of data from 63 fertilization experiments in boreal, temperate, sub-tropical and tropical forests, we estimate that these forests respectively store an additional 23.1, 20.7, 5.5 and 2.2 kg C per kg N deposition. These results agree well with those from stoichiometric scaling and modeling (except for tropical forests). We obtained a rough estimate of total global C sequestration in forest woody biomass induced by agricultural N use by multiplying NH_3 deposition on boreal, temperate, sub-tropical and tropical forests with C-N responses obtained from the meta-analysis. Adding results for N-induced C sequestration for belowground woody biomass and soils from stoichiometric scaling leads to a total estimate of 236 Tg C/year sequestered in forests due to agricultural N use. This N-induced C storage only offsets about 26-49% of the climatic effect of the N_2O emissions caused by agricultural nitrogen use.

References

[1] Reay, D.S., Davidson, E.A., Smith, K.A. , et al. 2008 Nature Climate Change 2 6 , 410-416
[2] de Vries, W., Du, E, Butterbach-Bahl, K. 2014 Current Opinion in Environmental Sustainability 9-10, 90-104
[3] Dentener, F. , Drevet, J., Lamarque, J.F. et al. 2006 Global Biogeochemical Cycles 20 4
[4] Fleischer, K., Wårlind, D. , van der Molen, M. et al. 2015 Journal of Geophyscical Research: Biogeosciences 120 12
[5] Davidson, E.A., Kanter, D. 2014 Environmental Research Letters 9 10 , 105012

EFFECTIVENESS OF AGRI-ENVIRONMENTAL MEASURES TO REDUCE AIR AND WATER N POLLUTION ACROSS VENETO REGION, ITALY

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Objectives

The adoption of sustainable land management practices to reduce agricultural nitrogen (N) pollution is largely sustained by the EU policy, especially through financing agri-environmental measures (AEMs). Nevertheless, a thorough quantification of the ecological benefits of AEMs at large scale is still missing due to difficulties of extensive as well as site-specific measurements. This is strongly emphasised in the case of mitigating nitrogen nonpoint-source pollution. Indeed N movement is markedly dependent on localised pedo-climatic and management conditions, resulting in substantial changes to the N cycle.

As a result, here we propose an integrated model-GIS platform to locally quantify water, air and soil quality with the aim of evaluating the overall effectiveness of AEMs (e.g., optimisation of irrigation, continuos soil cover of arable lands, maintenance of grasslands, etc.) to reduce nitrogen pollution across Veneto region, Italy.

Method

The study site was the Veneto region, an administrative area of 18400 km^2 which is located in north-eastern Italy. Most of the area is occupied by the Venetian plain (55%), where highly intensive agriculture coexists with one of the most densely populated and industrialised area of the country.

DAYCENT model, after calibration, was coupled with geographical and alphanumeric data. In particular the pedo-climatic database was combined with the spatial extension of cropping systems and land use management information, providing 1343 polygonal units covering the regional territory.

In order to evaluate the effects of AEMs on N reduced pollution through the overall area, two different scenarios were simulated: a) a baseline scenario without the adoption of any specific agri-environmental policy, thus emphasising the impact of traditional farming practices on the environment; b) an AEM scenario, which was based on the spatial extension data of AEMs for the period 2007-2013, in response to the regional Rural Development Plan. Totally, simulations for the baseline scenario covered *ca*. 60% of the regional used agricultural area (8007 km^2), while those for AEM scenario covered 1048.4 km^2.

AEMs effects were evaluated in terms of water quality (total N leaching) and greenhouse gas emissions (N_2O), by considering the absolute and relative yearly difference between agro-ecosystems that adopted - and did not adopted - the AEMs.

Results

The greatest nitrogen inputs (both organic and mineral) were localised in the Venetian plain, reaching values up to 340 kg ha^{-1} y^{-1} of efficient N where most of intensive croplands as well as animal farming are concentrated. By contrast, mountain areas rarely exceeded 50 kg N ha^{-1} y^{-1}.

Water quality, evaluated in terms of N leaching, was generally improved by adopting AEMs. At regional scale, DAYCENT model simulations estimated a decrease in total N (mainly NO_3) of around 9.0 kg ha^{-1} y^1, totally corresponding to -575 t y^{-1} across Veneto. Several AEMs positively affected N leaching reduction, in particular the maintenance of grasslands (median of -26.8 kg N ha^{-1} y^{-1}), the land use conversion from arable to no-till conditions (no-till or grasslands, median of -25.1 kg N ha^{-1} y^{-1}) and the introduction of cover crops

(-20.1 kg N ha^{-1} y^{-1}). Spatially, water quality of the piedmont area was markedly improved by the adoption of AEMs, with N leaching reductions down to -53.6 kg N ha^{-1} y^{-1}. By contrast, the south-western regional area was frequently affected by increased N leaching. In this case, the complex combination of AEMs, poorly improving N reductions (e.g. organic farming systems, introduction of biosolids), with unfavourable pedo-climatic conditions yielded a surplus of nitrogen that was only partially absorbed by crops.

In terms of greenhouse gas emissions, the simulated AEMs caused a reduction of nitrous oxide, averaging -0.2 kg N-N_2O ha^{-1} y^{-1} with respect to the baseline scenario corresponding, in relative terms, to -16%. Generally, positive effects were observed when grasslands replaced arable lands (-1.3 kg N-N_2O ha^{-1} y^{-1}, on average), as well as when croplands were managed with a permanent soil cover. Indeed, the adoption of conservation agriculture and the introduction of cover crops likely induced a permanent N uptake that implied halved simulated N_2O emissions (-50.0%) with respect to the baseline scenario. The piedmont area still benefited of the introduction of AEMs, while the northern and southern areas showed more complex results. Both macroareas showed alternating positive and negative ΔN-N_2O values in different geographical units, ranging between -2.5 kg N-N_2O ha^{-1} y^{-1} to +6.2 kg N-N_2O ha^{-1} y^{-1}.

Conclusions

The proposed integration of geographical information with the agro-ecosystem DAYCENT model showed its feasibility for spatially evaluating the AEMs outcomes on N cycle regulation at regional scale. Generally, both air and water quality were improved throughout the region, although with some distinctions between local areas as a result of a complex interaction between agronomic and pedo-climatic conditions. In particular, the simulated permanent soil cover (e.g., cover crops, permanent grasslands) and no-till conditions (e.g., conservation agriculture) were the best solutions to reduce N leaching and N_2O emissions across Veneto. By contrast, other financed strategies (e.g., biosolid inputs, organic farming systems) should be locally evaluated since unfavourable conditions yielded a surplus of nitrogen that was only partially absorbed by crops. These estimates provide a good starting point for decision-makers aiming to implement a spatial targeting approach that effectively evaluate the ecological effectiveness of agri-environmental policies.

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CHANGES IN FOOD CONSUMPTION PATTERNS AND NITROGEN DEMAND RELATED TO CHINA´S URBANIIZATION

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Objectives

Large difference exists in food consumption between urban and rural households, and the nitrogen (N) costs (defined as total N input/the N in consumed food stuffs) are difference in vegetable- (N_{vf}) and animal-derived food N (N_{af}). We speculate that urbanization will generate major effect on the N flow in Chinese food-chain system, with more and more people moving into cities with urbanization, however, it is not well understood. We addressed this issue by analyzing the difference in urban and rural per capita food N consumption caused by urbanization, and then, multiplied population movement in urbanization and the global mean N cost of food.

Method

Material Flow Analysis

The material flow analysis approach was adapted for quantifying the N flow in the Chinese food-chain system, which is defined here as the entire food production–consumption chain, including the recycling of wastes from food production and consumption. The system boundaries followed the geographic boundaries of China, and excluded Taiwan, Hong Kong and Macao because of limited data availability. In this study, the food-chain system was divided into five categories: crop production, animal production, food processing, household consumption (including urban and rural households), and waste disposal.

Mass balance calculations as a basic principle (inputs = outputs + accumulations) was adopted for the calculations of N flows and accumulations in different stages of the entire food-chain system.

Data Collection

Basic data used in this study, such as population, gross domestic product (GDP), fertilizer usage, which is mainly taken from governmental statistical yearbooks and bulletins. Food supply, food import and export, and the utilization of grain were estimated using food-balance sheets from the FAO database. The second category of data is coefficients used for the calculation of N fluxes, such as the crop harvest index, the contents of N in harvested products and foods; such information was mainly obtained from the literature.

Indicators for Assessing Nutrient Use Efficiency in Food System

The new N cost of food (NC_f) was selected as the indictors from the food system perspective. And the N costs of grain production (NC_g), vegetable- (NC_{vf}) and animal-derived food (NC_{af}) were used as indicators, for analyzing the driving force of vegetable- and animal-derived food consumption for new N imported into the food system, because grain products can be used for food, feed, and raw material.

Effects of Population Growth, Dietary Changes, and Urbanization on Food N Consumption and N Imported into Chinese Food System

The effects of population growth, dietary changes, and urbanization on N imported into Chinese food system was defined as the changes caused by above three factors multiplying by the global mean N costs of vegetable- and animal-derived food.

Results

N input to Chinese food systems

New N input to the food-chain system from chemical N fertilizers, BNF, N deposition, irrigation, imported feed, fodder and fish increased by 53.8% from 32.9 to 50.6 Tg N between 1990 and 2009. Meanwhile, the recycling of N increased by 39.5%, from 12.9 to 18.0 Tg N. Total N input to the Chinese food system increased by 22.8 Tg in 2009 relative to 1990.

Urban-rural Differences in Per Capita Food and Food N Consumption and Dietary-pattern Changes

Per capita food N consumption changed from 2.92 to 3.48 kg for urban areas, and from 4.16 to 3.63 kg for rural ones, during 1990–2009. Among these, per capita vegetable food N of urban households decreased from 2.12 to 1.87 kg, with a mean decrease rate of 0.01 kg N per year, and from 3.82 to 2.93 kg, with a mean decrease rate of 0.05 kg N per year for rural areas, during 1990–2009. These trends indicate that dietary-pattern changes decreased the demand for vegetable food N per capita in both urban and rural areas, and this demand was further reduced by 1.06 kg yr^{-1} with population movement in urbanization because residents had a lower demand for vegetable food N in urban areas than in rural ones. However, the per capita animal-derived food N increased from 0.80 to 1.61 kg for urban areas, and from 0.33 to 0.71 kg for rural areas. This difference translates to 0.90 kg more animal-derived food N consumption per capita per year who migrates from a rural to an urban area.

Urbanization, dietary changes, and population growth effects on food N consumption and N imported to Chinese food system

Population growth resulted in 0.69 Tg more food (vegetable- and animal-derived food) N consumption, while dietary changes and urbanization resulted in 0.26 and 0.04 Tg less food N consumption in 2009 relative to 1990; together, all three factors increased food N consumption by 0.40 Tg. Population growth, dietary changes and urbanization combined would have required about 21.0 Tg more N input to the Chinese food system in 2009 relative to 1990, using global mean N costs of food. This is close to the actual increase of 22.8 Tg N input to the Chinese food system during 1990–2009. Population growth, dietary changes and urbanization are responsible for 39.3%, 41.4%, and 19.3% of the increased N input into the Chinese food system during 1990–2009.

Conclusions

This study is the first integrated assessment of the changes in N input, food N consumption in the Chinese food-chain system from urbanization perspective during 1990-2009. Our results indicated that urbanization explained 0.28 Tg N_{vf} decrease and 0.24 Tg N_{af} increase, because per capita demand for vegetable food N decreased by 1.06 kg yr^{-1}, while that for animal food N increased by 0.90 kg yr^{-1}, when one migrated to cities from rural areas. As a result, the population movement that comes with urbanization accounted for 19.3% of the increased N imported into the Chinese food system. If we ignore the urbanization effect on food consumption and assume a uniform urbanization rate over the past two decades, the new increased N input to food system for the consumed food N could be underestimated by 0.06 Tg yr^{-1}. These findings indicate that urbanization effect on household's diets has a major effect on N import to the food system, in any country or region experiencing rapid urbanization.

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References

[1] Gu, B.J., Ju, X.T., et al. Proc. Natl. Acad. Sci. U.S.A. 2015, 112(28), 8792–8797.

[2] Ma, L., Velthof, G.L., et al. Sci. Total Environ. 2012, 434, 51–61.

[3] Ma, L., Wang, F.H., et al. Environ. Sci. Technol. 2013, 47(13), 7260–7268.

Poster presentations presented in parallel workshops

IMPROVING NITROGEN RECOVERY FROM GREEN MANURE ON CONTRASTING SOIL TYPES UNDER COLD CLIMATE CONDITIONS

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Objectives

To improve the N recovery from grass-clover green manure on contrasting soil types under cold climate conditions. Mineralization shortly after incorporation of the green manure in the soil in early spring is particularly important in this respect. Specific objectives within this scope were to:

- evaluate the effects of various strategies for green manure management, including biogas production and using the herbage-based digestate as fertilizer, on the yield and N recovery of a subsequent spring barley crop.
- estimate the effects that low temperature and soil type have on N and C mineralization of N-rich plant residue.

Method

In order to evaluate various green manure herbage strategies, a three-year field experiment was run in Norway at four locations with contrasting soil types. The first year, a green manure of 20% red clover and 80% grasses was established as a ley, undersown in spring barley. The second year, the green manure was cut three times, and the herbage was either removed or chopped and left on the stubble (mulched). In the following spring, green manure was ploughed and barley was sown, either unfertilized or fertilized with digestate (11 g N m^{-2}). The amount of N in the applied digestate represented about 45% of the N in the harvested herbage. A control treatment with repeated cereal cropping was also included; unfertilized spring barley the first year, unfertilized spring oats the second year, and spring barley fertilized with either digestate (11 g N m^{-2}) or inorganic fertilizer (8 g N m^{-2}) the third year.

Soil from two of the field trial locations with equivalent weather and cultivation history, a silty clay loam and a sandy loam, were also used in an incubation experiment to study the effect of low temperature and soil type on C and N mineralization from soil organic matter and added clover leaves. Soil with or without dried red clover leaves (4 g dry matter kg^{-1} dry soil) were incubated at constant 0, 4, 8.5 and 15°C for 80 days. Sampling was performed after 24 hours, and on days 3, 8, 15, 30, 52 and 80.

The net N mineralization was studied in soil samples equivalent to 50 g dry soil placed in 200 ml jars with the lids left loose, to allow some aeration. The four replicates were sampled destructively as the whole sample was extracted with KCl, and the amounts of NH_4-N and NO_3-N were analysed. Simultaneously, the C mineralization was measured in gas tight 1 l chambers containing soil equivalent to 400 g dry soil. There were three replicates within each temperature. A NaOH solution in a plastic tube placed in the middle of the chamber was used to trap CO_2.

Results

The field experiment showed in general that the grain yields of spring barley (dry matter and N) sown after the green manure were in the following order: herbage removal ≤ herbage digestate without green manure ≤ herbage mulched ≤ herbage removal and digestate application ≤ inorganic fertilizer without green manure [1]. Depending on the site, removal of green manure herbage reduced the barley grain yield by nil to 33%, compared to leaving it on-site. Herbage removal reduced the yields mostly on the two sites with sandy loam.

Applying digestate as fertilizer for barley gave the same yields as those when all herbage had been mulched the preceding season. The removal of the herbage and application of digestate increased the recovery in the barley crop of the N present in the herbage at the time of the three cuttings. Overall, the apparent N recovery was enhanced from 7% when all herbage was mulched, to 16% when approximately 50% of it was returned as digestate.

Relatively little of the total plant N was mineralized either in the field or in the laboratory experiment, yet noticable amounts of net mineralized N were observed below 5°C in both investigations. At the end of the incubation, net mineralization was only 13-22% of the N added with clover leaves, and about half of this was mineralized already the first few days. This rapid initial mineralization was unaffected by temperature.

Subsequently the short rapid mineralization period was followed by a phase of slow net N mineralization in the sandy loam and net N immobilization in the silty clay. The immobilization was greater at higher than at lower temperatures, and also the ratio between mineralized N and C was higher at low temperatures than at high temperatures during the first weeks of decomposition. A net immobilization in the silty clay loam in late spring after ploughing the green manure may also contribute to the low barley yields on clay loam compared to those on the sandy loam, which we found under field conditions.

The incubation of clover leaves in the two soil types showed delayed nitrification at the lower temperatures, which may reduce the risk of N leaching, as ammonium is less prone to leaching than nitrate.

Conclusions

Of the various green manure herbage measures tested, the digestate strategy was be the most promising option with regard to reduced risk of N losses and improved N recovery by a subsequent spring barley crop. Removal of the herbage reduces the risk of N losses from the crop rotation, since such losses are highly dependent upon the N input and weather conditions. Nevertheless, removal of the herbage without any fertilizer application to the subsequent crop is not recommended, unless the soil is very fertile. Cost-efficient and practical solutions are needed for running small herbage-based biogas plants under cold climate conditions.

Our results show that at low temperatures N mineralization is not simply a function of C mineralization. If soil-crop models fail to simulate the short-term dynamics of N mineralization from easily decomposable plant material under low temperatures, this can lead to erroneous estimates of N leaching and early N supply to the succeeding crop. This study suggests that fundamental model changes are needed for simulating the effects of low temperatures on N mineralization from fresh plant material.

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References

[1] Frøseth, R. B., Bakken, A. K., Bleken, M. A., Riley, H., Pommeresche, R., Thorup-Kristensen, K., Hansen, S. 2014. European Journal of Agronomy 56, 90-102

NITROGEN TRANSFER IN THREE-SPECIES MIXTURES OF GRASS, CLOVER AND FORBS

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Objectives

Nitrogen (N) transfer from legumes to non-legumes is one of the important biological pathways for N cycling in agroecosystems. However, investigations of N transfer in grasslands have mainly been performed in simple mixtures of grass and clover species, whereas knowledge about transfer to deep-rooted non-leguminous forage herbs (forbs) included in multispecies grasslands is very sparse. In this study, we investigated inter-species N transfer from clover to grass and forb plants in three-species mixtures. Our objectives were to analyze how the choice of forb species and the proportion of grass and clover in the mixture influence the N transfer dynamics.

Method

The experiment was conducted at Foulumgaard experimental station, Aarhus University, Denmark, in a sandy loam soil with a history of a mixed grass-arable cropping. Six grassland mixtures intended for forage production were established in spring 2013. All mixtures contained perennial ryegrass (*Lolium perenne* L.) and red clover (*Trifolium pratense* L.) grown together with one of three forb species: chicory (*Cichorium intybus* L.), ribwort plantain (*Plantago lanceolata* L.) and caraway (*Carum carvi* L.). The mixtures were sown in a replacement design where either grass or clover dominated with 80 percent of their pure stand seed rates. The N transfer from clover to neighbouring grass and forb species was estimated in situ during the following year (2014) using leaf feeding with ^{15}N-enriched urea [1].

Four replicate PVC cylinders (30 cm internal diameter and height) were installed in each mixture enclosing all three species. Five fully developed clover leaves in each cylinder were labeled with urea solution (0.5% w/v and atom fraction ^{15}N = 98 %) two times during each of four growth periods (May, June, July to mid-August, mid-August to early October). Each growth period was terminated approximately two weeks after the second labeling, by harvesting all above-ground plant material. Sampled material was sorted to grass, clover and forb fractions, then dried, weighed and analyzed for N concentration and atom fraction ^{15}N. Background samples were collected from each plot adjacent to the cylinder at a distance of at least 50 cm. In October, soil samples were collected and cylinders were manually excavated followed by recovery of roots. The N transfer was estimated from differences in excess atom fraction ^{15}N and N content in above ground plant tissue of ^{15}N-labeled clover and unlabeled grass and forb species [2]. Similarly, N deposited to soil was estimated from excess atom fraction ^{15}N in clover roots and soil.

Results

The above-ground biomass samples were dominated by clover in all mixtures, and especially when clover was sown in high proportion. Chicory and plantain constituted larger proportions of the sampled biomass than the grass component, whereas caraway contributed with much lower biomass proportions. On an annual basis, up to 15%, equivalent to 4.6 g m^{-2}, of N in clover was transferred to companion grass and forb species. The proportion generally increased with an increase in non-legume N accumulation. However, both the proportion and amount of N transferred were unaffected by the inclusion of forbs. The grass relied more on N transfer from clover than the forbs. The strong ability of ryegrass to absorb clover N was most likely due to a large fibrous root system with large surface area and inter-connection with clover roots. On the other hand, the deep root systems of the three forb species [2] are likely less interconnected with clover roots, reducing the rates of N transfer from clover to these forbs. The atom fraction ^{15}N in all three forbs confirmed these functional differences between grass and forbs in receiving N transferred from clover. However, the amount of N transfer to chicory and plantain was considerably higher than to caraway, reflecting differences between the three forbs in their proportion of total biomass. This is likely due to a higher competitive ability of chicory and plantain in the mixtures, compared to caraway. The similar strategy of the three forbs in assimilating

N transfer from clover, but different competitiveness for biomass and N accumulation demonstrate their varied abilities to utilize above- and below-ground resources, other than N transferred from clover, for herbage production.

The clover N deposited to soil ranged from 0.56 to 4.3% of soil N, equivalent between 3 and 24 g N m^{-2}, with more than 80% of N deposition in the top 10 cm soil layer. The N deposition was highest in the clover-dominated seed mixtures, but there was no difference between seed mixtures with different forb species. The N transfer measured in above-ground plant parts correlated to root biomass ($P<0.01$ and $R^2= 0.29$), amount of N in roots ($P<0.001$ and $R^2= 0.4$) and root density ($P<0.01$ and $R^2= 0.34$). Similarly, a correlation was found between N transfer measured in above-ground plant parts and rhizodepostion ($P<0.05$ and $R^2= 0.24$). This confirmed the importance of below-ground productivity for the dynamics of legume N transfer to neighboring non-legumes.

Conclusions

Our study demonstrated that forbs in grassland mixtures: 1) did not affect the amount of N clover transferred to companion species, 2) relied less on N transferred from clover than grass, and 3) differed in their competitiveness for biomass production and N accumulation, with chicory and plantain being more competitive than caraway. The dynamics of N transfer was strongly influenced by belowground productivity and therefor grasses are required in grassland mixtures for efficient utilization of N transfer from clover.

The three forb species did not differ in the N acquisition strategy regarding transfer from clover, but the quantity of N transferred differed between the species, mainly regulated by their competitiveness for biomass production. Thus, forbs can be included in seed mixtures for several other beneficial purposes, such as improved acquisition of nutrients and water from deeper soil layers and enhanced total forage production and nutritional quality, without affecting the total N transferred from legumes to non-legumes.

Acknowledgements

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References

[1] Ledgard, S. F., Freney, J. R., and Simpson, J. R. (1985). Assessing nitrogen transfer from legumes to associated grasses. *Soil Biology and Biochemistry*, 17(4), 575-577.

[2] Pirhofer-Walzl, K., Rasmussen, J., Høgh-Jensen, H., Eriksen, J., Søegaard, K., and Rasmussen, J. (2012). Nitrogen transfer from forage legumes to nine neighbouring plants in a multi-species grassland. *Plant and soil* **350**, 71-84.

NITROGEN SUPPLY AND DYNAMICS IN WINTER WHEAT FOLLOWING DIFFERENT GRAIN LEGUMES IN ORGANIC FARMING ROTATIONS

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Objectives

In the future, grain legumes shall become more important in all cropping systems. However actual market situations often do not allow profitable cultivation and cause reservation in farmers to grow grain legumes [1]. Therefore, the pre-crop effect of the legumes is an important factor when considering grain legumes in a systems-approach. Mostly, integration of grain legumes in crop rotations offer a multitude of benefits (e.g. N-fixation [2] or plant health[3]) and increase the chance to integrate a further cash crop (e.g. winter wheat) at nutritive adverse positions in crop rotations.

The aim of this study has been to evaluate the pre-crop effect of the different grain legumes (e.g. soy bean or lupines) in the same environment and to detect possible effects of grain legumes on the N-supply, the yield potential and the yield structure of the subsequent cash crop winter wheat. The presentation shows results of the first two years.

Method

The experiment, executed between 2014 to 2015 (continued in 2016), took place at the experimental station of the University of Kassel in Frankenhausen (51.24 N, 9.26 E, 200 m a.s.l.). The long term (1970-2000) weather conditions are characterized with an annual precipitation of 650 mm and a mean temperature of 8.5°C (2014: 10.8°C, 535mm; 2015: 10.2°C, 442mm). In 2015, the spring period was characterized by a heavy drought (72 mm April-June). The soil is classified as a silty loess luvisol (2% s, 81% u, 17% t), with a total carbon and nitrogen content of 1.02% and 0.11%, respectively. The content of phosphorus, potassium and magnesium was 83, 97 and 82 mg*kg^{-1} dry soil, respectively. In the first year agronomical relevant summer- and winter-grain legumes (lupine, peas, soybean and faba bean; 2 varieties for each species) pea-barley mixtures and a barley sole crop were grown as pre-crops in a block randomized design with 4 replications. After harvesting the legumes, winter wheat was sown as subsequent crop.

Soil nitrogen dynamic was assessed during the two seasons. Therefore, NO_3-N-status was regularly (up to 8 times, depending on the expected N mineralisation) determined in three soil layers (0-30, 30-60, 60-90 cm). Yield, N-removal and N-amount of plant residues were determined for the grain legumes at the end of vegetation period. At harvest of winter wheat, N-removal and yield structure were investigated to evaluate the influence of the different preceding legumes. Additionally, the NO_3-N-dynamics of soil was investigated concomitantly to the N-uptake of the above ground biomass at three sequential harvests (May 7, May 21, June 10).

Results

During the vegetation period of the grain legumes NO_3-N-status was very low (between 8 kg*ha^{-1} and 50 kg*ha^{-1}). Only in June 2014 mineralisation status in both soybean varieties was significantly ($p<0,05$)higher (between 108 and 112 kg*ha^{-1}), which can be explained with the slow development of both tested varieties. After harvesting the grain legumes, NO_3-N-status increased and differed significantly, depending on grain legume species. The yield of the monoculture treatments ranged from 0.5 t ha^{-1} for winter peas up to 3.0 t ha^{-1} for spring faba beans. Spring-pea-barley mixtures reached nearly 4 t*ha^{-1} total yield. The N-amount of the crop residues was low in all spring legume treatments and reached a maximum of 45 kg*ha^{-1}. In winter pea and bean treatments a large amount of crop residues were found. In addition, it was difficult to harvest the whole grain yield of winter peas, which causes significantly higher mineralisation rates in the following winter wheat. Especially in March and April the (significantly) highest mineralisation rates (50 kg*ha^{-1}) could be observed in winter wheat after winter pea. The NO_3-N-level in winter wheat was very low during May and

June (less than 15kg*ha^{-1}) and not significantly different for time and treatment.

N-removal in winter wheat increased in time and was significantly different for the treatments preceding crop. The interaction (preceding crop*time) was not significant. In the preceding summer legume treatment, an average N-removal of 42 kg*ha^{-1} was measured at the first harvest. At the third harvest (10 June) an average N-removal of 92 kg*ha^{-1} was detected. In the preceding winter legume treatments, winter wheat removed in average 48, 77 and 102 kg N*ha^{-1} in harvest 1,2,3, respectively. Grain yield was also significantly different for the factor preceding crop.

Conclusions

The presented results show that different grain legumes cause different N levels in soil. Possible reasons for this were losses during harvest processes, crop residues, bacterial N-fixation and rhizodeposition. Altogether, this can affect the nitrogen mineralization and influence the subsequent crops. Additionally, it could be shown, that due to of higher mineralization rates and higher N-supply during vegetation period, winter grain legumes can offer new opportunities in the cultivation in crop rotations.

References

[1] Zimmer, S., Liebe, U., Didier, J.-P., Heß, J. 2016. Agronomy for Sustainable Development 36 Issue 1, Article 2

[2] Peoples, M.B., Herridge, D.E., Ladha J.K. 1995 Plant and Soil 174, 3-28

[3] Köpke, U., Nemecek, T. 2010. Field Crops Research 115, 217-233

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BIOLOGICAL NITROGEN FIXATION AND TRANFER IN A HIGH LATITUDE GRASS-CLOVER GRASSLAND

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Objectives

Biological nitrogen fixation (BNF) by legumes is crucial for N supply in low-input forage production systems. However, in high latitude grasslands with long and unstable winter conditions, legume survival is often poor. Moreover, little is known about how winter conditions contribute to the well-known decline of clover over time, which is commonly attributed to N fertilization, soil compaction and cutting regime. In the present study we evaluated the performance of BNF and its contribution to total N yield in a grass-clover ley in Northern Norway over four consecutive spring seasons and compared it to the overall decline in annual clover mediated BNF. We also assessed the effect of grass-clover proportion, fertilization rate and soil compaction on whole-year BNF, and N transfer to companion grass species in spring. BNF was estimated by two different methods, the ^{15}N Natural Abundance method for spring BNF and the Difference Method for whole-year estimates.

Method

A four-year, fully factorial sward experiment (2010-2014) was established on sandy soil at Tjøtta in Northern Norway (65°49’22.76”N, 12°25’37.23”Ø). Seed mixtures consisted of white clover (*Trifolium repens L.*) and red clover (*Trifolium pretense L.*) sawn in three proportions (0, 15 and 30% in total) together with timothy (*Pheum pretense L.*) and meadow fescue (*Festuca pratensis L.*). Three levels of compaction were applied each year (no tractor, light tractor, heavy tractor) together with two different N rates; 110 kg N/ha as cattle slurry in May or 170 kg N/ha as 110 kg N/ha cattle slurry in May and 60 kg/ha as inorganic N after the first harvest. The plots were harvested twice per year, in June and August, to estimate N yield and BNF. Total aboveground BNF was estimated by the Difference Method for both harvests in all years, whereas the performance of the different clover species over time was assessed by the ^{15}N natural abundance method one, three and four years after sawing. The number of red clover plants was monitored in late autumn and early in the spring. The total N yield was estimated from harvested dry matter and N content in the aboveground biomass. The proportion of grass N derived from clover species was estimated from the ^{15}N depletion in grass species between the years.

Results

Biological N fixation enhanced aboveground N yields by up to 75% compare to pure grass mixture. Maximum aboveground N yield was recorded in the second year with 200 and 224 kg N ha^{-1} in low (15%) and high (30%) grass-legume mixtures, respectively. N yield declined dramatically over time in both mixtures to 148 kg N ha^{-1} and this decline was mainly due to loss of BNF associated with red cover. Greatest annual BNF was recorded in the second year with 95 kg N ha^{-1}, which declined to 32 kg N ha^{-1} in the fourth year. This is at the lower end of BNF rates reported for boreal grasslands. Both methods demonstrated decline in BNF over time, however, the Natural Abundance Method gave consistently lower BNF estimates than the Difference Method, as found previously. In our experiment, red clover dominated over white clover from the first year on, but decreased significantly while white clover proportions remained stable. The recorded decline in clover plants and BNF was consistent with previous studies in high latitudes and can be attributed to the cumulative negative effect of repeated N fertilization in combination with poor winter survival of red clover. We did not find any direct evidence for an effect of variable winter conditions on the overall decline in BNF. Clover plants in spring seemed well nodulated as indicated by the high (> 80%) fraction of N derived from the atmosphere (NdfA) in both clover species at first harvest, independent of winter climate. N transfer from clovers to companion grass species, as assessed by ^{15}N depletion in harvested grass biomass, was seen after the third growing season. This suggests that clover N recovered in grass species was mainly derived from decomposition of clover biomass rather than from rhizo-deposition. The percentage of grass

N that derived from clover species was relatively low (< 20%), probably due to the low proportion of white clover at sowing and the dominance of red clover that is a less efficient N donor than white clover. Increase in fertilization rate caused a slight but not significant decrease in the proportion of grass N derived from clover and, hence, in the amount of N transfer. In the sandy soil, compaction had no negative effect on neither BNF nor N transfer.

Conclusions

Our data show that BNF by clover can contribute significantly to N supply in Northern grasslands with as little as 15% clover in the seed mixture. However, the positive effect of BNF on the grassland's N yield is short-lived, owing to poor survival of red clover. Thus, the amount of clover plants is crucial for N input in the sward. N fertilization rate had a significantly negative effect on BNF, suggesting that the poor survival of red clover was mainly due to competition with none-legumes supported by fertilizer N. Winter conditions had no obvious effect on the observed decline in BNF over four years. Surviving clover plants seemed to be little affected in their capacity to fix nitrogen or recovered quickly in spring as judged from the fraction of nitrogen derived from the atmosphere (NdfA) at the first harvest. The ^{15}N Natural Abundance Method yielded up to 40% smaller BNF estimates than the Difference Method even when including N transfer, particularly in the third and fourth year. N transfer from clover species to companion grass species was significant but small (<20%). Improved clover varieties and cultivation strategies are needed to increase the persistence of red clover, if grass-clover mixtures are to be used in sustainable forage production in high latitudes.

STRATEGIC BIOMASS MANAGEMENT INCREASES NITROGEN FIXATION IN THE GREEN MANURE LEY OF AN ORGANIC ARABLE CROPPING SYSTEM

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Objectives

The overall aim of this research was to analyse how different biomass management strategies influence the nitrogen (N) dynamics in a stockless arable organic cropping system based on a six year crop rotation. Biomass resources from crop residues, cover crops and green manure ley included in the rotation were either left in *situ* (IS) or removed (REM) and redistributed to non-legume crops after storage as silage or as digestate after anaerobic digestion for extraction of biogas.
In the study presented here we have investigated the rates of N_2 fixation in legumes, as well as total biomass yields and N accumulation in the green manure ley, in response to leaving biomass resources *in situ* versus removing the same resources. The hypothesis was that removal of the cut biomass would increase N_2 fixation in the legumes included in the green manure ley.

Material and methods

A field experiment was conducted in Alnarp (Sweden) between 2012 and 2015. Green-manure ley was grown as a part of an arable organic crop rotation on a sandy loam soil without fodder production or animal manure. The crop rotation consisted of the following food crops: pea (*Pisum sativum*)/barley (*Hordeum vulgare*) as an intercrop, white cabbage (*Brassica oleracea*), lentil (*Lens culinaris*)/oat (*Avena sativa*) as an intercrop, beetroot (*Beta vulgaris*) and rye (*Secale cereal*). The green manure ley was composed of *Dactylis glomerata, Festuca pratensis, Phleum pratense, Medicago sativa, Meliolotus officinalis* and *Trifolium pratense.* The green manure ley was undersown in the pea/barley intercrop, then maintained and harvested three times during one year and harvested once again in early spring the subsequent year, before establishing white cabbage as the next crop in the rotation. Cover crops were included in the rotation after white cabbage, lentil/oat and rye.

The two treatments, IS and REM, were implemented by either leaving the biomass resources (crop residues, cover crops and ley cuttings) to decompose *in situ* (IS) in the experimental plot where the resources were obtained or removing (REM) and redistributing the biomass resources to experimental plots where non-legume crops were grown. All ley cuttings were weighed before returning or redistributing the cuttings to the plots and subsamples were taken for analyses of botanical composition (grouped into legumes and non-legumes) dry matter (DM), N concentration and natural abundance of the stable isotope ^{15}N.

The N_2 fixation was assessed according to the ^{15}N natural abundance method [1], using the lowest observed legume $d^{15}N$-value as β - value in the calculations [2] and the grasses grown together with the legumes in the green manure ley as reference plants. Treatment effects on amounts of total ley biomass, legume proportion of the biomass, amounts of N_2 fixed and total amounts of N accumulation from soil were tested by analyses of variance using the general linear model (GLM) procedure in the Minitab software.

Results and discussion

The total DM yield of the green manure ley (sum of legumes and grasses) did not differ significantly between the two treatments, but there was a general increase in DM yields from 2013 to 2014 (11.2 Mg ha^{-1} in IS and 11.1 Mg ha^{-1} in REM 2013; 16.2 Mg ha^{-1} in IS and 17.1 Mg ha^{-1} in REM in 2014). The proportion of legumes in the ley DM was often higher in REM (20-31 %) than in IS (17-19 %), but the differences were not statistically significant. In 2014, the grass DM yield was significantly higher in IS than in REM.

The proportion of N derived from atmosphere (N_{dfa}) in the legumes was close to 80% in both years and both treatments. On the other hand, significantly higher amounts of N_2 fixation were observed in REM than in IS. The total accumulation of N from soil (sum of legumes and grasses) did not differ significantly between the treatments, but was generally higher in 2014 (more than 200 kg N ha^{-1}) than in 2013 (around 170 kg N ha^{-1}). The treatments did not affect the yield or quality of the following crop.

Our results confirm the hypothesis that the continuous removal of biomass resources would increase N_2 fixation in legumes of the green manure ley. Leaving green manure ley cuttings and other biomass resources (crop residues, cover crop biomass) to decompose in situ meant that more soil N became available in the green manure ley, which led to a competitive advantage for the grass component of the ley. This explains both the significant increase in grass DM and decrease in amounts of N_2 fixed in IS compared to REM. The maintained high biomass and N yields of the green manure ley despite the export of nutrients via removal of biomass opens up for additional uses of the biomass resources, such as conversion to biogas and redistribution of nutrients to other crops. These are valuable possibilities for increasing nutrient circulation and resource use efficiency in crop production on organic stockless farms.

Conclusion

This study has shown that the N_2 fixation in legumes of a green manure ley in a stockless arable cropping system increased after the removal of cuttings compared to leaving them in situ, while high biomass yields were obtained in both treatments. Even though biomass removal did not influence the yield or quality of the following crop in the rotation, our results show that strategic biomass redistribution leads to more efficient use of N_2 fixation. There may be additional opportunities by removing the biomass both for use as a biogas substrate and recirculating nutrients to non-legume crops. Such systems have the potential to improve nutrient use and energy efficiency in organic cropping systems.

References

[1] Carlsson, G., Huss-Danell, K. 2003. Plant and Soil, 253 (2), 353-72.
[2] Huss-Danell, K., Chaia, E., and Carlsson, G. 2007. Plant and Soil, 299 (1-2), 215-26.

LARGE VARIATION IN NITROGEN EFFICENCY AMONG ORGANIC AND NON-ORGANIC DAIRY FARMS

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Objectives

Agricultural production is requested to be environmental friendly and resource efficient. A literature review of farm surveys and prototype farm studies found that increasing use of N fertilizer and imported feed increased the yields and the productivity of dairy farms, but also increased the N-surplus [1]. We studied the N-efficiency and cause of variation in organic and non-organic commercial dairy farms.

Hypotheses:

- Increasing amount of nitrogen in purchased fertilizer or feed per ha farmland, will decrease the N-efficiency and increase the N-surplus per ha, and per unit produce.
- The variation in estimated N-efficiencies are larger within organic and non-organic farm management than the between the averages of the two groups.

Method

Data were gathered for the years 2010 to 2012 from 10 organic and 10 non-organic dairy farms. They were typical farms on the Norwegian west coast (Møre og Romsdal County), but the selected farms differed both in cattle numbers, milking yield, farm area, fertilization intensity and share of concentrates. Most of the roughage were produced on the farms, with some import in cold years. All farms imported the feed concentrates. The dairy herds were grazing in summer time, either on fully cultivated land, in fenced uncultivated pastures (pasture), or in forest or mountain area outside the farmland (rangeland). **Farmland** is defined as fully cultivated land plus pasture area weighted by 0.3. Grazed rangeland is not included in the farmland.

We used the following definitions: **Dairy system**: the sum of the dairy farm plus area and N-input for production of purchased feed. Thus, the total N-input to the dairy system includes the N-surplus at the site of production of imported feed; **N-produce:** N in delivered milk plus net edible meat gain; **N-purchase**: purchased feed, fertilizer, manure and litter; **N-surplus**: net N-purchase plus biological nitrogen fixation (BNF) plus atmospheric deposition minus net N-produce; **N-Surplus of purchased N**: net N-purchase minus net N-produce; **N-efficiency farm:** net N-produce / net N-purchase; **N-surplus per unit of N-produce:** (total N-surplus of the dairy system) / N-produce

We used data from the Norwegian agricultural authority, the Norwegian Dairy Herd Recording System, farm advisors and farm accounts to collect data of farms N-input and produce. Farmers contributed with detailed information on fertilization, estimates of clover content at harvest, grazing and soil conditions.

The estimated clover content was used to calculate the BNF by clover according to Høgh-Jensen et al. [2]. The gross roughage yields used for estimating BNF included 40 % estimated loss from the standing plants to the net roughage intake by the herd, calculated as the herd's demand of metabolic energy.

Results

The N-purchased per ha farmland on the organic dairy farms was on average 68 kg N/ha (Range 41- 102), and on the non-organic dairy farms 233 kg N/ha (range 151 - 401). The net N-produce was 26 kg N/ha (range 17- 36) on organic dairy farms, and 42 kg N/ha (range 21 - 63) on non-organic dairy farms. The corresponding surpluses of purchased N were 42 and 191 kg N/ha. As expected there was a close linear correlation between the purchased N and the N-surplus of purchased N per ha (R^2=0.99). This was consistent for organic and non-organic farms. The average N-surplus increased to 85 kg N/ha on organic farms when BNF and atmospheric deposition was included.

The N-efficiency of purchased N by the dairy farm decreased on the 20 farms, as expected, with increasing purchased N (R^2=0.62). However, this was not so evident within the farm groups ($R^2_{\text{organic farms}}$=0.46, $R^2_{\text{non-organic farms}}$=0.06). A similar trend was observed for the N-efficiency when N surplus from imported feed was included (dairy system, R^2=0.63, $R^2_{\text{organic farms}}$=0.43, $R^2_{\text{non-organic farms}}$=0.07). On average, the N-efficiency of purchased N on the organic dairy systems was 0.32 (range 0.20-0.42) and on the non-organic dairy systems 0.16 (range 0.12 - 0.24).

The N-surplus per unit of produce increased slightly with increased N-purchase (R^2=0.39 all farms), but not within the farm groups ($R^2_{\text{organic farms}}$=0.17, $R^2_{\text{non-organic farms}}$=0.001). This is contradictory to the findings of Bleken et al. [1], and surprising. The average N-surplus per unit of produce was lower on organic dairy farms (4.1 kg N, range 2.7 - 6.5), than on non-organic dairy farms (6.2 kg N, range 4.7 - 7.7).

The main reason for the variation in N-efficiency among the non-organic farms could not be identified with the data available. Neither increased amount of purchased N nor fertilizer N, increased size of the farm or production level, milk yield, share of concentrates, or soil type, showed an evident relation with the N-efficiencies or the N-surplus per unit of produce on the farms within the two farm groups. Some farmers make a large effort to balance feed ratio, improve N-utilization of own manure, to reduce losses from field to feed table, to create optimal conditions for good animal health, improve soil drainage and to reduce soil compaction, but we did not have data on this. These are all factors that will improve N-efficiency. Because all farms are in the rainy western Norway, the variation in farm management is likely more important than variation in soil type and climate for the variation in obtained N-efficiencies.

Conclusions

- Increased amount of purchased-N per ha farmland increased the farm N-surplus per ha on organic and non-organic farms. Increased amount of purchased-N tended to decrease N-efficiency, but not on non-organic farms. The correlation between the N-surplus per unit of produce and N-purchase was weak.
- The organic farms had lower N-surplus per ha than the conventional farms, had higher efficiency of imported nitrogen and lower N-surplus per unit of produce, leading to an overall better utilization of available N.
- Within organic and non-organic farm management, the variation in estimated N-efficiencies is larger than the differences between the averages of these two groups.

References

[1] Bleken, M. A., Steinshamn, H., & Hansen, S. 2005. High nitrogen costs of dairy production in Europe: worsened by intensification. *AMBIO: A Journal of the Human Environment*, *34*, 598-606.

[2] Høgh-Jensen, H., Loges, R., Jørgensen, F. V., Vinther, F. P., & Jensen, E. S. 2004. An empirical model for quantification of symbiotic nitrogen fixation in grass-clover mixtures. Agricultural Systems, 82, 181-194.

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SIGNIFICANCE OF LEGUME COVER CROPS AS NITROGEN SUPPLY FOR CORN IN AN ORGANIC MANAGED SOYBEAN-WINTER_WHEAT-CORN SYSTEM IN SOUTHERN ONTARIO, CANADA

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Objectives

Soybean-winter_wheat-corn rotation is common in the humid temperate southern Ontario, Canada. There is a fallow period after wheat harvest (late July to November) and before the consequent corn (late March to early May). This bears a high risk for nitrate leaching out of the crop root zone into the water systems, eventually into the Great Lakes in the region. Cover crops have the potential to scavenge nutrient losses (N and others) and increase cropping system resiliency by providing nutrients to crops and adding organic residues to the soils. The objectives were to determine: (1) how much N can be scavenged in cover crop biomass (shoots and roots); (2) what is the reduction of residual mineral N (nitrate and ammonium) in soil profile in cover crop fields versus non cover crop control in early November (crops stop growing); (3) what is the contribution of cover crops to the consequent corn yields.

Method

The wheat stubble was disc-tilled, and the cover crops were planted into the soil in an organic managed soybean-winter_wheat-corn rotation system. The cover crop treatments included Crimson clover (CC), hairy vetch (HV), red clover (RC), sasbenia (S), a non cover crop conventional control (CK) and a non cover crop organic control (CKO). This 3 year study was arranged in a randomized complete block design with 4 field replicates on Harrow sandy loam soil. No synthetic fertilizer was added to the cover crop plots in either cover crop phase or soybean, winter wheat and corn phase except for the CK plots which N, P, K were added following conventional management protocol (150 kg N ha^{-1}). Soil cores (0-90 cm) were collected before planting cover crops and a second set of soil cores were collected again in early to mid-November (before freeze-up). The soil core samples were separated in 0-5, 5-10, 10-20, 20-30, 30-50, 50-70, and 70-90 cm segments and used to determine the amounts soil mineral N (nitrate and ammonium) remaining in the soil profiles. Cover crop biomass samples were collected in the same time as the second set of soil cores was collected. Cover crop biomass was collected again in following year at early May before plowing cover crop field for corn planting. Grain corn fields were organically managed, weeds were controlled using rotary tiller, and corn grain yields were recorded. Total nitrogen in cover crop plant biomass was determined using the dry combustion method with a LECO CN2000 Analyser (Leco Corp., St Joseph, MI, USA). The concentrations of soil inorganic nitrogen (nitrate and ammonium) were measured using the Berthelot reaction method (NH_4^+) and the Cd reduction method (NO_3^-) on a TRAACS 2000 (Bran + Luebbe Analyzing Technologies, Buffalo Grove, IL) auto-analyzer.

Results

Sasbenia growth and stands were considerably poor which stopped growing at mid-October with the lowest biomass N accumulation (0 to 25 kg N ha^{-1}) compared with other cover crop treatments. Before freeze-up, the amounts of total N in above ground biomass were 175, 146, and 107 kg ha^{-1}, respectively, in CC, HV and RC treatments and 9.1, 16.9, and 24.8 kg ha^{-1} in roots for corresponding treatments. The N contents in plant above ground biomass changed to 87, 241 and 207 kg ha^{-1} in CC, HV, and RC plots before corn planting. It indicates that the HV and RC gained more N but CC lost N over winter. Compared with the HV and RC, the CC was less winter hardy.

The contents of soil mineral N was around 75-80 kg N ha^{-1} in 0-90 cm after winter wheat harvest for all treatments (including CK). After about 3 month cover crop growth, the contents of residual soil mineral N diverged, with about a 10 kg N ha^{-1} decrease in the cover crop treatments versus a significant increase (65 kg

N ha^{-1}) in the non cover crop control treatment. Based on our model predictions (the CANB-N model and the IROWC-N model [1, 2], that a third to a half residual soil mineral N could be leaching out of the soil profile into the water system in the non-growing seasons, growing cover crops, particularly the HV and RC, in the fallow period can significantly reduce the risk of nitrogen loss.

The corn grain yields were 14363 kg ha^{-1} for the fertilized conventional control (CK) and only 6566 kg ha^{-1} for the organic control (CKO). In comparison, the corn grain yields were 10233 kg ha^{-1} for the CC, 12234 kg ha^{-1} for the HV and 12315 kg ha^{-1} for the RC treatments, respectively. Without the use of chemical N fertilizer, growing grain corn after Crimson clover attained 70% and growing grain corn after the hairy vetch or red clover achieved 85%, respectively, of the corn grain yield of the conventioanlly managed CK which received 150 kg N ha^{-1}.

Conclusions

The use of legume winter cover crop after winter wheat harvest has significant contributions to the agro-ecosystems and to the grain production in the region. The HV and RC performed better than the CC in term of N benefits to corn grain yield and all these cover crops could significantly reduce soil nitrogen loss during non-growing seasons.

References

[1] Drury, C.F., Yang, J., DeJong, R., Huffman, E.C., Reid, K., Yang, X.M., Bittman, S., and Desjardins, R.L. (2016). “Residual Soil Nitrogen Indicator.”, in Clearwater, R.L., Martin, T., Hoppe, T. and Kalff, S. (eds.) - Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicators (Report #4), Agriculture and Agri-Food Canada.

[2] Drury, C.F., Yang, J., and De Jong, R. (2016). “Indicator of the Risk of Water Contamination by Nitrogen (IROWC-N).”, in Clearwater, R.L., Martin, T., Hoppe, T. and Kalff, S. (eds.) - Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicators (Report #4), Agriculture and Agri-Food Canada.

SYMBIOTIC NITROGEN FIXATION AND NITROGEN FERTILIZATION VALUE OF LEGUME GREEN MANURES IN ORGANIC AGRICULTURE

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Objectives

Nitrogen (N) is often a yield-limiting factor in organic agriculture, especially on stockless farms. Biological nitrogen fixation (BNF) of winter legumes can thus make an important contribution to crop N nutrition. Our aim was to compare various green manure legumes with respect to total N yield, to assess BNF of the best species by natural abundance, to optimize sawing time, seed density and incorporation regime of the green manure, and to quantify the N fertilizer value for maize and vegetable crops.

Method

In a series of field experiments conducted in Switzerland between 2007 and 2011, we assessed the potential of various green manures sown in autumn and incorporated in spring to fix N from the atmosphere and enhance yield and N uptake in the subsequent crop (maize and various vegetables) relative to winter bare fallow and with or without application of commercial organic N fertilizers. In total, seven experiments with green manures before maize and ten experiments with green manures before vegetables were conducted.

Results

In the pilot experiments to compare various winter legumes, between 25-150 kg N ha^{-1} were fixed according to the difference method, with winter pea (*Pisum sativum*) being superior to winter vetch (*Vicia villosa*) and faba bean (*Vicia faba*). For winter pea, the natural abundance method with winter rye as reference plants indicated fixation of about 90 kg N ha^{-1} in two consecutive years. Total maize yields were almost doubled after winter legumes compared to either bare fallow or winter rye (*Secale cereale*) as green manure, and the additional N uptake by maize after legumes typically ranged between 50-100 kg N ha^{-1}.

Subsequent experiments focused on the winter pea variety EFB33 for which N yield was positively related to the temperature sum above 4°C during winter and reached 150 kg N ha^{-1} in several years. The proportion of N derived from the atmosphere according to the natural abundance method ranged between 70-100%.
In field experiments with vegetables, increased N uptake was found in slowly growing crops such as celery (*Apium graveolens*) and leek (*Allium ampeloprasum*) as well as in fast-growing crops such as broccoli (*Brassica oleracea* var. *italica*), but there was a large variation between years. In some cases, N uptake increased by up to 100 kg N ha^{-1} compared to the non-fertilized control. In combination with green manures, reduced tillage was possible, but not superior to conventional tillage.

Conclusions

The biggest benefits of legume green manures were achieved with early sowing of winter pea (mid to end of October), or compensation of later sowing (November to December) by larger sowing densities, and with long-duration crops such as maize, celery and leek sown late (end of May). Incorporation with mulching equipment mounted in the front gave best results. Based on these multi-year trials, we conclude that green manures and in particular winter pea can have a large N fertilization value for organic agriculture.

PREDICTING GRAIN YIELD AND PROTIEN CONTENT OF WINTER BARLEY WITH AN ACTIVE OPTICAL SENSOR

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Objectives

In-season forecasting of grain yield and quality could facilitate management decisions regarding input levels and would also facilitate orderly harvesting and marketing of grain. As well as being used to estimate in-situ biomass and nutrient content optical sensors, which measure reflectance, have been used to predict yield and protein content. However, optical sensors do not account for variation in environmental conditions that affect crop growth after reflectance measurements have been made, which will affect the accuracy of any predictions. This suggests that more accurate predictions would be achieved with measurements made later in the growing season. However, the later in the season that measurements are made the less useful any predictions will be for input management purposes. The objective of this work was to determine the effect of time of sensing on the relationship between reflectance measurements and grain yield and protein content of winter barley under Irish conditions.

Method

A split plot experimental design with five replications was carried out over two growing seasons, 2013 and 2014. Main plot factor was variety. Three varieties were included; KWS Cassia, a two row type, Leibniz, a six row type and Volume, a six row hybrid type. The split-split plot factor was N application rate (100, 140,180, 220, 260 kg N/ha). Crops were sown in early October and received standard inputs of pesticides to control weeds, diseases and pests.

Canopy reflectance was measured on 7 occasions in 2013 and 6 occasions in 2014. Measurements were taken at flag leaf emergence (GS 37), booting (GS 43/49), inflorescence/anthesis (GS 55/65), early dough stage (GS 83), soft dough stage (GS 85) and hard dough stage (GS 87) in each year. An additional measurement was made at early grain fill (GS 71) in 2013. Measurement dates were 10-14 days apart except for the last 2 dates in 2013 which were a week apart. Reflectance measurements at three wavelengths (760, 730 and 670 nm) were made using a hand held Crop Circle ACS 470 instrument (Holland Scientific, Nebraska, USA). At each measurement date 25-35 readings were made in each plot at a height of ~0.7m above the crop canopy, avoiding plot edges.

Reflectance data were used to calculate two normalised difference vegetation indices, one using the red (760 nm) wavelength ($NDVI_r$) and one using the red edge (R730) wavelength ($NDVI_{re}$). The former was calculated as (R760-R670)/(R760+R670) and the latter as (R760-R730)/(R760+R730) where R760, R730 and R670 are the reflectance values at 760nm, 730nm and 670nm respectively.

Repeated measures analysis of variance was carried out on vegetation index data for each season using SAS PROC MIXED. Correlation analysis between both vegetation indices and both grain yield and grain protein content was carried out using SAS PROC CORR. Subsequently the relationship between vegetation index and yield and protein content at each date was evaluated using regression analysis using SAS PROC GLM. Linear and quadratic regressions were tested and only significant ($p<0.05$) effects retained in the model.

Results

The values of both vegetation indices changed only slightly as the crop progressed from flag leaf emergence to booting, remained relatively constant between booting and the completion of anthesis and then declined at each successive sampling date thereafter, as grain filling progressed. Significant differences between varieties were detected for both vegetation indices in both seasons at many of the sampling dates.

$NDVI_{re}$ had a higher correlation than $NDVI_r$ with both yield and protein content on the majority of occasions in both seasons and therefore $NDVI_r$ is not considered further in this paper. A linear relationship (r^2 = 0.63-0.65 in 2013 and r^2 = 0.74-0.79 in 2014) was detected between yield and $NDVI_{re}$ for the first three dates in both years corresponding to the period between flag leaf emergence and full ear emergence. During this period varietal differences were observed for the intercept, but not the slope, of the linear relationships for two of the three dates in each season. After this period, as the crop began grain filling, curvilinear relationships were detected between $NDVI_{re}$ and yield on the majority of occasions with varietal differences in the relationships again detected on the majority of the occasions.

Quadratic relationships were detected between $NDVI_{re}$ and protein content on the majority of measurement dates in both years. R^2 ranged from 0.93 to 0.95 for the first three dates in 2013 and declined thereafter. In 2014 r^2 were 0.82-0.88 for the first three dates. Significant varietal differences in the coefficients for the intercept and linear component of the relationship were detected on the majority of occasions in both years. R^2 values for the relationships between $NDVI_{re}$ and protein were higher than those for the relationship between $NDVI_{re}$ and yield.

In order to determine seasonal effects reflectance data for the first three dates in the two seasons was combined and the relationship between $NDVI_{re}$ and yield and protein examined. This analysis revealed that there was a significant year effect on the relationship between $NDVI_{re}$ and both yield and protein. When using the combined data no variety effect was detected for the relationship between $NDVI_{re}$ and yield but a variety effect was still detected for the relationship between $NDVI_{re}$ and protein content.

Conclusions

Optical sensor measurements made between booting and anthesis can be related to both grain yield and grain protein content but the relationship can be influenced by both varietal and seasonal effects. While it may be possible to develop variety specific relationships between reflectance measurements and both yield and protein content, including seasonal effects is more difficult. Optical sensor measurements after the onset of grain fill are less well related to grain yield and protein content than earlier measurements

POTATO CROP NITROGEN STATUS ASSESSEMENT COMBINING OPTICAL INDICATORS BASED ON LEAF CHLOROPHYLL AND FLAVONOIDS CONTENTS.

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Objectives

Plant based indicators related to Nitrogen (N) status have been used to optimise the N fertilization. Leaf Flavonoids Content (LFC) appears to be a valuable indicator to assess the Crop Nitrogen Status (CNS). LFC can be assessed by rapid and non-destructive optical methods generating chlorophyll fluorescence. The objective of the current study was to evaluate the potential of LFC, alone or combined with Leaf Chlorophyll Content (LCC), for the assessment of potato CNS. Based on a comparative study of indices provided by various optical devices, three criteria were evaluated: (i) the sensitivity and the earliness of the diagnosis on CNS; (ii) the accuracy (precision and repeatability); and (iii) the specificity of the indices.

Method

Field trials were conducted in Belgium in 2012 and 2013 on two potato cultivars (Charlotte and Bintje). The experiment included six increasing N rates (from 0 up 250 kg N ha^{-1}). Measurements were recorded at different sampling dates with various optical devices providing indices related to N-status indicators (chlorophyll and /or flavonoids). The Dualex fluorimeter (Force-A, Paris, France) provides a chlorophyll index related to LCC, a flavonoids index (FLV) related to LFC and the so-called nitrogen balance index (NBI) related to both LCC and LFC. The Multiplex fluorimeter (Force-A) provides indices related to LCC, a flavonoids index (FLAV) related to LFC and the nitrogen balance indices (e.g. NBI-R) related to both LCC and LFC. The Hydro N-Tester chlorophyll-meter (Yara, Oslo, Norway) provides an HNT index related to LCC. The Cropscan radiometer (Cropscan, Rochester, USA) enables the calculation of different vegetation indices related to LCC and based on the combination of reflectance in the green, red and near infra-red bands. The ratios HNT/FLV and HNT/FLAV were also calculated. Plant tissue samples were collected and analyzed in order to calculate the N concentration in shoots and in the whole plant biomass. A secondary experiment was conducted in 2014 in Gembloux including four increasing N rates for the same cultivars to confirm the sensitivity, the earliness and the specificity of the indices for the two first years of trials.

The indices were evaluated using SAS software (SAS 9.4). The effects of N, cultivar, year and sampling date (expressed in day after emergence, DAE) on the indices were studied. A ratio of sensitivity was calculated between the value of the higher N treatment (250 kg N ha^{-1}) and the value of the lowest N treatment (0 kg N ha^{-1}) of each index in order to evaluate the ability of the index to assess highly contrasting N status. Pearson correlation coefficients were calculated between the index and the N concentration in shoots or in the whole plant biomass. Coefficients of variation (%) were calculated for each index as the ratio between the standard deviation and the corresponding mean measured between the four replications.

Results

Sensitivity and earliness of the diagnosis. Taking into account the 2012 and 2013 trials, with decreasing N rates the chlorophyll-based indices decreased (e.g. HNT index), the flavonoids-based indices increased (FLV and FLAV) whereas the combined chlorophyll to flavonoids-based indices decreased (NBI, NBI-R, HNT/FLV and HNT/FLAV) confirming the dependency of chlorophyll and flavonoids indicators to N. The FLV, FLAV, HNT, NBI, NBI-R, HNT/FLV and HNT/FLAV were able to reveal significant N responses among the six or five tested N rates. The other indices related to LCC showed less sensitivity with significant N responses between only two up to four N rates. The combined chlorophyll to flavonoids-based indiceswere classified according to the computed ratio of sensitivity as the better indicators able to react to a range of contrasting N conditions followed by the Red vegetation index (obtained from the Cropscan) and then both the flavonoids-based indices. The HNT index was ranked 17 on the list of 26 indices. The FLV, NBI-R, HNT/FLV and HNT/FLAV were able to reveal a significant N response for each sampling dates.

For both trials and cultivars FLV, FLAV, NBI-R, HNT/FLV and HNT/FLAV showed a consistent early response to N doses (significant N effect at 19 and 25 DAE in 2012 and 7-8 and 13 DAE in 2013).The indices obtained in 2014 and related to LFC combined or not with LCC also match the criteria of sensitivity and earliness of the diagnosis, confirming the previous results.

Accuracy (Precision and Repeatability).The precision was evaluated on the basis of the Person correlation coefficient obtained between the index and the N concentration in shoots or whole plant biomass. The coefficients obtained as the mean of 2012 and 2013 trials with N concentration were higher (over 0.8) for FLV, FLAV, NBI, NBI-R, HNT/FLV and HNT/FLAV compared to the other studied indices. These indices were also ranked in general as the six best performances in term of higher correlation with N concentration obtained for each sampling date. The repeatability of the indices assessed by the coefficients of variation indicated acceptable values.

Specificity. Besides the significant effect to N, most of the indices showed significant effect of cultivar, sampling date and year. Thus, the absolute indices values provided by optical devices showed low specificity to N. This low specificity could be alleviated by the use of relative indices using 0 or 250 kg N ha^{-1} as reference N rates. This result is in agreement with the need of using normalization procedure for crop measurements to alleviate as much as possible the influence of factors other than N rates on the performances on the optical readings [1] [2].

Conclusions

Despite the fact that absolute indices show low specificity to N (due to cultivar, sampling date and year effects on the optical readings), which can be improved by the use of relative values, the indices related to LFC combined or not with LCC were able to match successfully the required criteria and could be suggested as valuable tools for assessing potato CNS.

References

[1] Goffart, J-P., Abras, M. & Ben Abdallah, F. (2013). Gestion de la fertilisation azotée des cultures de plein champ. Perspectives d'amélioration de l'efficience d'utilisation de l'azote sur base du suivi du statut azoté de la biomasse aérienne. *Base*, 17(1), 221-230.

[2] Samborski, S. M., Tremblay, N., & Fallon, E. (2009). Strategies to make use of plant sensors-based diagnostic information for nitrogen recommendations. *Agronomy Journal*, 101(4), 800-816.

MITIGATION OF NITROUS OXIDE EMISSIONS USING A NITRIFICATION INHIBITOR, ALTERNATIVE PASTURE AND FORAGE PLANTS AND GIBBERELLIC ACID

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Objectives

In grazed pastures, nitrous oxide (N_2O), the potent greenhouse gas, is mostly emitted from animal excreta, particularly animal urine-N retuned to the soil during grazing. N_2O is produced in the soil through nitrification or denitrification. The first step of the nitrification process, ammonia oxidation, is a critical step of the N cycle which can significantly affect N_2O emissions. It is performed by ammonia oxidising bacteria (AOB) and archaea (AOA) in the soil. N_2O emissions are affected by a number of soil and environmental factors and major research efforts have been devoted to understanding these factors and developing effective mitigation technologies. This paper reports a series of laboratory and field studies designed to assess the effectiveness of different mitigation technologies for N_2O emissions in grazed pasture and forage systems, including the use of nitrification inhibitors, alternative pasture and forage plants, and the natural plant growth hormone, gibberellic acid (GA).

Method

A series of laboratory incubation and field studies have been conducted to determine the effectiveness of different mitigation options on N_2O emissions. Experiment #1: A soil incubation study was conducted to test the efficacy of DCD in inhibiting the growth of ammonia oxidising bacteria (AOB) and archaea (AOA) and in reducing N_2O emissions under different soil moisture conditions. Experiment #2: Field plot experiments were conducted to determine the impact of animal treading on N_2O emissions following the application of animal urine and on the effectiveness of DCD in reducing N_2O emissions. Experiment #3: Field lysimeter and plot studies were conducted to determine the potential of using alternative pasture or forage plants and/or GA to mitigate N_2O emissions in grazed pasture systems. The pasture and forage plants assessed in the experiments included Italian ryegrass (*Lolium multiflorum*), lucerne (*Medicago sativa*), diverse pastures (including plantain (*Plantago major*), chicory (*Cichorium intybus*), and perennial ryegrass (*Lolium perenne*) plus white clover (*Trifolium repens*)), fodder beet (*Beta vulgaris*), kale (*Brassica oleracea*), as well as the standard perennial ryegrass and white clover (RG/WC) pastures.

Results and Discussion

The incubation study showed that soil moisture content was a major driver affecting the growth of ammonia oxidizing bacteria (AOB) and N_2O emissions in the soil that received animal urine. Total N_2O emissions from the soil at 130% field capacity were 400 times higher than those from the soil at 60% field capacity. DCD was highly effective in inhibiting the growth of AOB in the wet soil conditions and total N_2O emissions were significantly related to the abundance of AOB *amoA* gene copy numbers but not to that of AOA. The field plot study showed that animal treading of a wet soil resulted in a reduction in air permeability and air-filled pore space. Trampling increased average cumulative N_2O emissions over a three month period from 15.9 kg N_2O-N ha^{-1} to 45.0 kg N_2O-N ha^{-1} in the urine treatments. DCD was highly effective in reducing N_2O emissions, with N_2O emissions being decreased by 58-63%. Trampling did not significantly affect the effectiveness of DCD in reducing N_2O emissions. The application of GA *per se* to urine-treated lysimeters with Italian ryegrass, lucerne, or RG/WC pastures did not result in lower N_2O emissions. However, the use of diverse pastures with the associated lower animal urine-N loading rate at about 500 kg N ha^{-1} significantly decreased N_2O emissions by 46% compared with standard RG/WC with a urine-N loading rate at 700 kg N ha^{-1}. The N_2O emissions from urine from cows grazing fodder beet were 39% lower than that from kale with the same urine-N application rate. These results suggest that N_2O emissions can potentially be reduced by the use of the nitrification inhibitor DCD, and by incorporating diverse pastures and fodder beet into the farm system.

Conclusions

These results suggest that soil moisture conditions and animal trampling are major drivers affecting N_2O emissions. The DCD nitrification inhibitor technology is an effective mitigation tool for N_2O emissions in both pastoral grazing and winter forage grazing systems. The application of GA *per se* did not lead to lower N_2O emissions from the animal urine applied to the pastures. Diverse pastures, incorporating herbs such as plantain, may have a role to play in mitigating N_2O emissions by lowering the N loading rate under the animal urine patch compared with the standard perennial ryegrass/white clover pasture. However, the pasture species themselves did not directly affect the amount of N_2O emitted when urine was applied to the different pastures at the same rates. Fodder beet may be a better winter forage crop than kale in terms of lowering N_2O emissions. Further studies are needed to verify some of the findings reported here under other soil and environmental conditions.

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INHIBITION OF BACTERIAL AND FUNGAL NH_4-N OXIDATION BY THE NITRIFICATION INHIBITOR DICYANDIAMIDE (DCD) IN A TEMPERATE GRASSLAND SOIL

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Objectives

Nitrification inhibitors have the potential to increase the efficiency of applied fertilisers by slowing NH_4^+oxidation to NO_3^-, thereby reducing losses via denitrification and leaching. It is believed that nitrification inhibitors target the enzyme ammonium mono-oxygenase (AMO), which is present in bacteria but has not been established in fungi. However, it has been shown that fungi can play a dominant role in NH_4^+ oxidation in grassland soils. As many grassland soils are fungal dominated; an interesting question is if DCD has any effect on soil nitrification in these soils.

This study aimed to quantify the efficacy of the nitrification inhibitor dicyandiamide (DCD) on gross soil N transformations in a fungal dominated grassland soil. A ^{15}N tracing study was carried out in the laboratory with specific bacterial (streptomycin) and fungal (cycloheximide) biomass inhibitors, with and without DCD.

Method

Soils (0-10 cm) were collected from a sandy clay loam temperate grassland site with moderate drainage at AFBI Hillsborough, Co. Down, Northern Ireland. Soils were partially air dried and then sieved to pass a < 6 mm sieve. A 120 g (on an oven-dry basis) sub-sample of soil was placed in an acid-washed 500g Kilner jar and three ^{15}N labelled ammonium nitrate (NH_4NO_3) treatments were applied in solution, at a rate of 0.857 mmol, to bring the soil moisture content to 60% WFPS. The NH_4NO_3 was labelled either singly as $^{15}NH_4NO_3$ or $NH_4{}^{15}NO_3$, or doubly as $^{15}NH_4{}^{15}NO_3$, at 60 atom % enrichment. The specific biomass inhibitors streptomycin (bacterial) and cycloheximide (fungal) were applied in solution at 3 mg g^{-1} and 6 mg g^{-1} respectively, either with or without DCD. DCD was applied at 10% of the NH_4^+-N concentration. Sodium acetate trihydrate was added to all sample jars to supply 100 µmol C g^{-1} oven-dried soil. Three replicates of each treatment were incubated at 20°C.

The concentration and ^{15}N enrichment of the mineral N pools were determined after extraction with 2M KCl at 24, 48, 72 and 96 hours after mineral N addition. The ^{15}N enrichments of the NH_4^+ and NO_3^- pools were determined by methods based on the generation of N_2O for IRMS measurement. Gross soil N transformations were quantified using a ^{15}N tracing model[1], which was developed for permanent grassland soil and considers six N pools and six simultaneously occurring soil N transformations.

Results

Overall, total gross mineralisation and total gross immobilisation was dominated by fungal activity which is in agreement with previous studies from the same permanent grassland soil [2]. Addition of DCD, relative to treatments without DCD, was found to increase total gross soil NH_4^+ immobilisation by 52% and total gross soil NH_4^+ mineralisation by 155% in the control treatment soils i.e. where both fungi and bacteria were active. Addition of DCD caused a 64% increase in total gross mineralisation but no change in total NH_4^+ mineralisation for treatments which received streptomycin (fungal activity). Total gross mineralisation and total gross immobilisation remained low in treatments which received cycloheximide, either with or without the addition of DCD.

Autotrophic NH_4^+ oxidation also appeared to be dominated by fungi, and addition of DCD caused almost complete inhibition; with a 94% and 99% reduction respectively in the control and streptomycin treatments compared to no DCD addition. The addition of streptomycin caused NH_4^+ oxidation to be almost halved

(55% reduction) compared to the control treatment, while the addition of cycloheximide caused no appreciable NH_4^+ oxidation to be observed (99% reduction compared to control). This highlights the important role the fungal community may play in nitrification and demonstrates that DCD is capable of inhibiting fungal communities in this soil. There was no noticeable NH_4^+ oxidation observed with the treatments which received cycloheximide, either +/- DCD. Heterotrophic oxidation of organic N (N_{rec} oxidation) was negligible compared to autotrophic NH_4^+ oxidation, either +/- DCD.

Conclusions

Nitrification inhibitors are believed to target the AMO enzyme which is associated with bacterial nitrification. This study shows that DCD inhibited both bacterial and fungal nitrification in a permanent grassland soil. Therefore, even in fungal dominated soils, DCD may have considerable potential to mitigate N losses from denitrification and leaching by inhibiting the oxidation of soil NH_4^+ to NO_3^-.

References

[1] Müller, C., Rütting, T., Kattge, J., Laughlin, R.J., Stevens, R.J., 2007. Estimation of parameters in complex ^{15}N tracing models via Monte Carlo sampling. Soil Biol. Biochem. 39, 715-726.

[2] Laughlin, R.J., Stevens, C.J., Müller, C., Watson, C., 2008. Evidence that fungi can oxidize NH_4^+ to NO_3^- in a grassland soil. Eur. J. Soil. Sci. 59, 285-291

THE EFFECT OF NITROGEN STABILISERS ON NITROUS OXIDE EMISSIONS AND SPRING BARLEY GRAIN YIELD FROM A FREE-DRAINING LOAM

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Objectives

The main straight N fertiliser used in Ireland is calcium ammonium nitrate (CAN) which contributes to nitrous oxide (N_2O) emissions. Urea may reduce N_2O loss but can increase NH_3 loss potentially reducing yields. N stabilisers can be added to fertiliser to reduce these N losses and maintain yields. The objectives of this study were:

- (i) To assess the effect of CAN and urea on N_2O emissions and spring barley grain yield
- (ii) To assess the effect of N stabilisers added to urea reducing N_2O emissions and maintaining spring barley grain yield relative to CAN

Method

The experimental field site was located in the southeast of Ireland on a free-draining loam soil cropped spring barley (cultivar Sebastian). This site has been in continuous spring barely production for over 20 years and is representative of the land primarily used for spring barley in the south east of Ireland. The experiment began in 2013 and was conducted over three successive field seasons. N_2O and yield performance were measured in 2013 and 2014 and yield performance only was measured in 2015. The experiment was laid out in a randomised block design with five replications of each treatment. The N fertiliser treatments were CAN, urea, urea + n-BTPT, urea + DCD and urea + n-BTPT + DCD and also an unfertilised control. The crop was sown in April in both years. Fertiliser N was applied at a rate of 150 kg N ha^{-1} with 30 kg N ha^{-1} applied at sowing (April) and 120 kg N ha^{-1} applied during mid-tillering (May). N_2O fluxes were measured using the static chamber technique [1]. The most intensive sampling occurred around fertilisation with samples taken four times per week in the first two weeks, twice per week for the next two weeks and then reduced to once per week until 2 weeks post-harvest where sampling was reduced to once every three weeks. In year 2 sampling was reduced to once every 3 weeks, 4 weeks after fertilisation, after assessing year 1 data. N_2O concentrations were analysed on a Varian CP-3800 Gas chromatograph using star software. Cumulative emissions were generated using trapezoidal integration and N_2O emission factors were generated and compared to IPCC default of 1%. The crop was harvested in August in 2013 and 2014 and in September in 2015 and grain yield was determined.

Results

CAN and urea produced similar direct N_2O emissions in both years. Cumulative emissions were higher in 2013 than 2014. In 2013 CAN produced the highest cumulative emissions of 1161 g N_2O-N ha^{-1} and in 2014 urea produced the highest cumulative emissions of 538 g N_2O-N ha^{-1}. In 2013 urea + n-BTPT, urea + n-BTPT + DCD and the unfertilised control were all significantly lower than CAN and in 2014 urea + DCD and the unfertilised control were significantly lower than CAN. The highest EFs were from CAN and urea with lower EFs from the N stabilisers added to urea but EFs from all treatments were at least 50% lower than the IPCC default value. This shows that using the IPCC default value would overestimate emissions and is not appropriate for use in this system. There is a need for more accurate data to move to a tier 2 methodology that generates more accurate EFs for national inventories.

Grain yield results for 2013 and 2014 show that grain yield from all treatments were similar. All treatments produced significantly higher grain yield than the unfertilised control but there were no significant differences between fertiliser treatments in either year. On average in both years urea + n-BTPT produced the highest grain yield numerically. Urea + n-BTPT produced 106% and 107% yield relative to CAN in 2013 and 2014 respectively. Although this is not statistically significant it represents approximately 0.5 t ha^{-1} more grain yield, on average, than CAN in both years which would mean a higher income to the farmer. Grain yield results for 2015 will be further discussed and presented at the 19th Nitrogen Workshop.

Conclusions

Overall direct N_2O emissions from all treatments were low and EFs were at least 50% lower than the IPCC default value of 1%. This shows that the IPCC default value is not appropriate and more accurate data is needed to move to a tier 2 methodology and provide more accurate data for national inventories.

The use of stabilised urea numerically reduced direct EFs compared to CAN in both years. Grain yield was similar regardless of the N source used but urea + n-BTPT gave approximately 0.5 t ha^{-1} more yield than CAN in both years.

Switching N fertiliser source from CAN to urea + n-BTPT could numerically reduce N_2O EF_S and may increase grain yield. This represents a win-win scenario for both the environment and the farmer.

References

[1] Clayton H., Arah J.R.M. and Smith K.A. 1994. Measurement of nitrous oxide emissions from fertilized grassland using closed chambers. Journal of Geophysical Research: Atmospheres. 99, 16599-16607.

EFFECTS OF ORGANIC MATTER INPUT ON NUTRIENT BALANCES, NITRATE LEACHING AND CROP YIELD IN A LONG TERM EXPERIMENT ON SANDY SOILS IN THE NETHERLANDS

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Objectives

Arable farming on sandy soils in the Southeast of the Netherlands has an average nitrogen concentration in groundwater of 79 mg NO_3^-/l, above the threshold of 50 mg NO_3^-/l set by the EU-Nitrate directive [1]. Important reasons for high nitrate concentrations in groundwater are the intensive arable and vegetable crop rotations with a large share of leaching sensitive crops and the relative high nitrogen and animal manure inputs. Organic matter input can on one hand buffer nitrogen and possibly reduce emissions. But on the other hand can organic matter give uncontrolled release of nitrogen, leading to increased emissions in periods without crop uptake. In a long term experiment on sandy soils in the Netherlands with arable and vegetable crops, three organic matter input strategies are compared and evaluated on nitrate leaching, nitrogen balance, and crop yield.

Method

The long term experiment is carried out since 2001 in an intensive six-year arable and vegetable rotation: since 2011: potato, peas, grass (grass clover in HIGH), leek, barley, sugar beet (carrot in HIGH) and maize. A comparison is made between three systems: 1) system STANDARD: conventional with regular organic matter input from crop residues and pig and cattle slurry, effective organic matter (EOM) input about 2000 kg/ha/year, 2) system LOW with organic matter input from crop residues only, EOM input about 1000 kg/ha/year, and 3) system HIGH organic with a high organic matter input from crop residues, farmyard manure and cattle slurry, EOM input about 3000 kg/ha/year. LOW and STANDARD have the same fertilization strategy on available nitrogen in the cropping season. HIGH has a lower fertilization input.

Nitrate concentrations in groundwater, crop yields, nitrogen concentrations in crop yield and some soil parameters as organic matter content, pH available P and K and plant parasitic nematodes were recorded yearly. Nitrate concentrations in groundwater are measured four times during the winter season (November till February) in the upper meter of the groundwater on three places within a field. Crop yield is established in four places in a field. Soil parameters and nitrogen concentrations in crops are assessed in mixed samples per field.

The nitrogen balance and nitrate leaching were analyzed using the WOG-model [2], taking into account as inputs: all manure and chemical fertilizer application, nitrogen fixation, seed and planting material and aerial deposition. Nitrogen offtake by crops and byproducts and ammonia losses during application of manure and fertilizers is taken into account as offtake. Nitrogen and surplus is calculated by subtracting offtake from input. Nitrogen leaching fractions, the part of the surplus that is leached to the groundwater, can be calculated by dividing the nitrogen leaching by the surplus. To calculate the amount of nitrate leaching, the average measured nitrogen concentration in groundwater per year was divided by the rainfall surplus. The rainfall surplus is calculated from rainfall and standard evapotranspiration measurements corrected with crop factors and corrected for yield levels.

Results

The average nitrogen input between 2012 and 2014 was for LOW 238, for STANDARD 274 and for HIGH 218 kg/ha/year. The average nitrogen offtake was for LOW 122, for STANDARD 143 and for HIGH 91 kg/ha/year. The average nitrogen surplus was for LOW 116, for STANDARD 131 and for HIGH 127 kg/ha/year. Although large differences in input and offtake exist, the surplus between STANDARD and HIGH is equal. Input, offtake and surplus are for LOW lower than STANDARD. The average rainfall surplus between 2012 and 2014 was for LOW 402, for STANDARD 369 and for HIGH 502 mm/year. The average nitrogen leaching fraction between 2012 and 2014 was for LOW 50%, for STANDARD 43% and for HIGH 23%. There is a clear difference in leaching fractions between the systems, where HIGH, with the high organic matter input and low fertilization has the lowest leaching fraction and LOW with the low organic matter input has the highest leaching fraction.

Average crop yields between 2011 and 2014 in LOW were 8% lower than STANDARD. Average crop yields in HIGH are not directly comparable with LOW and STANDARD because of the organic cropping system. Crop yields in HIGH tend to increase since the start of the experiment to the level of STANDARD. The average crop yields of maize are between 2011 and 2014 comparable to STANDARD. The average yields of peas, leek and potato were comparable to STANDARD in years when disease pressure was low. Variations in yield are large but there is a trend that dry summers lead to larger yield difference between LOW and STANDARD and smaller yield difference between STANDARD and HIGH.

Average nitrate concentrations between 2012 and 2014 were in LOW 67, in STANDARD 54 and in HIGH 26 mg NO_3^-/l. The nitrate concentrations in LOW and STANDARD are above the EU threshold of 50 mg/l. High nitrate concentrations are correlated with low organic matter input. In the period 2005-2008, the nitrate concentrations in groundwater were much higher in STANDARD and LOW because of difference in crop rotation with lily instead of grass. Besides the nitrate concentration in STANDARD (127 mg NO_3^-/l) was higher than in LOW (117 mg NO_3^-/l). In first instance, mineralization of slurry after crop uptake period is more important than binding of nitrogen by organic matter. Later on this changes, also because of lower crop yields and lower nitrogen uptake in LOW.

Chemical soil parameters in all systems are in range for good production. Organic matter content, total soil nitrogen, potential N and C mineralization and microbial biomass are somewhat higher in HIGH compared to LOW and STANDARD indicating higher microbial activity.

Conclusions

No input of organic matter with manure does increase nitrate leaching on the long term and lowers crop production. This is not a viable option as well from environmental as from economical point of view. High input of organic matter with manure in an organic system gives nitrate concentrations in groundwater below the EU-threshold and increasing yield levels up to conventional standards when disease pressure is low. Sufficient input of organic matter together with good soil management and crop rotation are vital to maintain yield and comply with the EU nitrate directive. However, variations in measurements are high and conclusions have still large uncertainties. Therefore the research is continued in the next years.

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References

[1] Hooijboer, AEJ, A de Klijne 2012. Water quality on farm lands. Evaluation of the Dutch fertilizer and manure policy 2012. Rijksinstituut voor Volksgezondheid en Milieu (RIVM). Rapport 680123001/2012. http://www.rivm.nl/bibliotheek/rapporten/680123001.pdf (in Dutch).

[2] Schröder, J.J., H.F.M. Aarts, J.C. van Middelkoop, M.H.A. de Haan, R.L.M. Schils, G.L. Velthof, B. Fraters & W.J. Willems, 2007. Permissible manure and fertilizer use in dairy farming systems on sandy soils in The Netherlands to comply with the Nitrates Directive target. European Journal of Agronomy 27, 102-114.

EFFECTIVENESS OF NITROGEN INHIBITORS AND APPLICATION METHODS ON REDUCING AMMONIA VOLATILIZATION AND NITROUS OXIDE EMISSIONS FROM SOILS

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Objectives

Less than 50% of applied nitrogen fertilizer is typically recovered in grain as a result of climatic constraints, over application and losses to air and water before the crop could utilize the applied N. In Canada, urea based fertilizers represents 74% of N fertilizer sales. We evaluated 3 different fertilizer N application methods (broadcast, streaming and injection) to corn at the 6-8 leaf stage as well as 3 different nitrogen sources and inhibitors to see if we could reduce ammonia volatilization losses and N_2O emissions and thereby enhance crop uptake and productivity. The objectives were to determine: 1) how much N is lost from the soil via ammonia volatilization and N_2O emissions; 2) the effectiveness of various N application methods on reducing gaseous N losses (ammonia and N_2O) and increasing corn N uptake; and 3) the effectiveness of urease inhibitors on reducing ammonia volatilization and nitrification inhibitors on reducing nitrous oxide emissions.

Method

Corn was planted at 79,700 seeds ha^{-1} on May 27, 2013 and May 26, 2014 on a Brookston clay loam soil in Woodslee, Ontario Canada (lat. 42.21°N, long. 82.75° W). Each plot was 20 m long and 9 m wide with 12 rows of corn. Starter fertilizer (142 kg ha^{-1} of 20-20-10, N-P_2O_5-K_2O) was applied at planting to all plots in a band 5 cm beside the corn row at 5 cm depth. The ten treatments consisted of 3 methods of N fertilizer application (broadcast, banding, and streaming) at the corn 6-8 leaf stage in a factorial arrangement with 3 N fertilizer sources with/without inhibitors (i.e. urea or UAN with either no inhibitors, a urease inhibitor or a urease and nitrification inhibitor) as well as a control with no N addition. There were 4 field replicates and they were arranged in a randomized complete block design.

Nitrous oxide emissions were measured 43 times over the 2013 and 2014 growing seasons. There were 2 acrylic collars (53.5 cm length, 17.7 cm width and 15 cm height) inserted into each plot in 3 of the 4 replicates for a total of 60 chambers. Gas samples were collected on a weekly basis at 0, 10, 20 and 30 minutes following the covering and clamping of each lid over the growing season with additional gas sampling collected following sidedress N application. There were over 10,000 gas samples collected and analyzed on a gas chromatograph fitted with an electron capture detector.

Wind tunnels (2 m long by 0.5 m wide) were deployed to measure ammonia volatilization losses the varying N source and application treatments. Ammonia losses were measured every day for 28 days following N application using acid traps which collected air samples before and after they passed over the soil under the wind tunnels.

Corn biomass was determined every 3 weeks after emergence until harvest. Soil samples were collected at the same time and extracted and analyzed for ammonium and nitrate on a Traacs 2000 analyzer. Corn grain yields were determined from two sets of 2-rows that were 1.52 m wide by 20 m long from each plot.

Results

Broadcast urea application resulted in 60.6 kg N ha^{-1} ammonia volatilization losses or about 46.6% of the applied urea-N. Ammonia volatilization was reduced to 22 kg N ha^{-1} or 17% of applied N when a urease inhibitor was added with the broadcast urea. Surprisingly, ammonium volatilization losses also occurred with the injected UAN treatment and the average loss was 24.3 kg N ha^{-1} or 19% of the applied N. Ammonia volatilization losses from the injected UAN+UI+NI treatment were only measured in 2014 and in this year, only

0.27 kg N ha^{-1} or 0.2% of applied N was lost as ammonia.

Nitrous oxide emissions were significantly affected by both the N application method and the inhibitor treatment. When the urease inhibitor was applied with the broadcast urea, there was on average 1.74 kg N ha^{-1} N_2O emissions. Nitrous oxide emissions increased by 17% (2.1 kg N ha^{-1}) when the urease inhibitor was added with the broadcast urea but emissions decreased by 27% when both a urease and nitrification inhibitor were applied (1.27 kg N ha^{-1}). Hence when ammonia volatilization losses are reduced, there is a potential increase in N_2O emissions unless a nitrification inhibitor is also used. This trend was also seen with injected UAN with slight increases in N_2O emissions when UI was applied with UAN whereas there was a 12% decrease in N_2O emissions when both UI and NI were applied with UAN.

Corn grain yields were only 4.29 t ha^{-1} when no N fertilizer was applied but ranged from 9.2 to 11 t ha^{-1} when N was added. Injected UAN had on average 11% greater yields than broadcast urea. When urease inhibitors were added alone or in combination with a nitrification inhibitor, corn grain yields increased by 4% with broadcast urea and by 7.5% when added with injected UAN. Hence both injection and the use of inhibitors can reduce environmental losses to ammonia and nitrous oxide emissions and enhance corn grain yields.

Conclusions

Soil and environmental conditions in central Canada were found to lead to significant environmental losses of ammonia and nitrous oxide. Ammonia volatilization losses were greatest when urea was broadcast applied to the soil. When UAN was injected into the soil, ammonia volatilization losses were decreased by over 50% compared to broadcast application. Treatments that received urease inhibitors also had dramatically lower ammonia volatilization losses compared to urea or UAN alone.

Treatments which reduced ammonia volatilization resulted in more inorganic N being left in the soil. The higher nitrate levels did however increase nitrous oxide emissions unless a nitrification inhibitor was also added. Corn grain yields and profitability were increased when nitrogen fertilizer was injected into the soil and when urease inhibitors were added with the N fertilizer.

THE EFFECTIVENESS OF SOME SELECTED MANAGEMENT STRATEGIES FOR REDUCING NITROGEN LEACHING RISK FROM DAIRY GRAZING SYSTEMS IN SOUTHERN NEW ZEALAND

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Objectives

Monitoring, experimentation and modelling is seeking to define the N leaching risks for 2 dairy farmlet systems designed to provide management options for reducing N losses to water, without incurring large reductions in farm profitability.

Method

Treatment farmlets of 110 cows were monitored over a 3-year period and compared against a Control dairy system where N-fertilised pasture and grazed winter forage crops were the main dietary components during lactation (spring-autumn) and non-lactation (winter), respectively. An Optimised farmlet system focussed on reducing N fertiliser inputs and improving winter feeding management practices as key strategies for reducing N losses to water. The managements implemented in this farmlet were: incorporation of cereal silage into the autumn diet to improve N partitioning and reduce urinary N excretion; a reduction in annual N fertiliser inputs to pasture from 110 to 40 kg N ha^{-1}; an increased area of high-producing annual ryegrasses to increase late winter/early spring pasture growth; and removal of forage crop land traditionally grazed during dry summer conditions. Using an alternative approach, a Restricted Grazing farmlet utilised a herd shelter for housing cows during autumn (overnight use only) and winter (fully housed) as the main strategy for manipulating urinary N returns and therefore N leaching risk.

An important factor in the evaluation of N leaching risk associated with each farmlet system was consideration of all hectares used to support milk production, particularly grazed forage brassica crop areas used for providing winter or summer feed. For each of these areas, N loss estimates (kg ha^{-1} yr^{-1}) were assigned based upon either measured loss values, assumed values based on local research data, or measurements of potentially leachable N. The latter was used as an indicator of the relative risk of N leaching between the farmlets and was based on measurements of the quantities of inorganic N residing in the soil to 450 mm depth in late-autumn each year, bench-marked against measured N leaching from experimental plots. This measurement date was chosen as an occasion when plant N uptake slowed to much less than 1 kg N ha^{-1} day^{-1} and the risk of surplus rainfall (and thus drainage commencement) likely. The mechanistic DairyNZ Whole Farm Model[1] (WFM) was used to isolate some of the effects that the individual management practices documented above had on N leaching from the farmlets.

Results

Whole-system farmlet assessments indicated that N leaching risk in the Optimised farmlet treatment was reduced by ca. 24% overall, compared to the Control. This was achieved due to the collective effect of the management measures specified above. Areas used for grazing of summer forage crops by cows from the Control herd were observed to have a relatively large potential for N leaching risk; removal of these areas from the dairy system was estimated to reduce overall N leaching risk from the Optimised farmlet by ca. 9%. Measurements of potentially leachable N in pasture areas grazed by lactating cows were highly variable, although mean values calculated for each farmlet were consistent with pre-experimental modelling estimates of N leaching risk. Interrogation of the datasets using the WFM modelling tool showed that reduced N fertilisation was the most effective management principle that reduced N leaching risk from pastures and accounted for ca. 40% of the total reduction calculated for this farmlet. The associated reduction in cow stocking rate and feeding of cereal silage in autumn were measures that made approximately equal contributions to the remaining decrease in N leaching risk calculated for pasture areas on the Optimised farmlet. Although milk production in this farmlet was reduced by 2%, preliminary economic analysis suggests that farmlet profitability was similar to that calculated for the Control farmlet.

Whole-system assessment of N leaching risk in the Restricted Grazing farmlet treatment was estimated to be reduced by ca. 29% overall, compared to the Control. Approximately half of this reduction was attributable to the removal of areas of grazed summer and winter forage brassica crops. Measurements of potentially leachable N in soil indicated that overnight use of the barn during autumn to reduce urinary N returns to pastures was the next most effective measure for reducing N leaching risk (by 10 - 12%); reductions in N fertiliser inputs from 110 to 74 kg N ha^{-1} yr^{-1} was modelled to account for the remainder of the N leaching benefit estimated for the Restricted Grazing farmlet. Although milk production in this farmlet was increased by 3%, the capital and operating costs of the barn resulted in a lower farmlet profitability than calculated for the Control farmlet. The costs associated with handling, storing and safely returning barn manure and slurry to pastures during spring and summer was a significant cost that contributed to this reduced profitability.

Conclusions

Whilst an appreciable reduction in whole-system N leaching risk was achieved in the Optimised farmlet, this was attained by the implementation of a set of collective measures that introduced additional complexity to the farm business. Regular assessments of pasture covers were vital to ensure that limited amounts of N fertiliser were used most effectively; targeting N fertiliser to the annual pastures with high N response helped to increase the efficiency of system N use. Autumn and winter use of a barn in the Restricted Grazing farmlet was another effective strategy for avoiding the relatively high potential for N leaching associated with grazed summer and winter forage crops. However, such infrastructure incurred substantial capital and operating costs and posed additional challenges for farm staff to adequately plan for and balance N returns in the organic material collected from the barn.

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References

[1] Beukes, P.C., Palliser, C.C., Macdonald, K.A., Lancaster, J.A.S., Levy, G., Thorrold, B.S., Wastney, M.E. 2008. Journal of Dairy Science 91, 2353-2360.

CONTROLLED DRAINAGE AS MEASURE TO REDUCE NITRATE LEACHING IN DIFFERENT SOIL AND CROPPING SYSTEMS

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Objectives

Subsurface drainage of soil to avoid water logging is a prerequisite for crop cultivation for a large proportion of the Danish agricultural land. Approximately 50% of Danish farmland has subsurface drains installed. To reduce the risk of nutrient losses to the aquatic environment effective measures are needed. Raising the upper ground water level by managing the drain depth during periods with low crop growth and high leaching rates has been found to be effective measures to reduce losses of nutrients through the drain systems. This measure is often referred to as Controlled Drainage (CD). So far CD has only been tested for spring sown crops but widespread implementation on drained clayey soils in Denmark would rely on its adaption to winter cereal production systems. The objective is to analyse the effects of CD on crop growth and losses of nutrients in mainly winter cereal cropping systems.

Method

A project on CD applied at four sites (by farmers) in Denmark running 2012-2015, representing both winter and spring cropping systems combined with dominating drained Danish soil types, has been completed. The field site selection was based on a number of criteria: slope (<2°); systematic pipe drain systems; soil type (drained sandy, sandy loam, or loamy); farmers willingness to cooperate.

At the start of the project the selected fields were characterized by: soil profiles description to app 1.5 m; hydraulic properties and soil chemical properties; soil heterogeneity mapped using soil electrical conductivity; soil texture and soil chemical properties in grid points (4-10 grid sampling points per drain system). Upper ground water heights were measured during autumn and winter time.

Field trial treatment plans for three years (2013-2015) were set up. Each site was split into two to four sub fields (separate drain systems. app. 1 ha). First year (2012-2013) was a control year with normal drainage. Second and third year (2013-2015) one sub field was a control field (No CD), and the other managed by using CD. The drain depth was adjusted to app. 60 cm below surface in 2013 and app. 40 cm below surface in 2014.

Measurements were conducted all years (2012-2015). Two measurement programs were setup (detailed and reduced). At two sites the detailed program included: N_2O fluxes during autumn, winter and early spring (campaign measurements at one site only); NO_3, NH_4, total N, P, concentration in drain water; drain water fluxes in pipes; mineral fertilizer N application; crop biomass and N uptake during the growing season (biomass cut) in fertilized and unfertilized micro-plots; fertilization rates were controlled; grain yield obtained with combine harvester (yield meter) and from micro-plots. The reduced measurement program included grain yields by with combine harvester and drainage water analysed for NO_3, NH_4, total N, and P concentration. Water fluxes were also obtained.

Results

In the three sites with winter wheat no effects on yields were observed. Thus CD did not affect crop growth.

In three of the four sites nitrogen leaching was reduced. Based on nitrogen concentrations in drain waters the reduction varied between 10 % and 45 %. The effects on the nitrate leaching measured in drain pipes varied between 2-12 kg N ha^{-1} yr^{-1}. Water and nitrate fluxes through deeper soil layers to the nearby canals were not measured. If these fluxes are through oxidized zones the observed/measured effects on the total nitrogen losses will be overestimated due to higher transport this way. But if the water passes through the reduced deeper soil layers, nitrate will most likely be denitrified and the observed effects measured in drain waters will be the total effect. The main effects on two of the sites were mainly due to lower drain water fluxes.

Swedish experiments on CD showed that losses of nitrogen could be reduced by 78-94 % (6 and 22 kg N ha^{-1} yr^{-1}) and losses of P were reduced by 58-85 % [1, 2]. Other field trials with CD have found that leaching through drain pipes was reduced from a level of 25-40 kg N ha^{-1} yr^{-1} to 1-7 kg N ha^{-1} yr^{-1} [3]. Woli et al. [4] found that N losses from CD systems were 2/3 lower than N losses from traditional drains. Williams et al. [5] found a 23 % reduction (9.4 kg N ha^{-1} yr^{-1}) in leaching through drains applying CD.

Overall the Danish results show generally a lower effect than reported in these studies.

Nitrification is expected to be retarded by wet soils during winter. Denitrification is on the other hand expected to increase in more wet soils during winter. Campaign measurements of N_2O fluxes during winter and autumn did not show any differences due to CD.

Losses of total P in drain water were increased by CD at three of the four sites. The P losses were for all years below 0.3 kg total P ha^{-1} yr^{-1} and therefore not considered as a major problem for the aquatic environment.

Piezometer measurements of the upper ground water level shoved a considerable variation during the entire drain period. Part of the drain system was not active in wintertime (ground water level was below drain pipe depth) while other parts had ground water table above the drain height all through the winter. These findings show that it is challenging to control the height of the upper ground water so saturation of the soil is uniform. This might be the reason to the lower effect than found in other international studies.

Conclusions

- CD and winter cereal productions were combined successfully without yield losses.

- Nitrogen leaching was reduced at three sites with 2-12 kg N/ha. At one site the effects of CD could not be isolated from effects from neighbouring fields.

- CD increased P losses but did not have an effect on N_2O fluxes or sediment in drainwater.

- Drain fluxes were reduced with CD which is the main reason to lower nitrate leaching .

- It is challenging to control the upper ground water height to get uniform saturation of soil with CD setup used in the project.

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References

[1] Wesström, I., Messing. I. (2007). Agric. Water Man. 87, 229-240.
[2] Wesström, I., Messing, I., Linnér, H., Lindström, J. (2001). Agric. Water Man. 47, 85-100.
[3] Gilliam, J. W., Skaggs, R. W., Weed, S. B. (1979) J. Environ. Qual. 8, 137-142.
[4] Woli, K.P., David, M.B., Cooke, R.A., McIsaac, G.F., Mitchell, C.A. (2010). Ecological Engineering 36, 1558–1566.
[5] Williams M.R., King K.W. Fausey N.R. (2015). Agricultural Water Management 148, 43-51.

A SYSTEM N BALANCE FOR A PASTURE-BASED SYSTEM OF DAIRY PRODUCTION UNDER MOIST MARITIME CLIMATIC CONDITIONS

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Objectives

Intensive pasture-based livestock production systems are reliant on imports of nitrogen (N) in fertiliser and purchased feeds to sustain high production. A relatively low proportion (15-35%) of this N is converted to tradable agricultural products (milk and meat) leaving large surpluses of N that are largely unaccounted for. Much of this N is presumed to be lost to water and via emissions of nitrous oxide (N_2O) and ammonia (NH_3) from such systems. Despite much research there is still large uncertainly as to the contribution of individual loss pathways to losses of surplus N. The objectives of this study were to (i) account for the N entering a pasture-based dairy production system by determining the amount of N exiting in products and lost to the wider environment and (ii) determine the relative importance of the components of this balance sheet.

Method

This study was carried out on a perennial ryegrass (*Lolium perenne L.*)/white clover (*Trifolium repens L.*) based system of dairy production at the Teagasc Solohead Research Farm in Ireland. The site has a moist maritime climate and the soils are seasonally wet, waterlogged or flooded due to impeded drainage and a shallow water table depth. The dairy system consisted of six paddocks with a total area of 10.67 ha and an annual stocking density (spring calving Holstein-Friesian cows) of 2.35 cows ha^{-1}. Detailed measurements and estimates of N entering and exiting the system were completed in each paddock of the system in 2011 and 2012. Measurements of N entering the system included, annual rainfall N deposition, N imported in feed, biological N_2 fixation associated with white clover and fertiliser N application. Measured N exiting in products included N in milk sales and calves sold. A range of N losses were also measured. Nitrogen lost to groundwater was measured using screened wells. Nitrous oxide was measured using a closed static chamber technique. An annual estimate of dinitrogen was quantified using a combination of bi-monthly measured N_2:N_2O ratios and measured nitrous oxide emissions. Losses of NH_3 gas from the manure management chain, fertiliser N applications and emissions of other N gaseous losses from slurry storage were estimated using activity data and emission factors [1, 2] (Misselbrook *et al.*, 2010; Forrestal *et al.*, 2015). A system N balance was calculated as the difference between the above mentioned N entering the system and N exiting the system as (i) products and (ii) losses. The difference between N entering the system and N exiting the system in products was called the system N surplus in the present study. The N use efficiency (NUE) of the system was the proportion of N entering the system that was retained in products.

Results

Total N entering and exiting the system was 245 kg ha^{-1} and 269 kg ha^{-1}, respectively, averaged over both years. The latter being comprised of N exiting in products: 79 kg ha^{-1} and losses to the wider environment: 190 kg ha^{-1}. The N use efficiency of the system was 29% and 37% in 2011 and 2012, respectively. The system N balance (mean ± 95% confidences intervals) was -50 ± 82 kg ha^{-1} in 2011 and +1 ± 22 kg ha^{-1} in 2012 and, hence, came close to equality between N entering and existing the system i.e. N balance closure. Up to this point other N balance studies have been unable to account for between 25 to 45% of N inputs with unaccounted for N generally assumed to be lost through denitrification. Dinitrogen gas emissions (43.7%) accounted for the largest proportion of N lost from the system followed by NH_3 emissions (41.6%), N_2O emissions (8%), N lost to groundwater (6.1%) and gaseous N emissions from slurry storage (0.5%). The results of this study provide evidence that denitrification losses, particularly $N_{2,}$ is the missing link in unaccounted for surplus N in pasture-based systems. The relatively high N surpluses previously reported for pasture based systems are often assumed to be lost as environmentally-detrimental losses. However, the results of this study suggest that this may not always be the case. Nevertheless, the significant size of the N_2 emissions indicates that this loss of N, whilst environmentally benign, represents a considerable economic loss of soil N which could have been used for the production of agricultural products.

Conclusions

There was relative equality between the N entering the system and the N existing the system in products and losses over the two year duration of this study. Nitrogen losses to water were relatively low and estimated NH_3 volatilisation was the largest environmentally damaging N loss from the system. Denitrification losses were the largest N loss pathway from this production system based on the fine textured soils and moist maritime climatic conditions at this site. The results suggest that a high proportion of system N surplus exits pasture based dairy systems as environmentally benign N_2 gas. This study also highlights that emphasis should be on NH_3 and N_2O to minimise environmentally damaging N losses from such systems of dairy production.

Acknowledgements

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References

[1] Misselbrook, T., Chadwick, D., Gilhespy, S.L., Chambers, B.J., Smith, K.A., Williams, J., Dragosits, U., 2010. Inventory of ammonia emissions from UK agriculture 2009. North Wyke Research, (DEFRA Contract: AC0112, CEH Project Number: C03642) (Unpublished). Available at http://nora.nerc.ac.uk/13234/, p. 34.

[2] Forrestal, P.J., Harty, M., Carolan, R., Lanigan, G.J., Watson, C., Laughlin, R.J., McNeill, G., Chambers, B.J., Richards, K.G., 2015. Ammonia emissions from stabilised urea fertiliser formulations in temperate grassland. Soil Use and Management DOI: 10.1111/sum.12232

NITROGEN BUDGET ESTIMATED FOR BEEF OPERATIONS ACROSS CANADA

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Objectives

The attributes of beef cattle production, especially in Canada, are typically a series of opposites [1]. The cow-calf operations are widely dispersed, often have <100 head, and use little off-farm nutrient input. In contrast many of the finishing operations are concentrated in two regions (north central Ontario and south-western Alberta), handle thousands of head each year and import feed supplements rich in nitrogen (N). A large scale survey was done of 1009 beef operations in 11 Ecoregions with focus on N management and emphasis on N in feeds and on farm practices that affect the fate of the N after feeding. The overall objective was to quantify N inputs, outputs and surpluses on a peranimal, perarea and peroperation basis for the various farm types in Canada, and to identify significant trends.

Method

The source of farm-specific data was the 2011 survey, described previously [1]. The algorithms [2,3] used to characterize excretion and emissions were based on a total ammoniacal N (TAN) balance model and the detailed management practices identified in the survey data. Cattle types included cow-calf, backgrounding and finishing animals, with consideration of gender (steers and heifers). Summer and winter grazing areas, corrals, barns and feedlots were modelled, along with manure storage and landspreading. Emissions from the application of N fertilizer to feed crops differentiated urea-, ammonia- and ammoniumbased materials from other N sources, with application to perennial-crop-land versus annual-crop-land and using different emission factors for Ecoregions and their predominant soil types. N fixation in hay crops and pasture was included based on reported legume contents of swards, and emissions from curing hay were estimated. Import and export of feed and animals were key variables. Deposition of N from the atmosphere to the entire land base and local deposition from on-farm point sources (confinement areas and manure storage) were estimated. The net N budgets were specific to the beef operation on each farm (excluding other livestock or cash crops), and were computed on per-operation, peranimal and perlandarea bases. The estimates were leptokurtic (strong narrow distributions with long tails), and extreme values were discarded on the assumption that in these cases the farmer misunderstood the questionnaire or neglected sections.

Results

The median of all N budgets was very close to zero. Because the budget was so close to zero and the data were leptokurtic, whether the budget estimate was positive or negative was very sensitive to changes in inputs and outputs. On a per operation basis the median annual budget was within 1.1 tonnes N of zero, and on a per animal basis it was within 14 kg N/animal of zero. The median budget per unit of land was within 6 kg/ha of zero.

The total imports, including N fixation, had a median 1.9 tonnes N/operation or 21 kg N/animal, and over all farm types this was dominated by N fixation, followed by purchased feedstuffs and then fertilizer inputs. However, ranking of these inputs was markedly different for farm type and region. For farms with finishing in feedlots or barns, the fertilizer inputs to grain and forage crops dominated because of the need for higher crude protein levels in the feed. Other types of farms relied more on pasture and perennial forages, and N fixation was the dominant input. Atmospheric deposition was a minor input in the prairie region, but was up to 6 kg N/ha in the east.

Total exports had a mean of 1.7 tonnes N/operation or 19 kg N/animal, and this was largely dominated by ammonia emissions. Ammonia emissions had a median of 1.5 tonnes N/operation or 18 kg N/animal. Animals sold were a major export especially for finishing operations. Manure was considered to be exported if it was applied to cash crop land, and the amount of N exported in manure was comparable to the amount exported in sold animals.

Conclusions

Peroperation N budget estimates across many operations and many landscapes are rarely possible. A recent detailed survey of farm practices on 1009 beef operations in Canada provided a unique opportunity to quantify N budgets and examine the sources of variability. The results emphasized the differences between types of operations, and among regions. The budgets in the spatially extensive, pasturebased cow-calf operations in the Prairie region were dominated by N fixation. In contrast, budgets in the very large feedlots in the same region were dominated by ammonia emissions, animal sales, feed import and export of manure. In the east, fertilizer import was more important that it was in the Prairies. With further analysis, these budget estimates will help to inform policy makers and may address concerns raised by the public about the environmental implications of beef production.

References

[1] Sheppard, S.C., S. Bittman, G. Donohoe, D. Flaten, K.M. Wittenberg, J.A. Small, R. Berthiaume, T.A. McAllister, K.A. Beauchemin. J. McKinnon, B.D. Amiro, D. MacDonald, F. Mattos, K.H. Ominski. 2015. Can. J. Anim. Sci. 95: 305-321

[2] Sheppard, S.C., S. Bittman. 2012. Can. J. Animal Sci. 92: 525-543

[3] Sheppard, S.C., S. Bittman. 2011. Anim. Feed Sci. Technol. 166-167: 688-698.

NITROGEN BALANCE AND NITROGEN FOOTPRINT OF BIOGAS CROPPING SYSTEMS: SHORT-TERM EFFECTS OF BIOGAS RESIDUE APPLICATION

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Objectives

Bioenergy is regarded an essential option to contribute to efforts in climate change mitigation and energy security. In Germany, anaerobic digestion of liquid animal manure and/or plant raw material has been promoted, resulting in a substantial increase in maize acreage. The diversification of cropping systems has been intensively discussed as alternative to continuous maize cultivation. Crop rotations provide many benefits, such as an increase in nutrient use efficiency and productivity. Resource-use efficient crop substrate production implies also that digestate is recycled to replace fossil-fuel based mineral fertilizer.

The Biogas-Expert project analyzed the short-term impact of different N fertilizer types on N flows for different cropping systems in northern Germany. The objective of the current study is (i) to provide a synopsis of the N flows by means of an N balance, and (ii) to quantify the N footprint of substrate production, i.e. the potential N loss per unit methane produced.

Method

The study is based on a 2-year (2007-2008) field experiment (4-factorial block design, 4 replicates) conducted at two sites in northern Germany. Treatments comprised the site, cropping systems, N fertilizer type and amount. At Site 1 (sandy loam) cropping systems were: continuous maize (R1), silage maize-whole crop wheat-Italian ryegrass catch crop (R2), silage maize-grain wheat-mustard catch crop (R3). At Site 2 (humus sand), continuous maize (R1) was compared to perennial ryegrass ley (R4). Nitrogen fertilization consisted of 4 levels (0-360/480/160 kg N ha^{-1} for cereals/ley/Ital. ryegrass) and 4 fertilizer types (mineral (calcium ammonium nitrate), cattle (Site 2) or pig slurry (Site 1), biogas residue). Digestate and animal slurries were applied using trail hoses and N amount was split into 2-4 dressings. Nitrogen concentration of the harvested products was estimated by NIRS. Specific methane yield (lN CH4 kg^{-1} DM) was determined in three replicates by the Hohenheim biogas yield test.

To quantify the impact of substrate production on the N flows in the soil-plant system, a full N balance was calculated as the difference between N input (N fertilization + N deposition) and N output (plant N recovery by the harvested products + N_2O emissions + NH_3 volatilization + N leaching). Thus, the N balance indicates changes of the soil-N pool. Ammonia-N loss of organic fertilizers was modelled [1], based on measurements in selected treatments. For mineral N, it was assumed that no ammonia volatilization occurred. N_2O-N emission was determined in selected treatments using the closed-chamber method [2] and emission factors were applied for plots without measurements. Soil water was sampled by suction cups to determine its N concentration, which was multiplied by simulated water fluxes to obtain the N leaching loss [3]. Nitrogen footprint (NFP, kg N (1000 m^3 CH_4)$^{-1}$) was calculated as an indicator of potential N loss intensity [4]: (N input-N yield)/methane yield. A regression analysis was applied to quantify the relationships between N input and N output as well as N balance and NFE using SAS 9.2 by assuming linear (N_2O), quadratic (NH_3, NFE) or quadratic-plateau (N recovery, N leaching, N balance, NFE of R4) relationships.

Results

At Site 1, the N balance and its components were not affected by the interaction of cropping system × N fertilizer type. Thus the cropping systems impact is exemplified for the mineral N (CAN) treatment, while the N fertilizer type effect is provided for rotation R2.

Nitrogen balance of continuous maize (R1) was highly negative for the 0-N treatment (-125 kg N ha^{-1}) and increased only slightly with N input since N not taken up was mostly lost via leaching. R3 showed a similar pattern, but with a higher increase with N input. In contrast, the N balance of R2 was less negative (-85 kg N ha^{-1}) compared to R1 and R3 and showed a steeper increase only when N input exceeded 323 kg N ha^{-1}. Compared to CAN, animal slurries and digestate applied to R2 showed similar N-recovery response, but caused lower N leaching and higher ammonia emissions. For digestate, N balance started increasing at a lower N input and achieved a balance close to zero at optimal N input (Nopt), while it was negative for CAN and pig slurry. At Site 2, the N balance of the CAN treatment of R1 was negative over the entire N input range due to higher leaching, while for the organic fertilizers, N balance increased with N input and achieved values close to zero at Nopt.

Overall, maize-based cropping systems supplied with CAN or pig slurry were characterized by a mobilization of the soil-N pool, while digestate and cattle slurry resulted in close-to-zero balances. There is considerable evidence to support a soil-N depletion also for intensive cropping systems. It was argued that a depletion of soil organic N is hardly to prevent in arable soils characterized by a high initial content of mineralizable organic N [5], which is controlled by a range of soil quality properties, e.g. accessibility and recalcitrance, history of crop management, organisms, and the environment. The perennial nature of leys with high inputs of organic matter characterized by high resistance to degradability and the absence of soil tillage result in an N accumulation, as indicated by positive N balances for the digestate and cattle slurry treatments of R4.

NFP of the maize-based cropping systems increased with N input, whereas cropping system and N fertilizer type had marginal impact. Total potential N loss at Nopt ranged between -11 (R1, CAN, Site 1) and 7.5 kg N per 1000 m^3 methane (R1, digestate, Site 2). NFP of R4 followed a quadratic-plateau response, revealing significant differences among N fertilizer types, with CAN showing a less steep increase and a substantially lower maximum NFP (14.8) than digestate (50.8) and cattle slurry (65.2).

Conclusions

Close-to-zero N balances of maize-based cropping systems fertilized with digestate might lead us to conclude that biogas substrate production is sustainable in the short term. However, gasesous N_2 emissions were not included in the N-balance calculation, and the optimal N input of R2 by far exceeded the limit of 170 kg N ha^{-1} set by the Fertilizer Ordinance. Thus, high-yielding rotations of maize and C3 crops most likely will require mineral-N supplementation. In contrast, for continuous maize the 170-N limit would allow maximum yield. There is, however, no clear scientific evidence substantiating that negative N balances will necessarily result in a decline of soil fertility and crop productivity. NFP of maize-based cropping systems was below those of perennial ryegrass ley, while the reverse situation was detected for N losses. The suitability of NFP as an indicator of N losses per unit of product thus has to be questioned. Instead, it seems more appropriate to relate product quantity to total N losses.

References

[1] Gericke, D., Bornemann, L., Kage, H., Pacholski, A. 2012. Water Air and Soil Pollution 223, 29-47
[2] Senbayram, M., Chen, R., Wienforth, B., Herrmann, A., Kage, H., Mühling, K.H., Dittert, K. 2014. Bioenergy Research 7, 1223-1236
[3] Svoboda, N., Taube, F., Kluß, C., Wienforth, B., Kage, H., Ohl, S., Hartung, E., Herrmann, A. 2015. Bioenergy Research 8, 1621-1635
[4] Leip, A., Weiss, F., Lesschen, J.P., Westhoek, H. 2014. Journal of Agricultural Science 152, S20-S33
[5] Korsaeth, A., Eltun, R. 2000. Agriculture, Ecosystems and Environment 79, 199-214

INDICATORS FOR NITROGEN USE EFFICIENCY BASED ON TOTAL NITROGEN FIXATION AS A COMPLEMENT TO TRADITIONAL SURPLUS-BASED INDICATORS

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Objectives

Recent research [1, 2] has emphasized the conversion of N_2 from the atmosphere into reactive nitrogen forms (Nr) as the ultimate driver of nitrogen pollution and the many serious adverse effects following from it. Therefore, in this abstract we use farm-gate nutrient budgets from Swedish dairy farms to compare traditional surplus-based indicators for N use efficiency to an alternative indicator based on the total conversion of N_2 to Nr. The alternative indicator accounts for all N_2 conversion associated with the dairy farms, including off-farm use of mineral N fertilizer and biological N fixation for cultivation of purchased feed, in addition to the dairy farms' own on-farm use of mineral N fertilizer and biological N fixation. We then compare the surplus-based indicators to the alternative indicator. What information can they provide? Can they be statistically explained using easily measured farm characteristics? What are the main uncertainties and sources of variability

Method

The full dataset of more than 17,000 farm-gate nutrient budgets collected on around 8,000 farms is provided by the National Advisory Project 'Focus on Nutrients' carried out by the Swedish Board of Agriculture since year 2000. The nutrient budgets were established by advisors during individual farm visits. We analyzed nutrient budgets from 1478 conventional, specialized dairy farms, exporting N primarily in milk and live animals. The selected farms sell little N in crop products, which simplifies our analysis.

Three indicators were calculated for each farm:

1) The farm-gate N surplus, divided by the farm's arable land (kg N/ha),

2) the farm-gate N surplus, divided by sold N in milk, animals and crop products (dimensionless), and

3) the N investment factor (dimensionless), defined as the farm's total N fixation divided by sold N in milk, animals and crop products.

The total nitrogen fixation (TNF) was estimated as the sum of purchased mineral N fertilizer, on-farm biological N fixation, and the off-farm N fixation associated with the cultivation of purchased feed. Based on an analysis of Swedish statistics on N fertilization and yields for common feed crops, we estimated the off-farm N fixation at 1.2 units of N per unit N in purchased feed. Sensitivity analysis was done by varying this factor in the range 1.1-1.5.

When dairy farms export manure, the manure can have both positive and negative effects at the receiving farm: It may cause N pollution, but it can also substitute mineral N fertilizer. We tested two simple methods to correct the indicators for such effects as follows. Indicator 2 was calculated with the N surplus either including or excluding exported manure N. For indicator 3, we decreased the TNF estimate by 0-50% of exported manure N, to reflect that the exported manure may substitute mineral N fertilizer at the receiving farm.

We investigated the variability of indicator values between farms using statistical methods, and explored the impact of uncertainties on the indicators. In addition to the preliminary findings outlined in this abstract, a detailed uncertainty analysis will be presented at the workshop.

Results

The dairy farms' inflow of N was primarily in purchased feed and mineral N fertilizer (about 40% each), around 10% in to biological N fixation, and less than 10% from other sources. The outflow of N was in sold milk and live animals (80%), manure (14%) and crop products (6%). The average values of the three indicators, plus/minus one standard deviation, were as follows: 1) The N surplus was 146 ±46 kg N/ha; 2) The N surplus per unit sold N in products was 3.1 ±1.1 excluding exported manure, or 3.2 ±1.0 including exported manure; 3) The N investment factor was 4.4 ±1.0 assuming exported manure N did not substitute mineral N at the importing farm, or 4.3 ±1.0 assuming it substituted mineral N by 50%.

The two traditional surplus-based indicators vary more (relative standard deviation 31% and 34%) than the N investment factor does (relative standard deviation 23%). Why is it so? It seems like accounting for the off-farm N fixation due to cultivation of purchased feed reduces the difference between farms. Thus, the N investment factor at least approximately accounts for the difference between farms that grow much of the feed on-farm and those that mostly purchase it from other farms.

We did not find any evidence that farms with a large supply of manure use less mineral N than farms with lower supply. The mineral N use per hectare varied significantly (±40%) and seemingly unrelated to the manure supply. In other words, it seems like the average dairy farmer does not fully consider the N in manure when deciding how much mineral N to apply.

The indicators provide different information that can be useful when exploring measures for reducing N pollution associated with dairy farming. For example, farms with high livestock density or high milk yield per cow typically had higher N surplus per hectare than the average farm, but on the other hand, lower N surplus and lower TNF per unit sold N.

While statistical models could predict some of the variation in indicators based on farm characteristics (e.g. livestock density, milk yield), most of the observed variation remains unexplained. Clearly, there is some combination of unobserved management factors, variations in soil and climate factors, and measurement errors, which must all be further studied to support recommendations on how to increase N use efficiency in Swedish dairy farming.

The main uncertainties are related to feed production. N fixation associated with off-farm feed production is uncertain both because the N fixation associated with cultivation of different feed crops is uncertain, and because the composition of purchased feed is unknown. For on-farm feed production, the largest uncertainty is in the estimates of biological N fixation.

Conclusions

The three indicators considered in this abstract provide different information which may be useful when exploring options for reducing the N pollution associated with dairy farms. Depending on whether the primary goal is to reduce local N pollution or to reduce the total system-wide conversion of N2 into Nr, different indicators may be appropriate.

Using statistical models, we could to some extent explain the variation in the indicators based on farm characteristics, but most of the variation remains unexplained. There are many potential reasons for this, which we may broadly categorize as unobserved management factors, unobserved soil and climate conditions, and errors in measurements and models for estimation.

Calculating N indicators based on a large and detailed dataset has several benefits, albeit with significant methodological difficulties. In contrast to model-based studies often based on one or a few typical or average production systems, this approach allows us to study the variability between farms and the correlation structure of indicators and some farm characteristics (e.g., livestock density, milk yield, and cultivated crops). In this way, we can to some extent empirically test and refine the assumptions made in model-based studies. We see a potential for very useful combinations of the two approaches.

Acknowledgements

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References

[1] Steffen et al. 2015. Science, 1259855, pp. 1-10.
[2] Sutton et al. (eds). 2011. The European Nitrogen Assessment. ISBN: 9781107006126.

PREDICTORS OF GROSS NITROGEN PROCESSES IN AGRICULTURAL SOILS: DOES QUALITY MATTER?

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Objectives

Agricultural soils are vital for a multitude of life-supporting ecosystem services, e.g. nutrient cycling, food supply, biofuel production and climate regulation encompassing carbon (C) sequestration. Understanding C and nitrogen (N) cycling in arable soils is crucial to establish sustainable agricultural production. Previously, it has been suggested that bulk soil N and C mineralization can be used as predictors of gross N processes in soils that received different amounts of past organic matter inputs. However, less is known on how differences in quality of past inputs affect the relationship between nutrient cycling, soil microbial communities and their functioning. The aim of this study was to determine if and how the quality of long-term past organic matter inputs affect C and N dynamics, their relation to soil microbial community composition and functional diversity.

Method

Soil samples were taken from the Ultuna Long-Term Soil Organic Matter Experiment (Uppsala, Sweden) which started in 1956 on a post-glacial clay loam. Since then, soils have been treated with different nitrogen fertilizers and organic amendments. For this study, soil treatments were selected with similar levels of C input, but of different quality: (i) green manure, (ii), straw, (iii) straw+N, (iv) farmyard manure, (v) peat, (vi), peat+N, (vii) sawdust, (viii) sawdust+N, (ix) sewage sludge. Gross N processes (i.e. mineralization, immobilization and nitrification), microbial community composition and functional diversity profiles were assessed using the ^{15}N isotope dilution technique, phospholipid fatty acid and multiple-substrate induced respiration, respectively. The chemical composition of soil organic matter was estimated using visible and near-infrared spectroscopy (vis-NIR) on whole soils, and Fourier-transform ion-cyclotron-resonance mass-spectrometry (FT-ICR-MS) was used to characterize organic matter in water extracts. Multi-variate statistics (principal component analysis, Mantel-test etc.) was used to describe the effects of differences in quality of past inputs on gross N processes, the relation between microbial diversity profiles and the chemical composition of soil organic matter.

Results

Except for the peat amended soil, bulk soil N was an appropriate predictor for gross N mineralization in soils with different quality of past organic inputs. Also, C mineralization was an appropriate predictor for gross N immobilization except for soils amended with peat or sewage sludge. Thus, soils amended with peat or sewage sludge require further predictors for evaluating nutrient cycling in these systems. Sewage sludge amended soils contained relatively more Gram-positive bacteria and fungi, and gross N mineralization rates were negatively correlated with the 2nd principal component axis of the microbial community profiles ($P<0.001$). Furthermore, functional diversity profiles were significantly different in sewage sludge and peat amended soil treatments in comparison to the remaining treatments: Microbial communities residing in peat and sewage sludge amended soils preferentially used C substrates with either a negative or positive nominal oxidation state of carbon (NOSC). The other seven treatments preferentially used C substrates with a neutral NOSC such as e.g. carbohydrates, and gross N mineralization was positively correlated with the 1st principal component of microbial functional diversity profiles ($P<0.001$). These differences in functional diversity profiles maybe due to differences in the chemical composition of soil organic matter (e.g. peat has a higher C-to-N ratio and aromatic composition of soil organic matter in comparison to the other treatments). Currently, we are examining the chemical composition of organic matter using vis-NIR and FT-ICR-MS, and the outcomes of these analyses will be related to microbial community composition, their functioning and nutrient cycling.

Conclusions

This study confirms that bulk soil N and C mineralization can be used as predictors for gross N mineralization and immobilization, respectively. The quality of soil organic matter, microbial community composition and/or functional diversity profiles need only to be taken into account when unconventional organic amendments (e.g. peat or sewage sludge) are applied to soils. Significant relationships were found between the microbial community composition, functional diversity profiles as well as C and N dynamics in soils. More explicit testing is required on how to include the soil biota and/or organic matter chemistry when bulk soil N and C mineralization are not sufficient predictors for gross N processes. We will discuss the importance of past organic amendments in shaping the relationship between gross N processes, the composition of microbial communities and their functioning. The implications of various soil management systems on ecosystem services will be evaluated.

LONG TERM (35 Y) EFFECTS OF MANURE AND FERTILIZER-N APPLICATION ON N BALANCE IN SOIL, CROP YIELD AND N UPTAKE EFFICIENCY

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Objectives

Long term application of fertilizer-N and manure may change soil fertility, crop yield, N uptake efficiency and nitrate leaching to underground water. Our objectives were to quantify those effects in a long term (35 y) permanent plots experiment carried out in typical arid zone (<250 mm rain) soil, and suggest fertilization and manuring regimes that may lead to reduced aquifer pollution by nitrate and yet sustain crop yield and soil fertility.

Method

The Permanent Plots Experiment is located at the Gilat Experiment Station in Israel (35°E, 30°N). The soil is loessial (Typic Haplargid) with pH 7.9, 16% lime, cation exchange capacity 110 mmol(c)/kg, soil organic matter C/N ratio 12, soil density increasing from 1.25 kg/L in top soil to 1.6 kg/L at depth of 4 m. The experiment started on 1960, and comprises 4 mineral-N x 4 manure treatments, replicated 6 times in random blocks. The manure treatments entailed control, 2 levels of standard cattle manure, and 1 level of city refuse compost. All treatments received identical P and K doses and same irrigation rate. The irrigation was applied to replenish class A pan evaporation (Ev_a) multiplied by a time dependent crop coefficient. Until 1984 irrigation was done by sprinklers and later on by drip fertigation. The major crops, grown over 35 years in rotation were corn, cotton, onion, carrot, potatoes, processing tomatoes, pepper, lettuce, broccoli, celery, Chinese cabbage and muskmelon. The time averaged monthly mean air temperatures in January to December were 11, 13, 16, 21, 24, 29, 32, 29, 25, 18 and 13°C, respectively. Dry matter (DM) was used to estimate transpiration (T) in treatment i ($T_i = T_{max}\ DM_i/DM_{max}$) where T_{max} was evaluated as 0.5 Ev_a and DM_{max} is DM in the treatment that gave maximum yield in a specific year. The annual mineralization (N_{min}, g/m^2) was calculated from 2 organic-N pools: the soil indigenous organic-N (SON) and manure organic-N (MON): N_{min} = 0.02 SOM + 0.15 MON. It was assumed that the MON pool that was not mineralized in 1 year became SON, and 5% of the N consumed by plants returned to the soil as SON. The water head available for solute leaching (L) was calculated according to: L = I + R - T - E where I and R are annual irrigation and rainfall rates, and T and E cumulative transpiration and annual evaporation from the soil, respectively. The E was estimated as 120 mm/y.

Results

We focus on 4 treatments: MoNo (no manure, no mineral-N), MoN3 (no manure, 789 g mineral-N/m^2 in 34 y), M2No (765 g organic-N/m^2, no mineral N) and M2N3 (765 g organic-N/m^2, 789 g mineral-N/m^2).

The cumulative total DM yields in the 4 treatments were 9.6, 21.5, 19.4 and 25.3 kg/m^2, respectively. The treatment effects were consistent along the experiment, and no significant changes in soil chemical or physical properties were observed. Due to the differential DM production, the cumulative water head available for solute leaching differed too and were 13.7, 8.5, 9.6 and 7.3 m, respectively.

The difference between the cumulative mineral N added to soil (fertilizer + mineralized) and N uptake by plants (NA-NU) in treatments MoNo, MoN3, M2No and M2N3 were 12, 542, 65 and 665 g N/m^2. The DM production in treatment M2N0 was slightly lower than in treatment MoN3 (19.4 vs. 21.5 kg/m2) but its potential N leaching was much smaller (65 vs. 542 g N/m^2). The NU:NA ratio is the long term crop N uptake efficiency. In treatment MoNo the uptake was 140 g N/m2 and since no N was added, it indicates the long term soil mineralization power (~4 gN m^{-2}y^{-1}). In treatment MoN3 the NU was 406 g/m^2 and NU:NA 0.51. This ratio is the N uptake efficiency when N was supplied solely as fertilizer. In treatment M2N0 (all N supplied as manure) the NU was 343 g N/m^2 and NU:NA 0.45. In treatment M2N3 the NU was 523 g N/m^2 and

NU/NA 0.34.

The mineral-N (NO_3 + NH_4) that was found in the 0-120 cm soil layer at the end of the experiment in treatments MoNo, MoN3, M2No and M2N3 were 12, 13, 35 and 42 g N/m2, respectively. The mineral-N did not accumulate in the soil because of leachhing. Organic-N in the 0-40 cm soil layer increased between 1963 and 1987 from 280 to 290, 310, 470 and 442 g N/m2 in treatments MoNo, MoN3, M2No and M2N3, respectively. Simulating the organic-N buildup by the aforementioned model gave reasonable agreement in treatments M2No and M2N3 but in MoNo and MoN3 it underestimated the empirical results because a larger quantity of plant residue was incorporated in soil than assumed in the model.

Solute leaching depth (IL, g/m^2) was estimated by the mass balance equation IL = IA - IU - IS (IA = cumulative addition to the soil; IU = cumulative crop intake; IS = quantity accumulated in the 0-420 cm soil layer. The estimated IL values in treatments MoNo, MoN3, M2No and M2N3 were -124, 437, -2, 557 g N/m^2.

Conclusions

Replacing fertilizer-N by manure-N under controlled irrigation and sufficient N supply had long term beneficial effect on reducing underground water pollution and minor adverse effect on crop yield. Plants producing high DM yield had less water available for leaching and hence the long term solutes displacement depth was shallower than in plants producing low DM yield.

The 35 years of cultivation had negligible effect on the crop response to studied treatments; the treatments had negligible long term effect on soil mineralogy and physical properties. The soil organic-N (SON) increased with time in all treatments according to their N dose; the annual mineralization of SON was 4 g N/m^2.

AGRICULTURAL MANAGEMENT AFFECTS BELOW GROUND NITROGEN AND CARBON INPUTS – A SYNTHESIS OF EIGHT YEARS ROOT RESEARCH IN SWISS LONG TERM EXPERIMENTS

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Objectives

Crops release nitrogen (N) and carbon (C) below ground via roots and rhizodeposition. Agricultural management intensity directly affects above ground biomass production in terms of differing crop yields. However, little is known about how management influences below ground N (BGN) and C (BGC) inputs of different crops on field scale. Scientific models use constant factors estimating below ground inputs by above ground biomass production, e.g. [1]. In contrast, we hypothesise i) decreasing below ground inputs with increasing management intensity and above ground biomass production, ii) correspondingly a decreasing ratio of below ground : above ground inputs and iii) we expect a higher proportion of rhizodeposition with decreasing management intensity. Here, we show unpublished field data of below ground N and C inputs from several projects performed from 2008 to 2015 in two long term experiments in Switzerland for soybean, red clover (in clover grass-ley), oilseed rape, maize and wheat.

Method

Field experiments were carried out in the two Swiss long-term field experiments “DOK” south of Basle (CH) where organic and conventional cropping systems at two fertilisation levels are compared (start 1978, [2]), and the conventionally managed “ZOFE” (Zurich Organic Fertilisation Experiment) where organic and mineral fertilisation treatments are compared (start 1949, [3]). In both experiments, we selected treatments according to an increasing management intensity along a fertilisation gradient: zero (NON), bioorganic half (ORG1), bioorganic full (ORG2), conventional mixed farm (CONFYM2), and conventional mineral fertilisation (CONMIN2) on the DOK site and zero (ZERO), manure (MAN), half mineral (NPK1) and full mineral fertilisation (NPK2) on the ZOFE site according to Swiss regulations.

Crops were grown in the field in microplots (plastic or steel tubes inserted to 25 and 50 cm soil depth, respectively) and ^{15}N and / or ^{13}C multiple pulse labelled with cotton wicks (soybean: ^{15}N urea, ^{13}C glucose), leaf-feeding (red clover: ^{15}N urea) and atmospheric application (maize, wheat, oilseed rape: $^{13}CO_2$). At maturity, and for red clover at the end of each vegetation period in two subsequent years, soil columns were excavated and separated into visible roots and soil. Soil was then wet sieved through a 0.5 mm mesh yielding in remaining fine roots and “root free” soil. Roots, fine roots and remaining soil were analysed for ^{15}N and / or ^{13}C enrichments. Rhizodeposition comprises all components released from the living root to the soil by the living crop and is defined here as remaining N and C in the soil after removal of fine roots. N and C derived from rhizodeposition (NdfR, CdfR) was calculated according to [4]. BGN and BGC is the sum of roots and rhizodeposition.

Results

Above ground biomass followed the expected pattern and increased with increasing management intensity. Above ground red clover N in the DOK in treatment NON was 42% of ORG2 which achieved the highest red clover yield. CONMIN N uptake achieved only 82 % of ORG2, due to a suppression of clover by mineral N fertilisation. For soybean, N and C uptake of NON achieved 57% of CONMIN2 in the DOK. For maize, C in ORG1 achieved 53% of CONFYM2 in the DOK and in the ZOFE ZERO achieved 50% of NPK2. Wheat above ground C uptake in the ZOFE in treatment ZERO was only 21% of NPK2.

BGN for red clover in the two years of clover-grass ley followed the pattern of above ground clover N uptake. In the first year of cultivation, root N increased with above ground N. Nitrogen derived from rhizodeposition as proportion of BGN was constant between treatments. However, in the second cultivation period root N decreased with increasing BGN due to an accelerated root turnover and an increasing NdfR pool. In contrast to red clover, the annual crops showed constant root N and C inputs over all treatments. For soybean, NdfR and CdfR increased with decreasing management intensity whereas for maize, wheat and oilseed rape CdfR inputs did not differ significantly between treatments on both sites resulting in constant BGC inputs and constant proportions of rhizodeposition related to BGC inputs. However, due to large differences in above ground biomass production, the ratios below ground N and C to above ground N and C (N_b:N_a; C_b:C_a) differed in a wide range: For soybean, N_b:N_a ranged between 1.6 (NON) to 0.6 (CONFYM2) and C_b:C_a between 2.2 (NON) to 0.5 (CONFYM2). For maize, C_b:C_a ranged between 0.42 (ORG1) and 0.24 (CONFYM2) in the DOK and 0.35 (ZERO) and 0.19 (NPK2) in the ZOFE. Wheat C_b:C_a in the ZOFE ranged from 0.78 (ZERO) to 0.18 (NPK2) and oilseed rape C_b:C_a in the DOK from 0.54 (ORG2) to 0.34 (CONFYM2). Below to above ground ratios of the remaining treatments were in between.

We calculated linear regression models using normalised data of fertiliser inputs (relative deviation from mean fertiliser input of NPK) and related it to below to above ground ratios. For annual crops, we found a strong linear relationship between fertilisation intensity in our long term experiments and the N_b:N_a and C_b:C_a ratios, respectively. Linear regression coefficients (R^2) ranged between 0.82 and 0.97.

Conclusions

Below to above ground N and C ratios of annual crops are strongly affected by management intensity. This could not be found for red clover below ground N inputs, which were inconsistent over time.

Using constant below to above ground N and C ratios as proxy for below ground inputs in scientific models leads to an overestimation of N and C inputs for high intensity management and underestimates inputs for low intensity management for the investigated annual crops.

References

[1] Bolinder et al., 2007. Agriculture, Ecosystems and Environment, 118, 29-42.

[2] Mäder et al., 2002. Soil fertility and biodiversity in organic farming. Science 296, 1694-1697.

[3] Oberholzer et al., 2014. Journal of Plant Nutrition and Soil Science, 177, 696-704.

[4] Janzen and Bruinsma, 1989. Soil Biology Biochemistry 21,189-196.

URBAN AND AGRICULTURAL WASTE APPLICATION AFFECTS NITROGEN TURNOVER, CROP UPTAKE EFFICIENCY AND SOIL FERTILITY IN LONG-TERM FIELD EXPERIMENT

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Objectives

Currently, the demand for nutrient inputs in agricultural system is growing. In parallel, the production of urban, agricultural and industrial organic wastes is increasing worldwide. These organic wastes contain significant amount of organic matter and nutrients and their use in agriculture can potentially contribute to closing the natural ecological cycle. Long-term experiments are most suitable to evaluate the effects of organic wastes application on soil fertility; N turnover and crop N availability in order to optimize overall N use efficiency from their application. The aim of this study was to evaluate the improvement of overall soil fertility and soil N supply capacity in a long-term field experiment with continuous application of different urban organic and agricultural waste amendments.

Method

We used data and soils from the long-term CRUCIAL field experiment (Denmark) [1]. This field trial has run in its present form since 2003 and includes 11 treatments with 3 replicate plots in a randomised block structure. The treatments included are human urine (HU), sewage sludge (S), composted organic municipal waste (CH), cattle deep litter (DL), and cattle slurry (CS); for some of these two different application rates were included, normal (around 100 kg available N ha-1 year-1) (S, CH and CS) and accelerated (three times the normal N levels) (SA, CHA and CMA (cattle manure). Three additional control treatments, a positive in the form of NPK fertiliser (NPK) and two negative in the form of no chemical or organic fertilisers but with a clover undersown as a green manure every autumn (UC) and a completely non-fertilised (U). Soil was sampled in March 2014 to ensure that there were minimal effects of the most recent fertilisation in (April 2013) and were analysed for pH (1:5 ratio soil:distilled water (w:w)) and water content at a tension of 10 (pF1) and 100 cm water column (pF 2) using a sandbox soil water equilibration system. Dried and ground soils and organic samples (subsamples from those applied in 2013) were analysed for total C (TC) and total N (TN) using an elemental analyser. The contents of NH_4^+ and NO_3^- were analysed in soils and organic wastes by flow injection analysis. Net N mineralisation and CO_2 and N_2O emissions of the different soils were estimated with an aerobic incubation during 42 days, whereas gross mineralisation was measured using ^{15}N isotopes dilution experiment described by Andersen and Jensen [2]. In both cases the inorganic N was extracted with 1M KCL (1:4; soil:KCL) and analysed for NH_4^+ and NO_3^- and ^{15}N. Crop yield and N uptake were calculated for 2003 and 2013.

Results

The application of organic wastes during 11 years has affected soil properties. The water retention and TC were between 6-25% and 2-10% higher in soil fertilised with DL, CS, S and CH compared to U and UC. These evidences support that the organic waste application improves soil physical fertility through the increase of organic matter in soil, which improves aggregates stability and water holding capacity. The fertilisation with HU and CS resulted in similar TN content than NPK and unfertilised treatments (U and UC), although these organic wastes contain significant amount of inorganic N (100 and 46 % of the TN, respectively), suggesting that most of the N is available immediately after their application and moreover may be more susceptible to losses by leaching. By contrast, the fertilisation with CMA, S, SA, CH and CHA increased TN by 32, 13, 23, 42 and 131 %, respectively, compared to the NPK treatment. Soil from CHA was estimated to be the highest net IN increase (91% higher than in NPK soil) and the gross mineralisation was twofold the gross immobilisation in NPK, confirming a relatively high microbial activity in compost amended soils. This was not true for the normal compost application rate (CH), suggesting that higher rate of compost application is needed to increase N availability. Sludge (S and SA) fertilisation increased the net IN increase by 40 and 50 %, respectively, compared to the NPK soil, rather similar in spite of the large differences between the rates of application. In spite of the high rate of N application with CMA, the residual N was only 30% higher than in NPK soils, whereas the much lower CS application raised the net IN increase by 40 % compared to the NPK soil. All manures, sludges and compost treatments showed similar C mineralisation relative to inputs, suggesting that as the labile C is assumed to be lost very quickly after field application, the remaining and less easily decomposable C compounds have similar rates of decomposition, and furthermore the potential to increase C accumulation is soil is very similar. After 11 years of continuous fertilisation with organic wastes the yield and N uptake were more than twofold higher than those observed in U or UC. The repeated addition of organic wastes to soil supplies nutrients and enhances the organic carbon pool, which increases crop yield. In soils from NPK, HU, CS, CMA, S, SA and CHA the NUE in 2013 increased to 88, 73, 55, 21, 51, 27, 11 and 6 %.

Conclusions

The repeated application of different organic wastes to soil has improved soil physical fertility by increasing of organic matter in soil, which in turn has improved water holding capacity. Although the application of organic waste may not results in a high short term N availability, due to a high proportion of N bound in organic compounds, the continuous application of organic wastes increased the available N pool and the overall N-use efficiency.

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References

[1] Magid, J., Luxhøi, J., Jensen, L.S., Møller, J., Bruun, S., 2006. Long-term Field Experiments in Organic Farming. International Society of Organic Agriculture Research (ISOFAR), Verlag Dr. Köster, Berlin, pp. 59-78.
[2] Andersen, M. K., Jensen, L.S., 2001. Soil Biology and Biochemistry, 33, 511-521.

ESTIMATING NITROUS OXIDE FLUXES FROM AGRICULTURAL SOILS AT EUROPEAN SCALE USING A CROP GENERIC META-MODEL

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Objectives

The agricultural sector in the EU is challenged to secure food production while simultaneously reducing environmental impacts, including greenhouse gas (GHG) emissions. Nitrous oxide (N_2O) emissions are still one of the most uncertain GHG sources, implying a need to improve regional scale estimates. There is thus a need to design a flexible comprehensive modeling framework that allows to calculate N_2O fluxes within EU27 at different scales in a consistent way, considering that data variability is very high and expensive to measure. The aim of this project is to develop a meta-model to predict N_2O emissions at European scale in response to agricultural practices. Meta-models are faster and use less resources than a process-based model, allowing fast scenario analysis relevant for a policy decision tool. This meta-model was developed from a detailed and spatially integrated dataset based on the process-based DNDC model at EU level, and included 17 types of crops.

Method

The meta-model consisted of statistical relationships between annual N_2O emissions and multiple input variables affecting those emissions (climate, crop, soil, management practices), based on simulation results obtained with the process-based model DNDC-EUROPE [1]. The data base that was used contained simulated N_2O fluxes from agricultural soils for almost 200,000 spatial calculation units in EU 25 for the period 1990-2000 using downscaled data on land use and farm management, including N fertilizer and N manure inputs (reference scenario). After data cleaning and processing, our database consisted of 52 input variables and 1,465,579 observations.

The meta-model was developed using a Random forest approach, which is a machine learning method [2] and works by assembling classification or regression trees. In this study, we used the VSURF (Variable Selection using Random Forest) package [3] in the R computing environment.

The meta-model was evaluated in two ways. First, we compared its performance with the results of DNDC. Therefore, we evaluated the prediction ability with a data set of DNDC simulations not used to train the meta-model. To do so, we partitioned our observations into 80% for the training set (1,172,615 observations) and 20% for the validation set (293,154 observations). Due to the large size of the training set we selected 4 random samples of 10000 observations to run VSURF. We excluded georeferenced variables, keeping only input variables related to biophysical data (10), management practices (16) and crop morphological parameters (18). The algorithm built the meta-model by selecting the main variables and ranking them according to their importance. We selected the sample with the best mean square error (MSE) and validated it with the test set. We then ran the meta-model in the whole dataset and calculated mean values of N2O emissions for crops and countries. Secondly, we analyze if the selected variables affecting N_2O emissions in the meta-model were plausible in view of current knowledge. For this we focused on analyzing the selection and ranking of variables in the three different steps of the algorithm (selection, interpretation and prediction) and compared our findings with other studies [4,5,6].

Results

The meta-model appeared to perform satisfactory on the test set as the R^2 was 69% and the NRMSE was 55%. Note that the test set was 30 times bigger than the training set to evaluate the prediction (see methods). When the meta-model was applied to all the observations, the performance was consistent with the test set validation (R^2 =69%). The correlation between the predicted and DNDC simulated annual N_2O emissions was 83%. The meta-model calculated a mean annual N_2O emission (in kg N_2O-N ha^{-1} yr^{-1}) equal to 3.8 (0.08 min, 33.35 max) for the whole dataset and it varied from 1.50 in Greece to 15.16 in Finland. In comparison, the original DNDC simulations calculated a mean annual emission of 3.74 (0.00 min, 40.00 max), and it varied from 1.21 in Greece to 15.78 in Finland. When considering the emissions by crop by the meta-model, we observed that the mean annual N_2O emission (in kg N_2O-N ha^{-1} yr^{-1}) was 3.8 and it varied from 1.8 for alfalfa to 6.7 for rye.

All variables related to biophysical inputs (10) were included in the meta-model and in each of the 4 runs with 10,000 samples, they were consistently ranked on top among the samples. The ranking between management practices (5 selected out of 16) and crop management (5 out of 18) were exchanging positions in the order of the rank in the lower half of variable selection for prediction.

The core variable selection in each of the 4 runs is in accordance with the general consensus of the key drivers leading to N_2O emissions, in terms of soil conditions, i.e. soil organic carbon (SOC) and nitrogen contents, clay fraction and soil pH, and climate conditions, i.e. annual average temperature[5,6,7]. However, N input, and in particular mineral Fertilizer input was found to have lower importance for N2O fluxes. Other studies [4,6] also reported a low ranking of importance for N fertilizer application in their meta-models. Villa Vialaneix et al. [4] reported that N input was ranked higher on predicting N Leaching but lower when estimating N_2O, for which SOC and pH were the most relevant variables. Perlman et al. [6] found that N input ranking varied among crops but overall SOC had the strongest impact on N_2O emissions. Further assessment is required to understand the effect of co-variance with other input variables, and the importance of extreme values (e.g. related to SOC) on the ranking/selection of main predictor variables.

Our meta-model included 17 crops and some of its morphological parameters were included in the selection for prediction. This information could be useful to explore agronomic adaptations to future climate scenarios.

Conclusions

The preliminary results of this research indicate the construction of robust meta-model that is able to effectively predict N_2O fluxes at the European scale based on DNDC simulations. It has the potential to become a reliable and effective tool with lower computational costs and adequate accuracy. Since our meta-model included 17 crops and some of its morphological parameters, it could be useful to explore agronomic adaptations to future climate scenarios.

References

[1] Leip, A., Busto, M., & Winiwarter, W. 2011. Environmental Pollution 159(11), 3223-32.

[2] Breiman, L. 2001. Machine Learning 45, 5-32.

[3] Genuer, R., J. -M. Poggi, C. Tuleau-Malot. 2010. Pattern Recognition Letters 31 (14), 2225-2236.

[4] Villa-Vialaneix, N., Follador, M., Ratto, M., & Leip, A. 2012. Environmental Modelling & Software, 34, 51-66.

[5] Philibert, A., Loyce, C., & Makowski, D. 2013. Environmental Pollution (Barking, Essex : 1987), 177, 156-63.

[6] Perlman, J., Hijmans, R. J., & Horwath, W. R. 2014. Global Ecology and Biogeography, 23(8), 912-924. doi:10.1111/geb.12166

[7] Skiba U, Smith KA. 2000. Chemosphere Global Change Sci 2, 379-386

N_2O EMISSIONS FROM ORGANIC FERTILIZERS AND CROP RESIDUE MIXTURE IN SUGARCANE CROPPING

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Objectives

A wide range of organic sources of N are available for fertilization and amendment. Compared to mineral fertilizers, organic by-products deriving from livestock, industrial and municipal sources, are less expensive and can contribute to climate change mitigation through C sequestration[1-3]. Organic fertilization addresses the rising cost of mineral fertilizers, waste management issues and promotes circular economy. Sugarcane cropping is a good candidate for organic fertilization. Nevertheless, little is known about greenhouse gas (GHG) production from soils receiving both organic fertilizers with variable physicochemical structure and the quantity of crop residues. We aimed to investigate (i) nitrous oxide (N_2O) emissions from nitisol, fertilized with liquid pig manure (LPM), solid sewage sludge (SS) and urea (U), and (ii) the potential mineralization interactions between sugarcane mulch quantity and these N sources.

Method

The experiment was conducted on SOERE PRO (http://ur-recyclage-risque.cirad.fr/en/principaux-projets/soere-pro-la-reunion) experimental station at La Mare (Sainte-Marie), Reunion island (20°54'12.2"S 55°31'46.6"E). This zone is characterized by tropical climate, high clay content nitisol (WRB-FAO), and 1650 mm annual rainfall. The treatments included liquid pig manure (LPM), solid sewage sludge (SS) and urea (U) at 174, 118, and 161 kg N ha-1, respectively. For each type of fertilization 3 replicates were realized. Two quantities of mulch were also tested: 10 t DM.ha-1 (M) which was the mean amount of mulch after sugarcane harvesting, and 5 t DM.ha-1 (0.5M), on LPM and U treatments. Results were collected through 11 sampling occasions from 5 days before and up to 49 days after sugarcane harvesting.

Gas sampling was inspired by a static-opaque chamber method [4, 5]. Homogenized atmosphere was sampled at chamber closure, 30 and 60 minutes after. Gas was aspired in a syringe tank of 20ml (BD Discardit II). The entire tank content was introduced into a vacuum vial of 12ml (Labco Exetainer ®). N_2O concentrations were determined by gas chromatography with electron capture detector (GC-ECD Varian 3800).

Mean N_2O emissions per treatment were calculated on hourly basis (g $N_2O.ha^{-1}.h^{-1}$). Results are also presented as a relative N_2O emissions over U-M control treatment. Temporal trends were monitored through mean emissions per sampling occasion (n=3). A linear regression was performed between mean N_2O emissions and N inputs and the slope value enabled a comparative estimation of emission rates.

Results

Mean emissions over the period from SS-M plots were 0.34 g $N_2O.ha^{-1}.h^{-1}$ which was half as high as U-M (0.65 g $N_2O.ha^{-1}.h^{-1}$) and similar to U-0.5M (0.36 g $N_2O.ha^{-1}.h^{-1}$). LPM-M emitted the highest amount of N_2O with 1.51 g $N_2O.ha^{-1}.h^{-1}$, while LPM-0.5M emitted 0.85 g $N_2O.ha^{-1}.h^{-1}$. Moreover, compared to control treatment (U-M), SS-M and U-1/2M emitted 48% and 45% less, respectively. LPM-M and LPM-0.5M emissions exceeded U-M by 133% and 32% respectively. The different fertilizers showed different temporal trends during 49 days after N input. Highest emissions from LPM plots were observed essentially within the first 9 days after fertilizer input, for both M and 0.5M treatments. Two weeks after LPM input until the end of the experiment, N_2O emissions were similar irrespective of mulch quantity. On the contrary, urea addition expressed highest emissions between the 7th and the 14th day after input. However, N_2O emission peaks were observed only for M treatment. Measured emissions from U-0.5M were relatively constant over the period. Highest emissions from SS-M treatment were reached at day 2 and 7 after SS input. N_2O emissions, occurring immediately after fertilization were stimulated by higher mulch quantity (M) and liquid organic fertilizer (LPM). Contrariwise, N_2O emissions from plots with solid organic fertilizer (SS-M) were relatively steady, depending probably on soil moisture condition. Indeed, in addition to the physical state of applied fertilizer, water conditions might influence emissions events. We hypothesize that especially for solid fertilizers, as SS and U, peaks of N_2O emissions are driven by soil moisture state, as the denitrification process occur in anoxic conditions. As a liquid fertilizer, LPM promoted denitrification immediately after addition. For M treatments, a linear relation (R^2 0.71) was found between N inputs and N_2O emissions over the period. Accordingly, the initial amount of N input is assumed to be the principal driver of N_2O production. Nevertheless, the emission rates varied between M and 0.5M. M treatment enhanced emission rates and magnitude compared to 0.5M, which is in accordance with recent findings [6]. Our work confirms those findings, but also quantifies an emission rate of 1.7 higher for M compared to 0.5M, independently of fertilizer type (U or LPM). Interactions between both factors, mulch quantity and fertilizer type may exist, since SS and U emissions were similar for two different mulch quantities (M and 0.5M). The physical state of organic fertilizer and the chemical form of N should influence N accessibility [7, 8], and therefore the emission factor.

Conclusions

In this work we aimed to evaluate nitrous oxide (N_2O) emissions from different N sources (urea, liquid pig manure and solid sewage sludge) at variable application rates. Over 49 days after fertilization, mean N_2O emissions varied between treatments. Our results suggest a relation between mulch quantity and N_2O emissions rate. However, the rate is disproportional to mulch quantity. Emissions magnitude was found to be related to added N independently of fertilizer type (urea or liquid pig manure). Thus, more mulch stimulates the magnitude of N_2O emissions, while depressing the rate of N_2O emissions. N input amount controls the emission magnitude.

We demonstrated that substituting urea by organic N sources may affect N_2O emissions in coupled systems of N input (mulching and organic fertilization). The variations of N_2O emissions may refer to different N qualities, depending on type of organic fertilizer (+/- inorganic N content). Moreover, liquid organic fertilizers seem to stimulate N_2O emissions immediately after input, while denitrification from solid N sources might be driven by soil moisture state. Addressing these questions is necessary for quantifying the impact of N quality and fertilizer physical state (liquid or solid) on N_2O emissions from various organic N sources.

A NEW APPROACH TO ESTIMATE NITROUS OXIDE EMISSIONS FROM ARABLE CROPS IN THE UNITED KINGDOM?

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Objectives

In Northern Europe most arable crops receive significant amounts of manufactured nitrogen (N) fertilisers, which can be associated with large losses of the greenhouse gas (GHG), nitrous oxide (N_2O). The UK GHG inventory, and commercial GHG accounting procedures, calculate N_2O emissions using non-UK specific methods e.g. the standard methodology defined as Tier 1 by the Intergovernmental Panel on Climate Change (IPCC) 2006. Thus the aims of a recent research project, 'Minimising nitrous oxide intensities of arable crop products (MIN-NO)', were to measure and model N_2O emissions associated with production of major UK arable crops (cereals, sugar beet, oilseeds, pulses) and their products, and then to devise and explore 'smart' emission factors (EFs), based on the findings of the project, so as to improve the accuracy of the UK's GHG inventory and commercial GHG accounting (carbon foot-printing).

Method

A UK evidence-base relating to cereals, oilseeds, pulses and sugar beet was collated from:

1. Data on emissions from fertiliser manufacturing collated by 'Fertilizers Europe' on behalf of the fertiliser industry (Brentrup & Pallière, 2008, *Proceedings of the International Fertiliser Society*, 639).

2. Existing UK data on N partitioning by crop species (to improve estimates of crop residues)

3. Data generated by the MIN-NO Project (Sylvester-Bradley *et al*., 2015, *AHDB Cereals & Oilseeds Project Report* No. 548) including:

a. Twenty-four field experiments (located in central & eastern England, and in central Scotland) testing effects of fertiliser N rates on direct N_2O emissions and crop yields

b. Empirical modelling of MIN-NO site experimental data (direct N_2O emissions) and extrapolation of MIN-NO model predictions to the National scale using spatially referenced activity data.

c. Three field experiments testing effects of leguminous N fixation, and crop residue removal, on direct N_2O emissions.

4. UK-related literature relating in particular to:

a. Nitrate amounts leached from UK arable land as estimated by Cardenas *et al*. (2013, *Atmospheric Environment* , 79, 340-348)

b. Ammonia volatilisation following the application of N fertilisers (Chambers & Dampney, 2009, *Proceedings of the International Fertiliser Society*, 657)

5. UK and wider literature describing how incorporation of crop residues and leguminous crops affects soil mineral N.

A set of UK-specific 'smart EFs' was then developed and its predictions of national N_2O emissions and arable crop GHG intensities were compared with predictions using Standard EFs based on default Tier 1 EFs from the IPCC 2006 methodology and from Brentrup & Pallière (2008).

These ‘smart’ EFs were explored in the knowledge that in the future there would be further analysis using a wider data set before new EFs could be formally adopted for UK use. The ‘smart’ EFs were developed with varying levels of provenance, e.g. some are based on few observations, thus they were not intended for direct adoption, either for national inventory reporting or for carbon foot-printing; rather, they were intended as the best current summary of UK-related evidence on arable N_2O emissions.

Results

New ‘smart’ UK emission factors (or coefficients) were derived in five areas:

1. Fertiliser manufacturing emissions: Total GHG emissions associated with ammonium nitrate (AN) fertiliser manufacturing (in European facilities) were abated from 6.31 to 3.52 kg CO_2e kg^{-1} N.

2. Direct soil N_2O emissions due to AN fertiliser use: Modelling of data from MIN-NO experiments gave a current best estimate for direct soil N_2O-N emissions due to applications of AN fertiliser in arable cropping at a national UK level of 0.46%; about half the default value of the 2006 IPCC Tier 1 EF (1%). Furthermore, significant variation with rainfall and soil type offered scope for adjustment according to location.

3. Indirect soil N_2O emissions arising from *ammonia* (NH_3) emissions due to AN fertiliser use: The fraction of applied fertiliser N lost as NH_3 through volatilisation was reduced from the IPCC Tier 1 default of 10% to the average of UK AN experiments of 3%. Since the same climate and soil conditions were applicable to fertiliser N as to re-deposited NH_3-N, both were taken to have the same EF i.e. 0.46%.

4. Indirect soil N_2O emissions arising from *nitrate* (NO_3) emissions: The relationship between N applied and N leached has been shown to have a significant intercept and to be non-linear; consequently it was considered best to associate the quantity of N leached with the crop type, soil type and over-winter rainfall rather with than the amount of N applied as N fertiliser (assuming recommended fertiliser applications) or in crop residues.

5. Direct soil N_2O emissions due to incorporation of crop residues: The default value for the 2006 IPCC Tier 1 method and many GHG accounting studies assume that 1% of N in incorporated crop residues will be emitted directly as N_2O. Since short-term mineralisation only tends to result where N in incorporated crop residues exceeds 2% of dry matter, this EF was only retained where incorporated residues were 'green' (e.g. sugar beet leaves, cover crops). The IPCC 2006 EF of 1% was not applied where crop residues were considered 'dead' (<2%; e.g. 'dead' cereal straw, most roots). Such residues would be considered to contribute to the new background EF (see below). However, results indicated that N_2O may be emitted during decomposition of 'live' root nodules. Thus, a smart EF of 0.8 kg N_2O-N ha^{-1} was proposed for any legume crops remaining 'alive' at harvest (e.g. vining peas, leguminous cover crops).

A new 'background' EF of 0.69 kg N_2O N ha^{-1} of arable land $year^{-1}$ was derived (UK weighted average) from the emissions observed in experimental treatments having no fertiliser N. This may be considered as 'replacing' the emissions attributed by IPCC to dead crop residues.

Conclusions

A set of 'smart' EFs has been devised for consideration by UK stakeholders, based on experimental and modelling results from the MIN-NO project, and from associated evidence. The 'smart' EF for direct emissions after N fertiliser application predicted a decrease in total emissions from UK agriculture of almost 10% compared to the current inventory. The GHG intensity of UK feed wheat (CO_2e emissions per tonne) estimated for commercial purposes with the 'smart' EFs was 20% less than the 'benchmark' GHG intensity using a current default methodology. The 'smart' EFs also lowered GHG intensity estimates of harvested rapeseed, gave similar intensities of sugar beet and increased intensities of vining peas. In calculations using 'smart' EFs, biofuels made from N-fertilised crops appeared more effective in lowering GHG emission estimates than is currently assumed. However, the 'smart' EFs indicated prospects for mitigation of N_2O emissions associated with UK arable cropping to be less than previously supposed. Whilst the MIN-NO project successfully improved UK estimates of N_2O emissions associated with arable crop production, its conclusions were reached with varying levels of certainty. Thus further research would be beneficial, to verify its findings.

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MULTI-FUNCTIONAL COVER CROPS FOR CROPPING SYSTEMS IN SOUTHERN SCANDINAVIA AND FINLAND

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Objectives

Eutrophication problems in water are an important driver for agri-environmental programmes in the Nordic countries, where cover crops (CCs) can effectively reduce nitrogen (N) leaching. CCs are mandatory in Denmark and subsidised in Sweden, Finland and Norway. Although there are positive effects of CCs, e.g. increased soil fertility, there are also negative effects such as increased costs and yield reductions, resulting in only 2-50% of the potential CC area in southern Scandinavia and Finland being used today. A multi-functional approach in development of cropping systems with CCs would increase their value to the environment and to farm productivity. This is exemplified in the present study, which evaluated systems combining undersown CCs with reduced tillage, in order to develop strategies for weed control that combine reduced herbicide requirements with reduced N leaching.

Method

This paper: i) summarises our experiences from the use of CCs under the climate conditions of southern Scandinavia and Finland, with respect to reductions in N leaching at field scale and national level [1], ii) examines possibilities for development of multi-functional CC systems, as illustrated by our previous study on CCs for weed control [2], and iii) presents a planned project starting in 2016, which will examine the effects of intensification of cropping systems in which CCs are harvested for biofuel production.

The review of CCs under Nordic climate conditions covered field leaching studies since the start of CC research in the 1980s. In total, 11 sites, mainly in Sweden and Denmark, where different short- and long-term studies (2-17 years) were conducted were included in the appraisal.

Methods for control of a perennial weed, couch grass (*Elymus repens L.*), using reduced tillage and CCs were investigated on a sandy soil in southern Sweden. The aim was to develop strategies combining weed control with lower herbicide use, without increasing N leaching due to intensive soil tillage. The experimental field consisted of separately tile-drained plots for measuring drainage flow and flow-proportional water sampling. Treatments with shallow post-harvest tillage (1 or 2 passes with a duckfoot cultivator), a treatment with hoeing between rows in combination with a CC, and a treatment without tillage and CC mown twice during autumn, were compared with conventional disc cultivation and a control without tillage or CC. A crop row spacing of 24 cm was used in the interrow hoeing treatment and 12 cm in the other treatments. The CC was undersown in spring barley and comprised mixed perennial ryegrass (*Lolium perenne L.*) and red clover (*Trifolium pratense L.*). A two-year experimental protocol was used, repeated once. Treatments were implemented after harvesting in year 1 and effects on couch grass abundance were measured during autumn of year 1 and in year 2 by grading shoot density, determining aboveground biomass and rhizome sampling. Leaching of nitrogen (N) and phosphorus (P) was studied during autumn and over winter.

Results

The field leaching studies showed wide variations, with an average reduction of 43% and with the largest N leaching reductions on sandy soil. The cool Nordic climate conditions constrained the use of CCs, with undersown ryegrass CCs being the most robust. Crucifers sown after cereal main crops were less reliable as CCs, due to the short time available for growth.

In Denmark, 211 000 ha of arable land were treated with CCs in 2011 and in Sweden 143 000 ha, corresponding to a substantial reduction in total N leaching of about 7000 and 1550 tons per year, respectively. However, the potential area suitable for CCs is estimated to be two-fold greater in Denmark and four-fold greater in Sweden. In Finland and Norway CCs were used on 23 000 ha and 3 400 ha in 2011, respectively, which corresponded to less than 10% of the estimated potential area. In Finland, the area with CCs are increasing rapidly.

The study on CCs for weed control produced promising results on how CCs can be used to reduce the need for herbicides. Treatments with CCs mowed twice or CCs with repeated hoeing between rows reduced couch grass shoot abundance during autumn and also reduced N leaching. Repeated disc or duckfoot cultivations resulted in mean annual N leaching of 26 kg N ha^{-1}, compared with 20 kg ha^{-1} in the treatment with one duckfoot cultivation, 17 kg ha^{-1} in the control, and 16 and 12 kg ha^{-1} in the CC treatments with mowing and hoeing, respectively. The P leaching was low (0.04-0.09 P ha^{-1} year^{-1}), but there were indications of increased drainage water P concentrations in the treatment where the CC was mown and plant material was left on the soil surface. This confirms the results from the meta-analysis that CCs do not reduce P leaching, and can in fact occasionally increase leaching when P is released from CC biomass exposed to freezing.

Use of fertilised CCs for biomass production enables intensification of cropping systems, e.g. by production of biofuel crops during autumn, thereby increasing the value of CCs. Although fertilisation of a CC in autumn might pose a risk of increased N leaching, it may also be associated with a lower risk of leaching if the CC is harvested. In the Nordic climate, where CCs are often killed by frost in late autumn, this would decrease the risk of N and P losses from plant material. The use of CCs for production of biomass for biogas digestion will be investigated in a Swedish field leaching experiment starting in 2016, in which measurements of N and P leaching will be combined with measurements of nitrous oxide emissions from CC systems with and without autumn harvesting.

Conclusions

Cover crops are important for reducing N leaching in the climate conditions of southern Scandinavia and Finland, and will become even more important with climate change resulting in mild, wet autumns. Strategies for increasing the multi-functionality of cover crops would increase their potential and value for future conventional and organic crop rotations, with weed control and biomass production being two important functions.

Acknowledgements

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References

[1] Aronsson, H., Hansen, E. M., Thomsen, I. K., Øgaard, A.F., Känkänen, H., Ulén, B., Liu, J. 2016.. Journal of Soil and water Conservation 71 (1), 41-55.

[2] Aronsson, H., Ringselle, B., Andersson, L., Bergkvist, G. 2015. Nutrient Cycling in Agroecosystems 102, 383-396.

IMPACTS OF DECLINING ROTATION DIVERSITY ON NITROGEN USE EFFICIENCY IN MAIZE

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Objectives

Crop diversity in the maize production region of North America has substantially declined [1]. Simplification of rotation has numerous agronomic and environmental consequences [2, 3] including negative impacts on nitrogen (N) processes, plant available water, and crop N requirement. These effects are of interest given escalating N fertilizer costs and continuing concerns about the negative impact of fertilizer N production and potential losses on environmental quality. While many studies have examined the N effects of legumes in rotation, much less is known about diversification using non-legume species, such as winter wheat, on N effects, or the effects of diversification on moisture dynamics that may influence N processes. Using three long-term studies located in Ontario, Canada, our objective is to demonstrate that rotation diversity increases maize productivity and N fertilizer use efficiency, and decreases maize N requirements.

Method

Three long-term trials in South-Western Ontario, Canada are considered:

The Ridgetown Crop Rotation trial was established in 1995 (42026’ N, 81053’ W) as a split-split plot design with four replications. Tillage system is the main plot, crop rotation is the split-plot, and N rate is the split-split-plot. Tillage treatments are conventional and zone-till. Crop rotation treatments are MM, SS, MS, SW, SW(rc), MSW, and MSW(rc) where M is maize, S is soybean, W is winter wheat and (rc) is underseeded red clover. Nitrogen rate treatments for maize are 12, 72, 132, and 192 kg N ha^{-1}, and for winter wheat are 0, 50, 100, and 150 kg ha^{-1}. Using maize N response data, maximum economic rates of nitrogen, agronomic efficiency and partial factor productivity were determined for maize under various rotations. See [1] for further details.

The Elora Maize Nitrogen trial was established in 2009 at the Elora Research (43039’ N 80025’ W) as continuous maize, randomized split-plot with nitrogen timing as the main treatment and nitrogen rate as the split-plot treatment. Timing treatments consist of urea-ammonium-nitrate applied at maize planting or V7-V8 stage. Nitrogen treatments consist of five N rates: 30, 58, 87, 145 and 218 kg N ha^{-1}. For each of the years, maximum economic rates of nitrogen and agronomic efficiency were calculated using a quadratic plateau model.

The Elora Crop Rotation trial was initiated in 1980 at the Elora Research Station as a randomized split-plot with four replications. Crop rotation is the main plot treatments and consist of MMMM, MMBB, MMB(rc) B(rc), MMSS, MMSW, MMSW(rc) and MMAA where M is maize, B is barley, S is soybean, W is winter wheat, A is alfalfa and (rc) is underseeded red clover. No-till and conventional tillage are split plot treatments. The response of crop rotation to weather patterns was characterized over the experimental period using various procedures that used precipitation, average, maximum and minimum temperatures, maize developmental stages, and average soil moisture deficit modeled using the Hydrus 1D modeling environment as input. Procedures included hierarchical clustering and principal component analysis. See [3] for further details.

Results

Ridgetown Crop Rotation: Wheat in the rotation increases maize and soybean yields, negates crop yield lags due to zone-tillage, and decreases maximum economic rates of nitrogen. The benefits of wheat in the rotation on maize yield are negated by high N rates; however, similar yields were obtained with lower N levels in rotationally grown maize, resulting in a 17% (conventional till) to 21% (zone-till) increase in partial factor productivity for N fertilizer at maximum economic rate of nitrogen. While N benefits to crops following wheat alone may be attributed to a higher indigenous plant available soil N, underseeding red clover further increased agronomic efficiency of N fertilizer up to 32%. Maize yields are less limited by N supply and less responsive to N fertilization when grown in rotation with wheat, especially in the zone-till system. Diversification of rotations, even when achieved using non-legumes, increases maize productivity and N fertilizer use efficiency, and decreases maize N requirements.

Elora Corn Nitrogen: Over the seven year period, maximum economic rates of nitrogen values ranged from 145-255kg N ha^{-1} with timing of N application having no effect. Given that previous crop, management, soil type and hydrid are all constant across years, variation in maximum economic rates of nitrogen is primarily due to year to year weather effects. Precipitation received during the grain fill period was most highly correlated with maximum economic rate of nitrogen, with years receiving the most precipitation during this period having the highest values. The ability to predict maize N requirement on this silt loam soil appears to be related to plant water availability conditions after fertilizer nitrogen is typically applied.

Elora Crop Rotation: When maize and soybean are integrated into more diverse rotations yield stability significantly increases. Crop diversification strategies increase the probability of harnessing favorable growing conditions while decreasing the risk of crop failure. In hot and precipitation limited years, diversification of corn-soybean rotations and reduced tillage increases yield by 7% and 22% for maize and soybean respectively. Diversification of crop rotation appears to stabilize maize response to variable plant water availability conditions across years. Presumably a more stable response to precipitation conditions should improve ability to predict maximum economic rates of nitrogen.

Conclusions

The combined results of these three long term trials highlight the value of diversification of a maize-soybean rotation, particularly through the addition of wheat. Diversification of crop rotation, with the addition of wheat, increases and stabilizes maize productivity, and reduces N fertilizer requirement. The potential interaction of crop rotation diversity, nitrogen and water may be of increasing interest in the future for several reasons. Predicted increases in maize yield will necessarily require more water for transpiration. Predicted effects of climate change on precipitation patterns may accentuate drought periods. Interest in crop residue removal for biomass purposes could reduce soil water holding capacity through impacts on organic matter. Combined these could accentuate limitations in plant available water and increase the benefit of crop rotation diversity in stabilizing N requirement.

References

[1] Gaudin, A. C. M., Janovicek, K., Deen, B., & Hooker, D. C. 2015. Agriculture, Ecosystems & Environment, 210, 1–10. http://doi.org/10.1016/j.agee.2015.04.034

[2] Deen, W., Martin, R. C., Hooker, D., & Gaudin, A. 2016. In Bao-Luo Ma (Ed.), Crop Rotations: Farming Practices, Monitoring and Environmental Benefits. Nova Science Publications, New York, NY.

[3] Gaudin, A. C. M., Tolhurst, T. N., Ker, A. P., Janovicek, K., Tortora, C., Martin, R. C., & Deen, W. 2015. PloS One, 10(2), e0113261. http://doi.org/10.1371/journal.pone.0113261

LEGUME-BASED CATCH CROPS FOR ECOLOGICAL INTENSIFICATION

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Objectives

Nitrogen (N) supply is a major constraint of crop yields in organic farming due to restrictions of inorganic fertiliser input. Legume-based catch crops (LBCCs) are capable to take up N from both the soil and the atmosphere (i.e., via biological N fixation (BNF)), and thus may act as an important source of N in crop rotations, enhancing crop yields but maybe also emissions of nitrous oxide (N_2O), in particular after soil incorporation of residues. Ecological intensification of agriculture requires more food being produced for the growing population with less environmental impact. It is still uncertain to what extent LBCCs may contribute to ecological intensification. The main objective of this study was to investigate the effects of five contrasting catch crops (legume-based *vs.* non-legume-based) on N_2O emissions, N accumulation and N supply to succeeding spring barley, using field experiment, ^{15}N labelling and laboratory incubation techniques.

Method

A one-year field trial (Sep 2012–Sep 2013) was conducted on a loamy sand soil in Denmark to monitor N_2O emission dynamics and N availability to a spring barley crop as affected by different catch crops. The catch crop treatment included three LBCCs (red clover, red clover/ryegrass mixture and winter vetch), two non-LBCCs (ryegrass and fodder radish) and a control without catch crops. Catch crops were either undersown in or sown after harvest of preceding spring barley in 2012. After residues plough-down (ca. 20 cm) in Apr 2013, all plots (20 × 3 m each) were sown to spring barley. The N_2O fluxes were measured 27 times using static chambers (75 × 75 × 20 cm) over a period of 366 days. Concentrations of N_2O in gas samples were analysed by gas chromatography; and N_2O fluxes were estimated by HMR method [1]. Cumulated emissions were calculated by linear interpolation. Catch crops were sampled in Oct 2012 to determine the dry matter and N yield, which were also done for barley at maturity in Aug 2013 [2].

Miniplots (35 × 25 cm) were also set up within the large plot experiment in order to determine BNF in LBCCs by in-situ ^{15}N labelling and quantify the residual effects on the following barley. A ^{15}N enriched KNO_3 (12 % excess atom fraction ^{15}N) solution was applied to each miniplot at 10 kg N ha^{-1}, which was split into three doses during Aug and Sep, 2012. Total N and ^{15}N abundance in catch crops (tops and 0–18 cm macro-roots) and the following barley were determined by IRMS the same time as for the big plot [3].

In addition, a 28-day laboratory incubation experiment was carried out to study N_2O evolution and differentiate sources of N_2O from simulated incorporation of catch crop residues under controlled environment (20 °C) with addition of ^{15}N-enriched nitrate (10 % excess atom fraction ^{15}N). Gas was sampled periodically to measure N_2O and CO_2 fluxes. The ^{15}N abundance in N_2O was measured with a N_2O Isotopic Analyser [4].

Results

LBCCs accumulated 59–67 kg N ha^{-1} in their tops, significantly more than non-LBCCs, 32–40 kg N ha^{-1}. More than 50 % of the N in LBCCs was derived from BNF as shown by ^{15}N dilution. By differentiation of N from BNF and soil N uptake with the ^{15}N labelling, LBCCs showed similar capacity in soil N extraction as the non-LBCCs. It implies that the LBCCs may have the similar ability as non-LBCCs in reduction of soil N leaching in period of catch crop growth. The macro-root of the five catch crops examined accounted for 31–50 % of the total plant N, which was a substantial source of N and usually underestimated.

The higher amounts of N accumulated in LBCCs increased the yield of the following unfertilised spring barley markedly, producing 3.3–4.5 Mg ha^{-1} grain compared with 2.6–3.3 Mg ha^{-1} in the non-LBCC and control treatments. In the miniplot, the ^{15}N-labelled tops and roots were returned in miniplots separately before sowing spring barley. The results of separate turnover of residues indicated that the root of LBCCs alone increased N supply of the following spring barley by ca. 20 kg N ha^{-1} compared with non-LBCCs or bare fallow, and a similar effect can be expected with the top residues of LBCCs. We also showed that harvest of catch crops, especially LBCCs, in late autumn tended to reduce the yield of the following barley compared with the unharvested treatments.

The annual emission of N_2O was comparable among all catch crop treatments, of which the highest emission was from fodder radish. This treatment also showed highest yield-scaled N_2O emission, at 499 g N_2O-N Mg^{-1} grain, in addition to 74–84 % of its total emissions observed during winter. It may be explained by the fact that fodder radish is not a winter-hardy species, which was killed and decomposed to fuel high winter fluxes under low temperatures. Although the 28-day laboratory study clearly showed a faster and greater release of N and N_2O after incorporation of LBCC residues than that of ryegrass, we did not observe greater annual emissions from LBCCs in the field. This highlights the importance to monitor N_2O fluxes over extended periods to cover seasonal variations, in particular when including winter catch crops in the system. After adding $K[^{15}N]O_3$ to the unlabelled residue-amended soil, we calculated the fraction of N_2O derived from denitrification by relating the ^{15}N enrichment in N_2O to that of soil nitrate and ammonium. The results revealed that denitrification was the dominant source of N_2O after residue amendment at water-filled pore space of 40–60 %, and the emissions were affected by the interaction between residue quality and soil inorganic N status.

Conclusions

We showed that LBCCs had the potential to supplement significant amounts of N in rotations to improve crop yield without increased environmental impact in terms of N_2O emissions, and thus could contribute to ecological intensification. More than half of the N in LBCCs derived from N fixation, and both tops and roots contributed with available N. The capacity of LBCCs to take up soil N was similar to or even greater than non-LBCCs, indicating their potential effectiveness on short-term reduction of N leaching loss. However, direct measurements of N leaching are needed. Although faster and greater N and N_2O release was seen after incorporation of LBCCs than from ryegrass during short-term laboratory incubation, LBCCs did not induce higher annual emissions of N_2O in the field study. Further studies of the complex underlying processes and controlling factors of N_2O emissions after incorporation of organic residues are needed.

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References

[1] Pedersen, A.R., Petersen, S.O., Schelde, K. 2010. Eur J Soil Sci 61, 888–902

[2] Li, X., Petersen, S.O., Sørensen, P., Olesen, J.E. 2015. Agric Ecosyst Environ 199, 382–393

[3] Li, X., Sørensen, P., Li, F., Petersen, S.O., Olesen, J.E. 2015. Plant Soil 395, 273–287

[4] Li, X., Sørensen, P., Olesen, J.E., Petersen, S.O. 2016. Soil Biol Biochem 92, 153–160

IMPROVING NUTRIENT USE EFFICIENCY AND REDUCING ENVIRONMENTAL LOSSES OF NITROGEN: INSIGHTS FROM A PROCESS-BASED MODEL AND ON-FARM TRIALS

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Objectives

Recently food supply chain companies have agreed to make unprecedented commitments to improve the sustainability of their production line. As the environmental footprint of many foods is dominated by the production of maize (*Zea mays*), this has led to an urgent and growing need to advise companies and their upstream farmers on how to reduce nitrogen (N) losses while maintaining or improving crop yields. Our objectives were: (1) to use a process-based model to explore options for maintaining or improving the Nutrient Use Efficiency (NUE) of maize; and (2) to use model outputs and field data to develop performance metrics and recommendations for improving the sustainability of the U.S. maize supply.

Method

We used a computational tool, Adapt-N, which integrates a process-based model for nitrogen (N) cycling in cropping systems with (1) soil, crop and farm management data and (2) near-real-time weather information [1]. This allows us to explicitly track crop N uptake and both atmospheric and leaching N losses. The Adapt-N tool is currently calibrated for use across 95% of the U.S. maize production area. It can be used by farmers and crop consultants at the scale of an individual production field to generate in-season fertilizer application recommendations, and can also be used in research mode to simulate the impacts of a variety of N management scenarios. The presented analysis was composed of two steps. First, the utility of the Adapt-N tool in guiding in-season N management decisions was tested in 113 paired strip trials conducted in the states of Iowa and New York during the 2011-2014 growing seasons. Each trial used the same pre-plant application coupled with either a grower-determined sidedress rate (control) or an Adapt-N- recommended sidedress rate (treatment). Fertilizer applications were tracked and yield information collected, allowing us to perform a partial profit analysis. Details of the trials are reported in Sela et al (*Agronomy Journal*, in review). In the second step, using results from a large synthetic database of 8100 simulations spanning 6 years (2010-2015) we explored the total fertilizer rates and N losses resulting from seven N management scenarios in the top five US maize production states. Our scenarios were selected to compare the effects of different timing of fertilizer application: fall fertilizer application (a common practice across the U.S. Corn Belt), spring (pre-plant) application, and use of a starter application at planting coupled with a sidedress application during the growing season. In addition we explored the effects of nitrification and urease inhibitors applied at different times. We further used model outputs to calculate changes in N surplus (total N applications minus N removed in the crop) resulting from various N management scenarios in order to test whether N surplus could serve as indicators of improved sustainability of maize production.

Results

In the field trials, the use of the Adapt-N tool resulted in lower N applications at sidedress than the control (farmer-selected) sidedress rate in 82% of the cases. This reduction in fertilizer application – averaging a 34% reduction across all the trials - was achieved without compromising yield, and led to a cost-savings averaging $65/ha across all trials. Simulations using the Adapt-N tool suggest that using the Adapt-N-recommended sidedress rate rather than the farmer-selected rate also reduced overall N losses to the environment by 38% Thus, field data suggests that – for those farmers who have already made the shift to split fertilizer application – the use of the Adapt-N tool leads to a better economic and environmental outcome. Our model simulations showed that on average, NUE was lowest for fall fertilizer application, with substantial losses of N to the environment and the need for large fertilizer applications at sidedress to avoid large yield declines. In contrast, simulations where fertilizer applications were split into a low amount at planting (starter) and with the majority of fertilizer applied as a subsequent sidedress at levels recommended by Adapt-N showed the highest NUE, with low values for total N applications and low N losses to the environment. Interestingly, the reductions in N losses occurred both for N losses to air and for N losses to water, suggesting that reduced fertilizer application led to decreases in soil nitrate which would be the precursor to both atmospheric and leaching losses. Spring pre-plant applications had a higher NUE than fall applications, but N losses could still be high under wet spring conditions and yields would be impacted without additional sidedress applications. Nitrification inhibitors had a marginal benefit in reducing N losses for fall application, but both nitrification and urease inhibitors decreased losses when used with spring applications. However, the use of inhibitors did not increase NUE as much as shifting to split (starter plus sidedress) fertilizer application. Finally, we compared Adapt-N generated data on N surplus against total N losses to the environment and total profit to the farmer for both our simulated N management scenarios and for the field trial data. This showed that decreases in N surplus corresponded to decreased N losses and increased profits, suggesting that N surplus could be a useful indicator for the sustainability of N management.

Conclusions

In conclusion, we find that for farmers in the Corn Belt of the U. S. the best way to improve NUE is to shift the timing of fertilizer application, at a minimum shifting from fall to spring application and ideally shifting to a split application of starter fertilizer with subsequent sidedress. Doing so will maintain crop yields while reducing N losses to the environment. For those farmers who have already decided to shift to split application, the use of the Adapt-N tool for generating sidedress recommendations is likely to increase farmer profits and reduce N losses to the environment. Food supply chain companies looking to reduce the environmental footprint of their products while maintaining crop yields and farmer income could use N surplus as a performance metric. By comparing N surplus across an array of farming systems or a group of farms in a given geography, companies could set benchmarks for performance or targets for performance improvement. Corporate claims of increasing sustainability could be supported by tracking trends in N surplus over time. Meanwhile, farmers seeking to improve their N surplus performance would be well-advised to consider shifting the bulk of their fertilizer application to the growing season and to use tools like Adapt-N to optimize in-season management.

References

[1] van Es, H.M., B.D. Kay, J.J. Melkonian, and J.M. Sogbedji,2007. Nitrogen management under maize in humid regions: case for a dynamic approach. In: T. Bruulsema, editor, Managing Crop Nutrition for Weather. International Plant Nutrition Institute.

ESTABLISHING THE NITROGEN DILUTION CURVE FOR POTATO IN BELGIUM

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Objectives

The Nitrogen Nutrition Index (NNI) is recognized as reliable plant-based method for diagnosing the crop nitrogen status (CNS). The NNI is based on the concept of critical nitrogen (Nc) dilution curve describing the whole plant Nc concentration (%, expressed in g per 100 g of dry matter weight) as an allometric function of total biomass (W, expressed in tons of dry matter ha^{-1}). In our knowledge, no Nc curve was established in Belgium for potato. The objectives of this study were: (1) to establish the specific potato Nc dilution curve for cultivar (cv) Bintje under Belgian growing conditions; (2) to verify the validity of this curve for cv Charlotte; (3) to compare the established curve to the existing Nc curves for potato established in other countries and; (4) to assess the possibility of using the obtained Nc curve to evaluate the potato CNS and to predict the final yield.

Method

Field experiments conducted by CRA-W from 1997 to 2014 in various regions of Belgium were used to estimate the Nc dilution curve. Experiments included three to six increasing N fertilizer rates and two cultivars (Bintje and Charlotte). Total biomass production and N concentration were determined for different sampling dates during the growing season and the tuber yield was determined at harvest.

The data points collected for cv Bintje (64 sampling dates) consisted into two sets of data: the first to determine the Nc curve and the second one to test the validity of the predicted curve. The determination of Nc dilution curve considered data points for which N does not limit crop growth. On each sampling date for cv Bintje, total biomass were analyzed by ANOVA and LSD test (SAS 9.4). The parameters of Nc dilution curve were estimated using non-linear regression (PROC NLIN). Pseudo-R^2 was used to assess model fit with SAS nonlinear procedure.The data used to validate the Nc curve for cv Bintje were classified using the LSD test as limiting and non-limiting N conditions.

The data set collected for Charlotte was used to check if the cv Bintje curve could be applied for cv Charlotte by identifying the limiting and non-limiting N conditions.The NNI for cv Bintje was calculated at each sampling date as the ratio between measured N concentration in total biomass and the predicted Nc.

For each experiment, the relative yield (RY) was calculated as the ratio of tuber yield obtained for a given N fertilizer rate with the highest tuber yield obtained among all N application rates. In order to establish the relationship between RY and NNI three different periods of the crop growth were considered for the calculation of NNI using the SAS quadratic plateau procedure and the pseudo-R^2.

Results

For each experiment, crop N concentrations in total biomass decreased as biomass increased during the growing season. This decline in N concentrations with time reported by many researchers corresponds to the dilution of N in the biomass. A fitted Nc dilution curve was obtained for cv Bintje (Nc (%) = 5.37 W$^{-0.45}$, R^2=0.86) including 16 sampling dates. Using the data set of validation for cv Bintje, the predicted Nc identified situations of limiting and non-limiting N concentration. According to the same approach for cv Charlotte, the predicted Nc curve for Bintje could be applied also for Charlotte.

The Belgian Nc curve presents similar values for the parameters a and b than the Nc curve (Nc (%) =5.36 W$^{-0.46}$) established by Greenwood et al. [1] from data obtained in Scotland and the Netherlands but differs from the Nc curve (Nc (%) =5.21 W$^{-0.56}$) proposed by Duchenne et al. [2] from data obtained in France.

To establish the relationship between RY and NNI different function were determined. The first function considered the average of NNI values per year across all sampling dates, the second one takes into account the average of NNI values per year across the period between 20 and 55 days after emergence (DAE) and the third one considers the NNI calculated for the last sampling date (the closest to harvest) for each sites (dates between 44 and 94 DAE). The quadratic relationship obtained between RY and NNI varied with the periods of plant sampling for NNI determination. From this study we decide to keep the relationship obtained for the period between 20 and 55 DAE corresponding to the optimal period for the assessment of the CNS as previously demonstrated [3]. Based on this relationship, the potato RY reached a plateau near 1.0 (plateau of 0.97) for NNI values >0.98. With decreasing NNI values below 0.98, the RY decreased. Therefore, the NNI identified situations of deficient and non-deficient N nutrition. This plant-based diagnosis tool can therefore be used for the assessment of CNS.

Conclusions

A Nc dilution curve (Nc (%) = 5.37 $W^{-0.45}$) was developed for potato for cv Bintje under the Belgian conditions, that matched also for cv Charlotte. The Belgian Nc dilution curve was different from the one developed for potato in France but similar to the one developed in Scotland and the Netherlands. The Belgian Nc curve and the resulting NNI adequately identified situations of limiting and non-limiting N concentration and could be used to establish the potato CNS and to predict the final yield. However, establishing the NNI at field level requires destructive and chemical analysis and is not appropriate for a quick assessment of CNS. The NNI can be used as a reference for calibrating other non-invasive methods for a quick and easy in-season monitoring of CNS [4].

References

[1] Greenwood, D. J., Lemaire, G., Gosse, G., Cruz, P., Draycott, A., & Neeteson, J. J. (1990). Decline in percentage N of C3 and C4 crops with increasing plant mass. *Annals of botany*, *66*(4), 425-436.

[2] Duchenne, T., Machet, J. M., & Martin, M. (1997). Potatoes. In *Diagnosis of the nitrogen status in crops* (pp. 119-130). Springer Berlin Heidelberg.

[3] Olivier, M., Goffart, J. P., & Ledent, J. F. (2006). Threshold value for chlorophyll meter as decision tool for nitrogen management of potato. *Agronomy Journal*, *98*(3), 496-506.

[4] Goffart, J. P., Olivier, M., & Frankinet, M. (2008). Potato crop nitrogen status assessment to improve N fertilization management and efficiency: Past-present-future. *Potato Research*, *51*(3-4), 355-383.

IMPACT OF VARIETIES ON BREAD WHEAT NITROGEN USE EFFICIENCY FOR YIELD AND GRAIN PROTEIN CONTENT: WHEN AGRONOMY MEETS GENETICS

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Objectives

Optimizing bread wheat Nitrogen Use Efficiency (NUE) in most Western Europe countries pursues two objectives: reaching high yield and obtaining enough grain protein content to satisfy market requirements. To achieve this goal, French farmers have many ways to improve their practices: use of N balance sheet method, optimizing N fertilizer application periods, use of Nitrogen Status Remote Sensing Tools... Among them, choosing varieties with improved NUE is seldom used, because of the lack of systematic characterization of varieties: only a global N requirement for yield [1] and grain protein deviation index [2] are available. Moreover, these characteristics are calculated on trials without knowing the optimum Nitrogen rate and are based on a methodology developed in the 1990's with outdated genotypes. Consequently, we acquired new references to better characterize the impact of current varieties on NUE and their interaction with agricultural practices.

Method

Twelve trials were carried out during two growing seasons in France (six during 2013-2014 and six during 2014-2015). The soil types were various (chalky, loamy and clay soils) and locations were representative of the main bread wheat cultivation areas through the country. Two-factor (nitrogen fertilizer rate and genotype) experiments were implemented, either in split-plot or criss-cross designs. The first factor was the bread wheat variety: six to ten varieties in each trial (seven common for all and some specific of the trial cultivation area). They were chosen to represent the currently available genetics in France, including hybrid, with putative differences in NUE characteristics. An "old" genetic reference was included (SOISSONS) to link the results with the previous studies from the 1990s. The second factor is the total N rate applied along a N response curve: six rates (0-100-150-200-250-300 kgN.ha^{-1}) spread in three applications (zadoks growth stages 25, 30 and 39) with ammonium nitrate fertilizer. Most of the measurements were made at harvest: grain yield, grain protein content, N uptake in straw and grain, soil mineral N stocks on 60 to 90 cm deep. To complete this set of information, N uptake measurements were made at flowering for one N rate.

The impacts of variety, N rate and their interaction on the trial network were studied with a variance analysis using a mixed model (trial location x growing period and its interactions with variety and N as non-fixed factors). Inside each trial, the N response of each variety was determined with models adjusted for each variable measured at harvest. It permitted us 1) to estimate the optimum yield and N rate to achieve it, 2) to characterize the grain protein content allowed at this optimum rate, 3) to calculate components of the NUE like apparent fertilizer N recovery (calculated as the slope of the linear regression between N rate and total N uptake at harvest) and total N requirement per ton of grain for the optimum yield and for grain protein content objective (11.5 %) and, 4) to estimate the impact of N rate on soil mineral N stocks at harvest.

Results

The first results presented in this paper consider 11 trials and 7 varieties (APACHE, ARLEQUIN, HYFI, HYXPRESS, PAKITO, RUBISKO and SOISSONS). Global variance analysis shows a significant effect of the variety x N interaction on grain yield and grain protein content. These results justify the need to take into account variety to manage N fertilization to reach grain yield and protein content objectives. Apparent Fertilizer N recovery is sometimes different between varieties. When it is, the significant difference could reach 15% of N fertilizer applied. There are significant differences between varieties concerning the optimum grain yield (optimum N rates ranging from 52 to 417 kgN.ha^{-1}) and the grain protein content obtained at the same N rate. We also demonstrate significant difference concerning total N requirement per ton of grain for the optimum yield and for grain protein content objectives. Indeed, some varieties clearly need some "extra-N" to reach 11.5% protein in grain once they have reached their optimum yield. These preliminary results are promising. They seem to indicate that the choice of the "good" variety could have an impact on the efficacy to uptake nitrogen fertilizer applied but also greatly influence the effectiveness to convert this nitrogen amount in grain yield and protein content. It could allow us to propose improved management options accounting for agronomy x genetic interactions, targeting spring period, but also during later growth periods when this conversion occurs. The fact that varieties are not equal facing the double challenge of high yield and grain protein content must lead us to define N requirement estimation system including extra-N for the weakest varieties, so long as this practice does not create negative environmental impacts. The first analysis of residual soil mineral N at harvest vs N rate seems to show that it is possible in many cases. At last, Nitrogen Nutrition Indexes calculated at flowering give precious information on the relationship between wheat physiology and NUE components.

This type of experiment is quite expensive and cannot be carried out every year for the whole varieties available in France. So, the measurements are also analyzed to know if variety x N characterization could be achieved in more simple designs (one to three N rates, many more varieties and no straw N uptake measurements for all). The first step is to know if Nitrogen Harvest Index (NHI) could be generalized from "references". The global variance analysis shows us that variety and N rate have significant effects on NHI, but not their interaction. Further analyses on this topic are required.

Conclusions

The first results showed in this paper clearly renew the available information in France to include bread wheat variety choice in Nitrogen management. Particularly, they emphasized the need to consider genetic specificities to reach both objectives of high yield and grain protein content. They are consistent with previous studies on the same topics in Western Europe countries [3] [4]. Finally, they will be completed with a third year of experiments and included in a wider study aimed to apply the conclusions in more usable trial designs to characterize all new varieties each year.

Acknowledgments

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References

[1] Le Souder C., Bernicot M.H., 1992. Blé tendre et bilan azoté - Faut-il fertiliser de la même façon toutes les variétés ?. Perspectives Agricoles, 179 (avril), 67-73.

[2] Oury F.X., Godin C. (2007). Yield and grain protein concentration in bread wheat: how to use the negative relationship between the two characters to identify favourable genotypes? Euphytica, 157: 45-57.

[3] Sylvester-Bradley R., Kindred D.R., 2009. Analysing nitrogen responses of cereals to prioritize routes to improvement of nitrogen use efficiency. J. Exp. Bot., 60, 1939-1951.

[4] Cormier, F., Faure, S., Dubreuil, P., Heumez, E., Beauchêne, K., Lafarge, S., Praud, S., Le Gouis, J. (2013). A multi-environmental study of recent breeding progress on nitrogen use efficiency in wheat (Triticum aestivum L.). Theoretical and Applied Genetics 126, 3035-3048.

NITROGEN FERTILISER FORMULATION: THE IMPACT ON YIELD AND GASEOUS EMISSIONS IN TEMPERATE GRASSLAND

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Objectives

Agriculture is responsible for 31% of Ireland's Greenhouse Gas (GHG) emissions, with 39% of these emissions coming from chemical/organic fertilisers in the form of nitrous oxide (N_2O). The IPCC default emission factor for N_2O from soils is 1% of N applied, irrespective of N form. However, highest N_2O emissions are associated with nitrate fertilisers, particularly in mild, wet conditions (Watson *et al*., 2009). Switching from calcium ammonium nitrate (CAN) to a urea based fertiliser is a potential strategy for reducing N_2O losses. However, urea is susceptible to ammonia (NH_3) volatilisation but this risk can be managed using urease inhibitors. The aim of this study was to evaluate the effect of switching from CAN to urea, urea with the urease inhibitor N- (n-butyl) thiophosphoric triamide (nBTPT) (trade name Agrotain®) and/or the nitrification inhibitor dicyandiamide (DCD) on (1) N_2O emissions (2) Ammonia (NH_3) emissions and (3) DM yield and N Uptake.

Method

A two year study (commenced March 2013) was conducted at six permanent pasture sites at three locations on the island of Ireland, Johnstown Castle, Co.Wexford, Moorepark, Co. Cork and Hillsborough, Co. Down covering a range of soil textures and drainage characteristics. The experimental design was a randomised complete block design with five replicates. There were six fertiliser N treatments at an annual N rate of 200 kg N ha^{-1} applied in five equal splits during the growing season. The grass was harvested at the end of each of the five fertiliser cycles. Dry-matter (DM) yield and N offtake was measured at each harvest; N_2O emissions were measured using static chambers throughout the year and NH_3 emissions were measured using wind tunnels throughout the growing season and annual emission factors calculated.

Results

Dry matter yield, measured over six harvests in six site-years, showed no significant difference between fertiliser formulations apart from Urea with DCD which produced significantly lower DM yield than CAN in three site-years. Urea with nBTPT did not have significantly different N uptake to CAN in all six site-years, urea with nBTPT and DCD did not have significantly different N uptake to CAN in five of six site-years and was significantly lower in one site year and urea did not have significantly different N uptake to CAN in four of six site years and was significantly lower in two site years. Urea with DCD had significantly lower uptake than CAN in four of six site years. The highest NH_3-N losses were generated by the urea and urea with DCD treatments although the NH_3-N losses generated by the urea with DCD formulation were not consistent across sites (Forrestal et al., in press) and the addition of nBTPT reduced NH_3-N emissions relative to the Urea and Urea and DCD treatments. Finally, the results of N_2O emissions show that N_2O losses were significantly affected by fertiliser formulation, soil type and climatic conditions. The direct N_2O emission factor (EF) from CAN averaged 1.49% overall sites, but was highly variable, ranging from 0.58% to 3.81 (Harty et al., in Preparation). Amending urea with nBTPT, to reduce NH_3 volatilisation, resulted in an average direct EF of 0.40% which was both significantly lower and less variable (ranging from 0.69-0.21%) than CAN. Cumulative N_2O emissions from urea amended with both nBTPT and DCD were not significantly different from background levels. Switching from CAN to stabilised urea formulations was found to be an effective strategy to reduce N_2O emissions (direct and indirect), particularly in wet, temperate conditions.

Conclusions

Switching from CAN to any of the urea based formulations significantly reduced N_2O emissions, dramatically so in drainage impeded soil when conditions were wet. However, some urea treatments, Urea and Urea with DCD displayed evidence of pollution swapping of direct for indirect N_2O for NH_3. While there was little difference between fertiliser formulations in dry-matter yield, the incorporation of nBTPT with urea and nBTPT and DCD generated no significant difference in uptake to CAN in all six or five of six site years, respectively. The use of stabilised urea based formulations has potential to reduce both N_2O emissions compared to CAN in temperate grassland whilst maintaining grass production.

COMPARATIVE ENVIRONMENTAL ASSESSMENT of AMMONIUM NITRATE versus UREA FERTILIZER on A TYPICAL CROP ROTATION

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Objectives

Nitrogen fertilizers are essential for ensuring food security and quality of proteins in cereals and other crops. Improving Nitrogen Use Efficiency NUE provides positive environmental impacts such as optimizing production on each hectare saving land for grassland and ecological focus area and minimizing Greenhouse Gas GHG emission and fossil energy per kg of grain.

At an optimum rate, NUE differs with the type of fertilizers. Ammonium Nitrate AN and urea U can easily be substituted in the same spreader. They cannot be incorporated in soil when applied in split application on rapeseed, wheat and barley and urea is more sensitive to ammonia volatilization. The nitric form in AN is also readily available to plants irrespective to the soil temperature. It is important to inform farmers on NUE efficiency achieved by these two fertilizers as well as on their environmental impacts.

Method

From 2002 to 2013, a network of 12 long-term experiments, comparing urea U and ammonium nitrate AN, were carried out by several partners in the framework of a project co-ordinated by UNIFA. In addition to the traditional comparison of the response to nitrogen fertilisation on single-year experiments (annual effect), the originality of the trial design made it possible to demonstrate the existence of a past effect, depending on which kind of fertiliser has been applied the previous year. The repeated use of the same nitrogen fertiliser each year has provided new results amplifying the difference in favour of AN.

Under a common succession of oilseed rape, wheat and barley, comparative effectiveness of these fertilizers in terms of performance per hectare, nitrogen losses, greenhouse gas emissions, energy used and land spared have been established. The variability of response to nitrogen fertilisers was high between the trials, with a very important effect of the location and of the annual climate. The multiplication of trial sites in terms of location and years, and the convergence of the results made it nevertheless possible to quantify the differences in efficiency between the two fertilisers form tested.

Results

The main conclusions resulting from this network are as follows: (1) an annual positive effect on crop yields for ammonium nitrate compared to urea, with an average difference of 2%***, which corresponded to a yield difference of 1.2**, 1.4** and 1.3* dt/ha for rapeseed, wheat and barley respectively[1] (crops fertilized at the provisional balanced rate); (2) a positive past effect of fertilisation on yield, in the same order of magnitude as the annual effect of nearly 2%** in favour of ammonium nitrate ; (3) a "system" effect on yield, combining the annual effect and the past effect when the same fertilizer is applied every year, of 4.1%***which corresponds to a difference of 2.4*** 2.7*** and 3.1** dt/ha for rapeseed, wheat and barley respectively. This effect was also significant on the crop nitrogen uptake. For crops fertilized each year with ammonium nitrate, the nitrogen uptake was increased by 27** 19*** and 15*** kg N/ha for rapeseed, wheat and barley, respectively. The NUE calculated reached 91% with AN compared to 84% with U.

The lower amount of nitrogen absorbed following urea fertilisation may be related to a higher risk of ammonia volatilisation after spreading. The increased nitrogen uptake with ammonium nitrate increased the nitrogen content in crop residues and could explain partly the past effect on the following year.

Greenhouse gases inherent to industrial production and use of nitrogen fertilizers are 5.5% higher for urea, i.e. additional emissions of 104 kg CO2 equivalent per hectare. This footprint was established with the Cool Farm Tool. Taking into account the 4.1% harvest increase with ammonium nitrate, this difference even reaches 9.6% per ton produced. Energy consumed during fertilizer production is lower for ammonium nitrates. The difference is 19.3%, i.e. a difference in favor of ammonium nitrate of 2,337 MJ per hectare (or 23.4% per ton produced) established with the EGES© online tool.

By producing more per hectare, a little more residue – roots, stubble and straw – is left each year to the soil. The SIMEOS-AMG tool, developed by INRA-Agro-Transfert, simulates the evolution of the carbon storage in soil over 60 years. Applied to these trials AN with a gain in harvest of 4.1% per year shows a storage supplement equivalent to 60 kg of CO2/ha/year thanks to more residue.

[1] NB: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

Conclusions

Farmers have to combine decisions for each crop on the 4R scheme: right rate applied at the right time and the right place and finally choose the right fertilizer providing the higher NUE while minimizing environmental impacts. They can choose between two major forms in the granular form: ammonium nitrate and urea. Results on the succession of rape-wheat-barley show that AN performs better than U on yield and protein content and at the same time reduces the GHG emission and the fossil energy consumption. By producing 4.1% more per hectare, AN helps to limit the cultivated area and relieve pressure on natural habitats for biodiversity. Urease inhibitors associated to urea and nitrification inhibitors have not been studied in these experiments but they probably open new possibilities for further NUE improvement on different crops.

[1] LAMBERT(1) M. ; HERVE(2) M. ; EVEILLARD(3) P. ; BOUTHIER(4) A. ; CHAMPOLIVIER(5) L. ; MARQUIS(6) S. ; ROCCA(7) C. ; ROUSSEL(8) D. Comparaison de l’urée et de l’ammonitrate en essais de longue durée, synthèse de 10 ans d’expérimentation. In : Actes des Rencontres COMIFER in Reims, France, on November 2013

[2] [1] M. LAMBERT,[3] M. HERVE,[2] A. BOUTHIER,[4] L. CHAMPOLIVIER,[5] S. MARQUIS,[6] C. ROCCA[7] and D. ROUSSEL[8]. 2014. COMPARISON OF UREA AND AMMONIUM NITRATE IN LONG-TERM TRIALS**.** P. EVEILLARD. In: Proceedings 760 presented to the International Fertiliser Society in Cambridge, UK, on 12th December 2014.

N FERTILIZER TYPE HAS SMALL EFFECT ON DIRECT N2O EMISSIONS BUT STRONG INFLUENCE ON THE TOTAL CLIMATE IMPACT OF RAPESEED CROP ROTATIONS

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Objectives

Biodiesel from rapeseed is one of the major renewable resources in Germany used for fuel production. For ecological reasons, biofuels have to fulfill strict sustainability requirements (e.g. substantial reductions of greenhouse gases). However, the mitigation of nitrous oxide (N_2O) emissions is still challenging and depends on numerous factors, such as soil type, climatic and management factors, e.g. fertilizer type. To achieve these aims, it is one opportunity to substitute mineral N fertilizer by fermentation residues (FR) from biogas production since high upstream climate impact occurs during the energy-demanding mineral N fertilizer production. However, based on their physical-chemical characteristics (e.g. high NH_4^+ and pH values) these residues may lead to higher direct GHG emissions than unfermented residues [3].

The objectives of our study are to investigate the effects of I) N fertilizer type (mineral vs. FR) and II) site and climate heterogeneity on direct N_2O emissions and total climate impact.

Method

Since 2012, measurements of the collaborative research project “Mitigation potential of greenhouse gas emission from winter oilseed rape cultivation” were conducted at 5 study sites throughout Germany representing the main precipitation-frost classes identified as relevant for N_2O production [1]. A semi-randomized block design was established at each study site investigating the complex effects of I) crop rotation of winter rape - winter wheat - winter barley and II) fertilizer type (granular calcium ammonium nitrate; CAN and fermentation residues) on N_2O emissions. Therefore, 7 fertilizer regimes (non-N fertilized control, 60 kg CAN-N, 120 kg CAN-N, 180 kg CAN-N, 240 kg CAN-N, 180 kg FR-N without nitrification inhibitor and 180 kg FR-N with nitrification inhibitor) were installed.

At each study site, nitrous oxide field emissions were measured all-year-round by the same approach daily for 3-5 days following fertilization and subsequently weekly using a manual non-flow-through non-steady-state closed chamber method after Livingston und Hutchinson ([2]; 20-minute interval sampling and enclosure time of 1 hour). Flux rates were calculated according to Pedersen et al. [5] and annual N_2O emissions were summarized by linear interpolation between sampling dates. Accompanying to the GHG measurements several soil and plant parameters (e.g. soil N_{min} status, soil moisture, yield and C/N uptake) were determined. To take account of indirect N_2O emissions originating from ammonia (NH_3) losses at FR fertilized treatments (1% of N lost as NH_3), NH_3 volatilization following FR application was measured by open dynamic chamber Dräger-tube method after Pacholski et al. [4]. In this analysis a value of 6.34 kg CO_2-eq kg^{-1} CAN-N is assumed for the upstream emissions of CAN production [6]. In order to assess the effect of mineral fertilizer substitution by fermentation residues on the total climate impact yield normalized field emissions, indirect N_2O emissions as well as upstream emissions has to be considered. All emissions are referred to an energy yield of 15.27 MJ RME (rapeseed methyl ester) per kg dry matter yield.

Results

We present triennial results of the CAN (180 kg CAN-N) and FR (180 kg FR-N without nitrification inhibitor) treatments featuring three climatically contrasting seasons. In 2013, the weather conditions were characterized by a cold and long winter with snow until mid-spring, whereas almost no freezing events occurred in

2014. Especially the growing season 2015 was very dry below the long-term average.

Across all investigation sites and years strong short-term N_2O emission rates occurred after fertilization and harvest events as well as from occasional heavy rain. Only minor effects on N_2O emissions were caused by the type of N fertilizer. In particular, both sandy sites (Dedelow and Bornim) showed extremely low N_2O emission levels for the entire investigation period. Whereas the Dedelow and Hohenschulen (loamy soil) site showed highest emissions following fertilization in spring, post-harvest emissions dominated from the Merbitz site (sandy loam).

Except of field site Merbitz, annual N_2O emissions were very low in all three seasons, ranging from 0.2 kg N ha^{-1} a^{-1} to 1.2 kg N ha^{-1} a^{-1} and from 0.2 kg N ha^{-1} a^{-1} to 1.1 kg N ha^{-1} a^{-1} for the FR and CAN treatments, respectively. Whereas, highest cumulated N_2O emissions at field site Merbitz amounted to 3.7 kg N ha^{-1} a^{-1} (FR) and 4.9 kg N ha^{-1} a^{-1} (CAN). Caused by productive plant growth, the yield-normalized N_2O emissions also were at a very low level. As expected for top dressing considerable amounts of FR-N are lost as NH_3 (ranging from 7 kg NH_3-N ha^{-1} a^{-1} to 52 kg NH_3-N ha^{-1} a^{-1}) and thus indirect as N_2O.

Nevertheless, the high upstream emissions of CAN production at mineral fertilized treatments accounted for the largest proportion of the total climate impact, ranging from 60% to 97% out of 13 g CO_2-eq MJ^{-1} RME to 30 g CO_2-eq MJ^{-1} RME, respectively. However, at field site Merbitz the high total climate impact mainly is caused by direct N_2O emissions accounting for about 55% out of 41 g CO_2-eq MJ^{-1} RME in 2013. But in general, the mineral fertilized treatment showed a clearly more negative climate impact compared to the FR fertilized treatment. These findings are consistent for all measurement years and sites.

Conclusions

Our results showed that climatic conditions, N fertilizer type, and site specific differences play a minor role regarding direct field N_2O emissions. However, the substitution of mineral fertilizer by fermentation residues can be seen as a good option in terms of reducing the negative climate impact by avoiding upstream emissions which are supposed to be the largest proportion regarding the total climate impact.

References

[1] Jungkunst, H. F., Freibauer, A., Neufeldt, H. and Bareth, G. 2006. Journal of Plant Nutrition and Soil Science 169, 341-351

[2] Livingston, G. P. and Hutchingson, G. L. 1995. In: Matson, P. A. and Harriss, R. C. (eds) Methods in ecology – Biogenic trace gases: Measuring emissions from soil and water. Blackwell Science Oxford, England. pp. 14-51.

[3] Möller, K. and Müller, T. 2012. Engineering in Life Sciences 3, 242–257

[4] Pacholski, A., Cai, G., Nieder, J., Fan, X., Zhu, Z. and Roelcke, M. 2006. Nutrient Cycling in Agroecosystems 75, 259-273

[5] Pedersen, A. R., Petersen, S. O. and Schelde, K. 2010. European Journal of Soil Science 61, 888-902.

[6] http://www.biograce.net/img/files/2014-07-10-222336BioGrace_additional_standard_values_-_version_1_-_Public.pdf, 10/02/2016, p. 5

SCENARIO MODELING OF AMMONIA EMISSIONS FROM SURFACE APPLIED UREA UNDER TEMPERATE CONDITIONS - APPLICATION EFFECTS AND MODEL COMPARISON

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Objectives

On a global scale, urea is the most widely used synthetic nitrogen (N) fertilizer. It is characterized by a high N concentration and ease of application. In contrast, urea is the synthetic fertilizer with the highest risk of N losses by ammonia volatilization. Actually one single EMEP [1] emissions factor, 24.3 % of applied N, is evenly applied for all geographical and managment situations. However, it is well known that ammonia emissions are highly variable under different agro-ecological conditions (0 - 60% of applied N) in particular depending on soil characteristics, temperature, canopy and rainfall, resulting in a high uncertainty of a single emission factor. Aim of this study was to estimate emission factors for surface applied urea under central European conditions by use of an extensive data set based on multi-year measurements on three sites in Southern, Central and Northern Germany and two calibrated models (a. statistical/empirical, b. deterministic).

Method

In 2011-2015 ammonia loss after surface application of urea was measured in replicated field trials (n = 4) at Hohenschulen, Cunnersdorf and Duernast in the German federal states of Schleswig-Holstein (North), Saxony (Central) and Bavaria (South). Urea was applied to winter wheat depending on crop phenology at 4 application dates (tillering, stem elongation, flag leaf appearance, before anthesis). Ammonia emissions were determined by a combination of passive sampling and a calibrated dynamic chamber method [2,3]. Measured emissions ranged between 2% and 33% of applied N. Overall, 41 application dates were used to parameterize and validate an empirical and a deterministic model which were later on used to calculate ammonia emissions for the 4 phenology related applications per year in a time span of 18 years (1997-2014) for each of the three sites. For these calculation mean site specific application dates obtained from the field trials were used.

The empirical model was based on a sigmoidal function [4]: loss(t)= asymptotic loss (*a*; % N applied) *(1-exp(-*b**t)^*i* (*t*= hours after application, *b* = rate constant, *i*= form parameter). Firstly, this function was fitted to each of the cumulated loss curves. In a second step the three obtained parameter values for *a*, *b*, *i* were calculated based on environmental and management variables by multiple linear regression. Average environmental conditions one week after application were used as input variables but for precipitation where the effect of different precipitation sums (1 up to 4 days, 1 week after application) on ammonia emissions was tested. For the scenario calculations identified independent variables were used to calculate the three model parameters and final cumulative emissions (% N applied) for each application date within the years.
As deterministic model the model 'Volt'Air' [5] was applied. Three model parameters were modified to fit the model to the data. For model validation and scenario calculations site specific mean parameter values were used.

Both models were parameterized on a data set of 26 applications selected by random sampling while the remaining data sets were used for model validation. Model performance was evaluated using RMSE, modeling efficiency, model bias and d-index.

Results

For the empirical models several sets of variables were applicable to estimate the model parameter *a*. After evaluation the final model included the variables air temperature (°C), wind speed (m/s, 2 m height) and precipitation sum 3 days after application (mm). While temperature and wind speed have strong positive effects on ammonia emissions, precipitation within 3 days after fertilizer application reduces the losses. Model evaluation yielded performance parameter values (parameterization/validation) of 4.1/5.5 (% N applied), 0.3/1.7

(% N applied), 0.54/0.56 and 0.89/0.88 for RMSE, bias, modeling efficiency and d-index respectively, indicating a satisfactory model performance. However, it was not possible to satisfactorily fit models for the parameters *b* and *i*. As these parameters are not independent in the chosen algorithm this resulted probably in a high degree of parameter equifinality. Nevertheless, this shortcoming has no effect on the main aim, the calculation of multi-year based emissions factors. Median *b* (0.025) and *i* (3.6) values are suggested to be used in combination with the variable paramter *a*.

Model performance of the deterministic model was not as satisfactory. Model evaluation yielded performance parameter values (parameterization/validation) of 4.5/3.7 (% N applied), -0.59/1.5 (% N applied), 0.31/0.72 and 0.72/0.91 for RMSE, Bias, modeling efficiency and d-index respectively, when 4 outliers in the validation data set were excluded. However, modelling efficiency (0.01), d-index (0.66) as well as RMSE (6.7 % N applied) were not satisfactory using the full validation data set while model bias was unaffected.

Both models were used to calculate the variation and the mean of relative ammonia emissions between the years depending on application date. Overall, both models showed similar trends depending on the application date and application site with a higher variation of emissions by the empirical model ranging between 0 and 60% of applied N, while Volt'Air output varied between 0 and 35 %. However, the frequency distributions of calcualted emissions were very similar for both models (180 calculations for each model), 60% of the cases with emissions varying between 0-10% of applied N. Ammonia emissions were lower at the first application (5 %), on a similar level at the 2nd and 3rd application (10%) while highest emissions close to the EMEP factor were observed at the 4th application (17%). On average/median emissions were about 10% of applied N, half of the EMEP [1] emission factor . The choice of identical Julian dates for application may have affected average emissions. Dates with rainfall at urea application which would be avoided in practice may hae caused underestimation of the average emissions while application much later as the true application dates probably resulted in overestimation due to higher temperatures. The overall effect on averaged emissions is uncertain but probably not very strong.

Conclusions

The simple empirical model yielded a better modeling performance than the deterministic model with moderate model performance under central European conditions. For both models average ammonia emissions were about 10% of applied N with lower emissions at the first application and higher emissions at later applications. Relative ammonia emissions in the scenario calculations varied strongly indicating a potential bias of average emissions factors based on a limited set of field data. Under conditions of Germany the risk of ammonia emissions after urea application at the first application in March is low with low variation. The highest risk of ammonia emssions is connected to late surface applications of plain urea in late May or June.

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References

[1] EMEP/EEA, 2013, doi:http://dx.doi.org/10.2800/92722

[2] Pacholski A. (2016). Calibrated Passive Sampling - Multi-plot Field Measurements of NH_3 Emissions with a Combination of Dynamic Tube Method and Passive Samplers. J. Vis. Exp. (109), e53273
[3] Ni K., Pacholski A., Kage H. (2014) Agriculture, Ecosystems and Environment 197:184-194
[4] Demeyer, P., G. Hofman and O. Van Cleemput (1995). SSSAJ, 59: 261 - 265
[5] Genermont, S., and P. Cellier P. (1997). Agricultural and Forest Meteorology 88(1-4), 145-167

EFFECTS OF CRUSHING AND DRYING ORGANIC PRODUCTS ON THEIR NITROGEN AND CARBON MINERALIZATION IN SOIL INCUBATIONS

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Objectives

The use of organic products contributes to crop fertilization (fertilizing value) and to the maintenance of soil organic matter content (soil improver value). Methods to characterize C and N mineralization in laboratory have been developed and standardized in France. The recommended methods (AFNOR) are using dried and crushed products mixed to soil samples and incubated during 3 months. However it is expected that the conditions of sample preparation and the optimal conditions of incubation under controlled conditions may accelerate organic substrates decomposition and organic N mineralization, as it has been observed for crop residue decomposition studies. The PROLAB project aims at studying the transposition of measurements carried out in controlled conditions to the context of field. The study explores the effects of drying and crushing organic products varying by their origin, and their initial chemical and physical characteristics on C and N mineralization during soil incubations.

Method

Seven products of various origins and compositions were studied: a municipal solid waste compost, a co-compost of sewage sludge and greenwastes, a sewage sludge, a solid digestate issued of dry mesophilic batch process, a raw liquid digestate issued of liquid mesophilic continuous process, a cattle manure and a poultry manure. The products were sampled in March 2014, and stored at 4°C until incubations.

Two series of experiments were conducted in controlled conditions. The first series consisted in running incubation with soils amended with the 7 products, dried and 1mm-crushed before incubation, and homogeneously mixed with moist soil. To do so, products were applied at the equivalent rate of 2000mg C kg^{-1} dry soil, in the equivalent of 25g dry soil samples. Inorganic N was added to the soil in the form of KNO_3 to obtain an initial concentration of about 35mg N-NO_3 kg^{-1}. Hermetic jars of 1L were used with 10mL NaOH traps, to measure C-CO2 evolved during incubation. The second series of incubation consisted in applying the same products but fresh in a soil sample equivalent to 500 g of dry soil, to reduce the heterogeneity of the added product in each samples. In this latter case, hermetic jars of 3L were used.

Incubations were performed at 28°C for six months with four replicates for each treatment and each sampling date (13 dates for C and 8 dates for N measurements). The soil used for the incubations had the following main characteristics: clay = 210 g kg^{-1}, silt = 713 g kg^{-1}, sand = 73 g kg^{-1}, $CaCO_3$ = 4 g kg^{-1}, pH = 7.9, organic C = 10.7 g kg^{-1}, and organic N = 1.06 g kg^{-1}. Organic N and C mineralization was calculated for each sampling date from the difference between the amounts of C-CO_2 produced or N mineralized by the control soil and by the soil amended with the product.

Results

Regarding C mineralization, the differences in C mineralization were small and mainly observed over very short time, i.e. between day 3 and day 7 after start of the incubation, with an increase rate of mineralization for the dried/crushed products, compared to raw products. The only exception was the municipal solid waste compost, where the difference lasted 50 days.

We obtained three types of response:

- no effect of products preparation: solid digestate and poultry manure
- rate of C mineralization of dried/crushed products > raw product : co-compost of sewage sludge and

greenwastes, municipal solid waste compost, sewage sludge; the effect was small and transitory.

- C mineralization of the raw product > dried and crushed product: cattle manure. In this case the final difference in C mineralization was + 9% added C in favor of raw product.

Regarding N mineralization, the net N mineralization was significantly higher for raw products compared to the same but dried/crushed products, except for the co-compost of sewage sludge and greenwastes. For this product, the net N mineralization was nil over the whole incubation with no difference between the two treatments.

Conclusions

The results of the project will make it possible to understand and quantify how sample preparation modifies the kinetics of potential mineralization. The results will be further used to determine transposition factors from laboratory to field conditions. These transposition factors will take into account the particle size, the heterogeneity of the mixture and the availability of nitrogen. This will allow to improve the way to integrate the kinetics of mineralization of organic products in decision-making tools to calculate additional mineral fertilization for crops receiving organic products.

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STRIP-TILLAGE COMBINED WITH SLURRY BAND INJECTION BELOW THE MAIZE ROW – A NEW APPROACH TO IMPROVE THE NITROGEN USE EFFICIENCY OF ORGANIC FERTILIZERS

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Objectives

Strip-Tillage is one form of conservation tillage. Hereby soil only is loosened in the seed row whereas the soil in the interspace remained un-tilled and covered by crop residues [1]. The strip-tillage system can be well combined with liquid organic fertilizer injection such as slurry into the root zone in one operation with tillage. Additional nitrogen (N) stabilization of slurry ammonium-N by application of nitrification inhibitors (NI) may furthermore reduce N losses [2]. Study aimed to determine the potential of strip-tillage combined with slurry band injection below the maize row and additional NI application to improve N efficiency of maize crops by performing plot trials at three different study sites. The main objectives were to:

i. evaluate the stability of ammonium(NH_4)-N depots

ii. determine nitrate(NO_3)-N leaching into deeper soil layers

iii. quantify gaseous N losses (ammonia, nitrous oxide) at slurry application and

iv. determine yields and N uptake of plants.

Method

Plot trials with randomized block design (width: 12 m, length: 50 m, 4 replications) were conducted in 2015 at three different study sites in Saxony-Anhalt (Central Germany) representing slightly and moderately loamy sandy soils to loamy soils. Climate conditions of the study sites are comparable with long-term average annual air temperature and average annual precipitation of 9.2 °C and 562 mm (Lückstedt), 9.0 °C and 550 mm (Burgsdorf) and 9.7 °C and 533 mm (Quellendorf), respectively (dates of the German Weather Service).

The following treatments were considered in the plot trials:

- Control without slurry **(0)**

- Strip-Till + slurry injection **(STR)**

- Strip-Till + slurry injection +NI **(STR+NI)**

- Conventional broadcast surface application and immediately incorporation of slurry **(CONV)** and

- Conventional broadcast surface application and immediately incorporation of slurry + NI **(CONV+NI).**

Fertilization and soil tillage were realized in April 2015 with an application rate of 30 m^3 ha^{-1} cattle slurry (Lückstedt), 20 m^3 ha^{-1} cattle slurry digestate residue (Burgsdorf) and 25 m^3 ha^{-1} cattle slurry digestate residue (Quellendorf) according to N amounts of 100 kg N ha^{-1}, 136 kg N ha^{-1} and 113 kg N ha^{-1}, respectively. In the treatments STR+NI and CONV+NI an amount of 5 l ha^{-1} NI was added to the fertilizers. Manure was applied as a deep band placement in a depth of 25 cm in the strip-till treatments with a XTill S machine (VOGELSANG, Germany). In the conventional treatments the manure was immediately incorporated close to the soil surface (depth of 6-8 cm) by a disc harrow. Soil mineral N contents were determined in depths of

0-90 cm before fertilization and at three different times until harvest of maize plants. Harvest of maize plants was performed in an area of 2 m² manually in the mid of July, August and September 2015. To calculate N uptake dry matter yields and N contents of plants were determined. Gaseous N losses were measured in Lückstedt by the closed chamber method (N_2O) and by the calibrated dynamic chamber method (ammonia) according to Gericke et al. [3].

Results

At all study sites the strip-till treatments with NI showed a small share of NO_3 on mineral N until about 30 days after manure application indicating that NH_4 depots were nearly stable. Afterwards NO_3 contents of soil increased markedly to 52 %, 75-96 % and 92-96 % after 40, 90 and 170 days after fertilization, respectively. With addition of NI NH_4 contents of manure were 13–60 % higher compared to the treatment without NI 30 days after fertilization.

In contrast to STR NI application to the conventional treatments showed nearly no effect. Here the NO_3 share on mineral N was in the range of 74-88 % already 30 days after slurry application without significant decrease by addition of NI. Reason for this might be the larger contact surface at broadcast surface slurry application compared to targeted band placement of manure at the STR treatment as also shown by Laurenz [4]. During the study period NO_3 leaching into deeper soil layers (> 30 cm up to 90 cm depth) was lowest in the STR treatments in particular in the stabilized variants about 90 days after manure application. Afterwards no significant differences in NO_3 leaching between various treatments were observed associated with high precipitation amounts registered in July (83 mm) and August 2015 (97 mm). Results showed up to 54 kg ha^{-1} higher N uptakes of plants in the STR treatments compared to conventional manure application. Highest differences between treatments were observed at the harvest date in the mid of August 2015. Until the final harvest in September 2015 smaller differences in N uptakes between treatments were observed presumably caused by optimal growth conditions for maize (high precipitation amounts and warm conditions) from July compared to dry conditions in spring of 2015. These results indicate the benefits of strip-tillage especially in times with lower water availability. As not expected the treatments STR and STR+NI showed no significant differences neither in N uptakes of plants nor in dry matter yields. It can be assumed that small precipitation amounts in the spring 2015 to mid of July associated with a smaller risk of NO_3 leaching might be one reason for this. Otherwise it is known that the application of a highly concentrated NH_4 depot in the STR treatments may also cause an inhibition of nitrification itself also without addition of a NI. Analogous to the N uptakes highest dry matter yields were determined in the STR treatments with a surplus of maximal 33 dt ha^{-1}. Gaseous N losses of N_2O and NH_3 showed no significant differences between treatments and were altogether on a low level accounting for < 1 % (N_2O) and maximal 3.5 % (NH_3) of the total applied N in manure.

Conclusions

Strip-tillage combined with slurry deep band placement is a suitable system to improve N efficiency of organic fertilizers. Targeted application of high concentrated NH_4 depots directly into the root zone of maize plants might reduce NO_3 leaching into deeper soil layers and thus enhance N uptake of plants. The additional application of NI is recommended to avoid NO_3 leaching in times with high precipitation amounts. Benefits of strip-till can be particularly effective at conditions with low water availability. Further investigations are required to evaluate gaseous N losses with consideration of the whole course of a year.

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References

[1] Herrmann, W., Bauer, B., Bischoff, J. 2012. Strip Till –Mit Streifen zum Erfolg. AgrarPraxis kompakt. DLG-Verlag, Frankfurt a. M.

[2] Ruser, R., Schulz, R. 2015. Journal of Plant Nutrition and Soil Science 178, 171-188.

[3] Gericke, H., Pacholski, A., Kage, H. 2011. Biosystems Engineering 108, 164-173.

[4] Laurenz, L. 2014. Top Agrar 3, 92-95.

COMPARISON OF THE EFFICIENCY OF NITRIFICATION INHIBITORS DMPP AND DMPSA ON A MAIZE-RYEGRASS CROP ROTATION

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Objectives

Nowadays intensive farming systems are based on the intensive supply of nitrogen fertilizers, whose application causes environmental problems such as nitrate leaching and the release of nitrogenous gases due to N loses by nitrification, denitrification and ammonia volatilization. Among the gases derived from the microbial processes of nitrification and denitrification we can find nitrous oxide (N_2O), which causes atmospheric pollution because of being a strong greenhouse gas. In order to mitigate environmental pollution nitrification inhibitors have been developed from the 70s. A first objective of this work was to compare the effect of the new nitrification inhibitor 3,4-dimethylpyrazole-succinic acid (DMPSA) with respect to 3,4-dimethylpyrazole-phosphate (DMPP) reducing N_2O emissions as well as to determine if its application affects the yield of maize under temperate oceanic conditions. A second objective was to evaluate the residual effect of its application on a subsequent ryegrass crop after maize.

Method

The work was conducted in a forage maize-ryegrass crop rotation maize-ryegrass in the Basque Country in 2015. Maize was sowed on 5th May and harvested on 9th September. Afterward, the soil was ploughed and ryegrass was sowed on 24th September and harvested on 7th January. A randomized complete block factorial design with four replicates was established, with an individual plot size of 28 m^2. Four treatments were applied: a control treatment without fertilizer, a second one with ammonium sulphate (AS) and two treatments consisting in the combination of AS with the new nitrification inhibitor 3,4-dimethylpyrazole-succinic acid (DMPSA) and with 3,4-dimethylpyrazole phosphate (DMPP), respectively. Maize fertilization was the usual in the region, split into two amendments: 5th May, when 80 kg N ha^{-1} were applied and 16th June, when 100 kg N ha^{-1} were applied. Ryegrass was not fertilized in order to observe any possible residual effects of the different treatments.

N_2O emissions were measured using a close chamber technique during the whole experimental period, with a frecuency of three days per week after fertilizer applications and decreasing this frequency gradually to one or two times per week. Samples were analysed by gas chromatography (GC) (Agilent, 7890A) equipped with an electron capture detector (ECD) for N_2O detection. N_2O standards were stored and analysed at the same time as the samples. Cumulative N_2O emissions during the sampling period were estimated by averaging the rate of emission between two successive determinations, multiplying that average rate by the length of the period between the measurements, and adding that amount to the previous cumulative total.

Results

During the maize crop cycle the application of N fertilizer as ammonium sulphate induced an increase in N_2O emissions. While cumulative emissions in the unfertilized treatment were 1.86±0.21 kg N_2O-N ha^{-1}, those from the treatment with ammonium sulphate were 2.39±0.30 kg N_2O-N ha^{-1}. Along the same period, both nitrification inhibitors reduced N_2O losses. When DMPP was applied combined with ammonium sulphate, the N_2O emissions had a magnitude of 1.86±0.15 kg N_2O-N ha^{-1}, thus being reduced up to the unfertilized treatment level. The application of the new nitrification inhibitor DMPSA induced cumulative losses even lower than in the unfertilized treatment, being these losses of 1.27±0.22 kg N_2O-N ha^{-1}. So, although both nitrification inhibitors have the same active molecule (dimethylpyrazole), the efficiency reducing N_2O emissions was different for each combined compound, being this efficiency higher for DMPSA. During the following months along the ryegrass lifecycle between september and january, cumulative N_2O losses were also affected by the previous spring fertilizer application to maize. While the unfertilized treatment showed cumulative N_2O losses of 0.56±0.06 kg N_2O-N ha^{-1}, the residual effect of the spring ammonium sulphate application induced losses of 1.42±0.22 kg N_2O-N ha^{-1} during this autumn period, while its combination with DMPP and DMPSA induced losses of 1.26±0.15 kg N_2O-N ha^{-1} and 1.51±0.36 kg N_2O-N ha^{-1}, respectively. Nevertheless, no significant differences between fertilized treatments were observed, which reveals no specific residual effect of the nitrification inhibitors was ocurring.

In the unfertilized treatment maize yield was 15,514±615 kg Dry Matter ha^{-1}. The application of ammonium sulphate increased the yield up to 18,769±589 kg DM ha^{-1}. The use of nitrification inhibitors maintained this yield value, being of 18,430±635 kg DM ha^{-1} for the DMPP treatment and of 18,563±482 kg DM ha^{-1} for DMPSA. As was observed for N_2O emissions, the application of fertilizer to maize in spring had a residual effect on ryegrass yield in january, since the unfertilized treatment yielded 1,409±97 kg D M ha^{-1}, while fertilized treatments showed higher yields, whitout differences among them. These ryegrass yields ranged from 2,305±109 kg DM ha^{-1} in the ammonium sulphate treatment to 2,153±105 kg DM ha-1 and 2074±176 kg DM ha^{-1} for DMPP and DMPSA treatments respectively, which reveals again, in terms of yield, no specific residual effect of the nitrification inhibitors applied on spring.

Conclusions

Both DMPP and DMPSA showed to be efficient nitrification inhibitors reducing N_2O emissions and maintaining yield in a maize crop. Nevertheless, in spite of having the same active molecule (dimethylpyrazole), DMPSA resulted to be better mitigating N_2O emissions. The positive effect of both nitrification inhibitors reducing N_2O emissions could not be observed residually in a longer term at the following ryegrass-crop period.

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EFFECT OF CONTRASTING APPLICATION TECHNIQUES ON AMMONIA EMISSIONS FOLLOWING FOOD-BASED DIGESTATE APPLICATIONS TO GRASSLAND

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Objectives

As a result of increasing pressure to divert biodegradable 'waste' from landfill, a wide range of 'new' organic materials are becoming available for recycling to agricultural land. Notably, the anaerobic digestion of source-segregated food waste is an area of significant growth in the UK. Typically *c.*90% of total N content of food-based digestate is in a readily available (ammonium-N) form. Minimising ammonia (NH_3) emissions following the land application of digestate is important to maximise crop available N supply and reduce environmental impacts. The effect of different application techniques on ammonia emissions following livestock slurry applications has been widely reported, however it is uncertain if the results from livestock slurries can be applied to food-based digestate. The overall objective of this work was therefore to evaluate the effect of shallow injection and bandspreading (trailing shoe) on ammonia emissions from food-based digestate applied to grassland, compared with conventional surface broadcast applications.

Method

The work was undertaken at the three experimental sites which are representative of agro-climatic zones used for grass production in the UK:

1. Newark (Nottinghamshire), England

2. Aberaeron (Ceredigion), Wales

3. Beith (Ayrshire), Scotland

At each site, there were 3 replicates of the following treatments, arranged in a randomised block design, viz:

1. Untreated control
2. Surface broadcast food-based digestate
3. Bandspread (trailing shoe) food-based digestate
4. Shallow injected food-based digestate
5. Surface broadcast livestock (cattle) slurry
6. Bandspread (trailing shoe) livestock (cattle) slurry
7. Shallow injected livestock (cattle) slurry

Treatments were applied in both the autumn (2013) and spring (2014) to separate plots at application rates targeted to supply 100-150 kg/ha total N. The food-based digestate had a pH of *c.*8.4 and dry matter content of *c.*3.6% compared to the cattle slurry which had a pH of *c.*8.0 and dry matter of *c.*6.6%.

Following application ammonia emissions were measured for seven days using wind tunnels [1].

Results

Analysis of the combined data from the three sites indicated the following:

- Ammonia emissions were around 1.4 times higher ($P<0.05$) from the surface broadcast food-based digestate (at *c.*30% of the N applied, or 44 kg/ha NH_4-N) compared with the surface broadcast cattle slurry (at *c.*22% of the N applied, or 21 kg/ha NH_4-N), reflecting the elevated ammonium-N content (*c.*3.6 kg/t compared to *c.*1.7 kg/t fresh weight) and higher pH (*c.*8.4 compared to *c.*8.0) of the food-based digestate.

- Both the trailing shoe and shallow injection application methods significantly (*P*<0.05) reduced ammonia emissions from the food-based digestate by 40-50% compared with surface broadcasting, although there was no significant difference between the effectiveness of the trailing shoe and shallow injection techniques.
- Only shallow injection reduced (*P*<0.05) ammonia emissions from cattle slurry compared with surface broadcasting; a reduction of *c.*50% was achieved.

The assessments of the effectiveness of precision application techniques in reducing ammonia emissions compared with broadcast applications in this study are comparable with other field-based experimental studies using livestock slurries [2]. However, although shallow injection reduced ammonia emissions, the greater susceptibility of shallow injection to the prevailing soil conditions was also highlighted in this study. Specifically, problems were experienced where soils were wet, leading to smearing of the injection slot which reduced infiltration of the food-based digestate and slurry into the soil. The trailing shoe technique is less affected by soil conditions, which together with lighter equipment, enables greater opportunity for spreading food-based digestate in wet springs.

Conclusions

Both precision application methods reduced ammonia emissions from food-based digestate by 40-50% in comparison with the surface broadcast treatments. In this study there was no difference between the effectiveness of the trailing shoe and shallow injection techniques when used with food-based digestate, however shallow injection was more effective than trailing shoe for cattle slurry applications, reducing ammonia emissions by *c.*50% compared with surface broadcasting.

The use of shallow injection when applying liquid organic materials (i.e. food-based digestate) to grassland is an important method for reducing ammonia emissions. However, it is more sensitive to soil conditions (e.g. wetness and stone content) than other application methods, which may be a barrier against its more widespread adoption in the UK.

References

[1] Lockyer, D. R. (1984). *Journal of the Science of Food and Agriculture*, **35**, 837-848.

[2] Misselbrook, T. H., Smith, K. A., Johnson, R. A. & Pain, B. F. (2002). *Biosystems Engineering*, **81**, 313-321.

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WHICH SOIL DATASET SHOULD I USE? SIMULATION UNCERTAINTIES FOR REGIONAL NITROGEN MANAGEMENT

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Objectives

Agro-ecosystem simulation models are increasingly used for assessing climate-soil-management effects on crop yield and nitrogen (N) leaching. The models require spatially and temporally detailed, site-specific, environmental (weather, soil) and field management data as inputs, which are often difficult to obtain consistently for larger regions. Moreover, the level of detail of the input data may impose uncertainty in the model simulations to an extent that is not well studied.

This study estimates the uncertainty of using three different soil datasets input to a simulation model in a regional nitrogen management approach. Based on the field-scale agro-ecosystem model *Daisy* [1], simulated crop yield and N leaching out of the root zone with each of the three soil datasets were obtained and up-scaled for a region in the North China Plain (NCP). The uncertainties are investigated by means of descriptive statistics and “beanplots”.

Method

The *Daisy* model was calibrated for crop production (dry matter yield and N content) and N leaching with field data of maize-winter wheat annual rotation in the NCP [2]. Three soil datasets were used as an input to the calibrated *Daisy*:
S1) point data from field station representing the entire region: a silty loam soil with 17% topsoil and 30% subsoil clay content.
S2) FAO Digital Soil Map of the World, nominal scale of 1:5.000.000, resolution 10x10 km, a vector-format data containing six soil types comprising four dominant soils in the region varying from sandy to clay loams with <30% clay in topsoil, but 18-34% clay in subsoil.
S3) specific Chinese soils described in [3], nominal scale 1:1.000.000, resolution 1x1 km, a multi-dimensional raster dataset; units with the highest spatial coverage were aggregated based on their frequency distributions, resulting in six dominant soils with 6-21% clay in topsoil and subsoil.
The soil hydraulics parameters of van Genuchten-Mualem for each soil type in the three soil datasets were derived by five pedo-transfer functions [4,5,6,7,8]. The final soil hydraulic parameters between the results from the pedo-transfer functions for each soil dataset were calculated with RETC [9].
The *Daisy* model was run for 2000-2013 and for all simulations: i) single-station weather data were used for the entire region, ii) three N fertiliser inputs (400, 600 and 800 kg N ha-1 year-1) were used as inputs, covering the lower and upper quartiles of the statistical N fertiliser data, iii) the sowing date of maize was 15 June, after which wheat was sown and harvested next year, and iv) crop growth was simulated under optimum irrigation.
The simulated mean annual crops yield (maize+winter wheat) and N leaching were up-scaled on a 5x5 km grid over Shijiazhuang prefecture using the spatially distributed cropping area. Uncertainty analysis was conducted with the use of descriptive statistics, “beanplots” showing the frequency distribution of crop yield and N leaching across the region, and maps.

Results

The median of the statistical yield was 13.6 Mg ha-1, ranging from 9-14 Mg ha-1. The spatial variation of statistical yield is partly attributed to weather variation across the region, whereas a single-station weather data was used in the simulations. Yet, there is low temperature gradient in the region, thus little effect on crop phenology, growth and associate evapotranspiration processes. Also, precipitation gradient is about 50 mm northwest to southeast in Shijiazhuang prefecture, which is leveled off with sufficient irrigation by the farmers. Hence, soil spatial variability, in addition to field management not accounted for in the study (e.g. P and K fertilisation, weed control), are probably the major contributors for yield variation in the study region. The soil input dataset influenced only marginally the modality (peaks) and the distribution range of simulated yield. The median yield simulated with S1 and S2 were, respectively, 11.0 Mg ha-1 and 11.5 Mg ha-1, and ranged 11-12 Mg ha-1 and 10-12 Mg ha-1. The median of simulated yield using S3 was 12.6 Mg ha-1, thus being closer to the statistical yield (RMSR=2.0 Mg ha-1) than the former two (RMSR=2.8 and 3.0 Mg ha-1, for S1 and S2 respectively).

The soil input dataset significantly influenced the modality (peaks) and the distribution range of simulated N leaching. The results for S1 and S3 showed similar leaching ranges of 30-160 kg N ha-1 and 5-180 kg N ha-1 respectively, whereas the variation in the results for S2 was higher and ranged as 8-250 kg N ha-1. However, S1 and S2 results had similar medians of, respectively, 59.1 and 59.6 kg N ha-1, whereas S3 results had median of 43.8 kg N ha-1. S1 cannot reflect the regional variation of N leaching and it was included only for comparison purpose. S2 shows markedly different soil texture across the region compared to S3, and requires percent-wise contribution of the soil types into the main soils. S3 provides soil texture consistent with the common knowledge of Chinese soil scientists and well-represented spatial variations over large areas.

Interestingly, all three soil datasets resulted in similar total annual N leaching for the region of 55600, 41600 and 49300 Mg for S1, S2 and S3 respectively. This means that the choice of soil dataset loses importance if the scale of the analysis is the entire Shijiazhuang region. However, careful choice should be made when the scale of the analysis is higher, e.g. county level or 5x5km grid as used in this study.

Conclusions

This study found that increasing detail of the soil dataset input to the *Daisy* model has minor uncertainty implications for simulating regional crop yield in Shijiazhuang region in the NCP, but it improves the simulation of the regional variation in N leaching. The results are useful for scientists and regional environmental managers in China and wider. The next step is inclusion of weather data from several stations across Shijiazhuang region in order to quantify the effect of weather variability on crop yield and especially N leaching, in comparison to the herein results obtained by using single-station weather data.

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References

[1] Hansen, S., Abrahamsen, P., Petersen, C.T., Styczen, M., 2012. *Daisy*: Model Use, Calibration and Validation. Transactions of ASABE 55, 1315-1333.
[2] Manevski K., Børgesen, C., Li X., Andersen M., Zhang X., Abrahamsen P., Hu C., Hansen S., 2016. (submitted).
[3] Shangguan, W. et al., 2013. J Adv Model Earth Syst 5(2): 212-224.
[4] Børgesen, C.D., Iversen, B.V., Jacobsen, O.H., Schaap, M.G., 2008. Hydrol Process, 22(11): 1630-1639.
[5] Rawls, W.J., Brakensiek, D.L., 1985. USDA.
[6] Schaap, M.G., Leij, F.J., van Genuchten, M.T., 1998. Soil Sci. Soc. Am. J., 62(4): 847-855.
[7] Weynants, M., Vereecken, H., Javaux, M., 2009. Vadose Zone J., 8(1): 86-95.
[8] Wösten, J.H.M., Lilly, A., Nemes, A., Le Bas, C., 1999. Geoderma, 90(3-4): 169-185.
[9] van Genuchten, M.T., Leij, F.J., Yates, S.R., 1991. USDA.

STRENGTH AND WEAKNESSES OF EARLY WARNING MONITORING SYSTEMS FOR WATER QUALITY PROTECTION: MONITORING EFFECTS OF MEASURES TO REDUCE NITRATE LEACHING

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Objectives

Agricultural use of nitrogen (N) decreased since the mid-1980s in the Netherlands[1]. This led to a strong improvement of environmental quality. However, in recent years the improvement came more or less to a standstill and target values are not always met for nitrogen. Further measures and legislations are nowadays drafted and implemented. To assess how effective these measures actually are, monitoring water quality is essential. In the Netherlands, like most countries, water quality is monitored by permanent groundwater wells in combination with surface water monitoring of larger (agricultural fed) canals and streams. Additionally, the water leaching from the root zone and ditch water is sampled on farms, enabling an early warning monitoring system. In this study we compared three monitoring networks in the Netherlands to assess the capability of these networks to detect the effects of measures to reduce nitrate leaching on groundwater and surface water quality.

Method

This paper compares three monitoring programmes in the Netherlands; (1) the National Groundwater Quality Monitor Network (LMG), (2) the Monitoring Network for Nutrients in Agriculture Specific Headwaters (MNLSO), and (3) the Minerals Policy Monitoring Programme (LMM).

Groundwater quality under agricultural, natural and urban areas is measured in the LMG throughout the Netherlands[2]. The LMG network was established in 1984, and comprises approximately 350 groundwater wells. At each well, groundwater is sampled at 10, 15 and 25 meters below surface level.

Surface water quality is monitored in the MNLSO at locations in agriculture specific headwater streams and canals[3]. The MNLSO was established in 2012 and is composed of existing sampling locations of the Dutch Water Authorities. Only locations where agriculture was the only relevant antropogenic source of nutrients were selected (no point sources such as sewage systems in the source area). In total, 173 locations were selected for compliance testing and 99 of these locations have time series of at least 10 years and were also used for trend analysis.

Additionally, the Minerals Policy Monitoring Programme (LMM) monitors the effect of the manure policy on agricultural practices and water quality at farm level[4]. At these farms both root zone leaching water and ditch water are sampled. Starting in 1992, in the Sand region, nowadays the LMM comprises about 450 farms, covering the main farm types in all four main soil type regions.

For this paper we compared annual mean monitored nitrogen concentrations of all three monitoring programmes, and compared these with national N-surpluses for the 1990 - 2014 period. Effects of weather influences, period of sampling and differences in sampling population were taken into account. The strengths and weaknesses of the three monitoring networks for assessing effects of measures were discussed.

Results

In the Netherlands, around 1985 the maximum in soil nitrogen surplus was found. Since then the surplus declined from 400 to 180 kg N ha^{-1} of agricultural land in 2011. As a consequence the nitrogen concentration decreased in the upper meter of the groundwater (LMM), having a very short response time. For instance in the sand region, the nitrate concentration in leaching water decreased from around 150 mg NO_3 l^{-1} on the average to about 50 mg NO_3 l^{-1} between 1996 and 2014. In the headwaters of the MNLSO a relatively rapid response was seen as well, due to shallow groundwater levels and relative short flow routes. Nitrate concentrations declined roughly from 25 to 15 mg NO3 l^{-1}. At a depth of 5 to 15 meter in the groundwater (LMG) the peak in nitrogen concentration was found with a delay of about 10 years after the peak of the soil nitrogen surplus. NO3 concentrations increased from the start of the monitoring network in 1984 up to 1996, following the same trend as the national nitrogen surplus numbers. A maximum concentration of 28 mg NO3 l^{-1} was found in 1996 and concentrations decreased as from 1997 onwards.

Preliminary results show that the LMM detects effects of measures most rapidly, due to short travel times of water and nitrate to the sampled root zone leaching and local ditch water, and therefore relative small impacts of soil processes on water quality. Additionally, the results are not or minimally influenced by non-agricultural sources of nutrients. A disadvantage is the relatively large spatial and temporal variability, due to small spatial and temporal extend (farms which are sampled between 1 and 9 times per year). Because of this small temporal extent, the effect of weather variations are larger, attributing to the influence of sampling season on measured water quality. Especially ditch water quality is sensitive for sampling season and weather variations. Both the LMG and the MNLSO monitoring networks give a better view of how much nitrate is either penetrating down into the deep groundwater resources (leaching minus denitrification) and how much nitrogen is discharged towards downstream surface water reservoirs after mixing and uptake by biota. However, lag times are larger for these waters, especially for groundwater.

Conclusions

The LMM detects effects of measures most rapidly for groundwater and surface water. The groundwater measured in the LMG has a longer response time. For surface water the MNSLO responds relatively rapid as well. The LMM could function as an early warning system for effect of measures on water quality in the Netherlands, but has a relatively large spatial and temporal variability. For surface water quality the MNLSO could have a similar function, and has the advantage of smaller spatial and temporal variability. Such an early warning monitoring system can help drafting the most effective measures and legislations, and aid in reaching both a healthy agricultural sector and a healthy environment.

References

[1] Hooijboer, A., De Klijne, A, (2012). Waterkwaliteit op landbouwbedrijven. Evaluatie Meststoffenwet 2012: deelrapport ex post. RIVM, Bilthoven, The Netherlands, report 680123001.

[2] Van Vliet, M.E, Vrijhoef, A., Boumans, L.J.M., Wattel-Koekkoek, E.J.W. (2010). De kwaliteit van ondiep en middeldiep, grondwater in Nederland in het jaar 2008 en de verandering daarvan in 1984-2008. RIVM, Bilthoven, The Netherlands.

[3] Rozemeijer, J. C., Klein, J. Broers, H. P., van Tol-Leenders, T.P., Van der Grift, B., 2014. Water quality status and trends in agriculture-dominated headwaters; a national monitoring network for assessing the effectiveness of national and European manure legislation in The Netherlands. Environmental Monitoring and Assessment 186, 8981-8995.

[4] De Goffau, A., Van Leeuwen, T.C., Van den Ham, A., Doornewaard, G.J., Fraters, B. (2012). Minerals Policy Monitoring Programme Report 2007 - 2010. Methods and Procedures. RIVM, Bilthoven, the Netherlands.

NITROGEN LOSSES FROM AUSTRIAN AGRICULTURAL SOILS - MODELLING TO EXPLORE TRADE OFF-EFFECTS (NITROAUSTRIA)

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Objectives

Results of the ACRP project “FarmClim” highlight that the IPCC default emission factor is not able to reflect region specific N_2O emissions from Austrian arable soils. The methodology is limited in identifying hot spots and hot moments of N_2O emissions. When estimations are based on default emission factors no recommendations can be given on optimisation measures that would lead to a reduction of soil N_2O emissions.

The better the knowledge is about Nitrogen and Carbon budgets in Austrian agricultural managed soils the better the situation can be reflected in the Austrian GHG emission inventory calculations. Therefore national and regionally modelled emission factors should improve the evidences for national deviation from the IPCC default emission factors and reduce the uncertainties.

The overall aim of NitroAustria is to identify the drivers for N_2O emissions on a regional basis taking different soil types, climate, and agricultural management into account.

Method

NitroAustria uses the LandscapeDNDC model to update the N_2O emission factors for N fertilizer and animal manures applied to soils. It includes Austrian specific data on agricultural management and integrates climate change scenarios. Results will be evaluated for integration into the national emission inventory.

Key regions in Austria will be selected and region specific N_2O emissions calculated using the LandscapeDNDC model. The software is able to simulate N cycling of agro-ecosystems and associated matter flux into the atmosphere and hydrosphere.

Using this approach will help to identify hot spots and hot moments of N_2O emissions. Finally recommendations can be given regarding optimization measures which support the reduction of soil N2O emissions. The derivation of suitable mitigation options by optimization of common and evaluation of potential management practices for current and future climatic conditions is crucial to minimize threats to the environment while ensuring the long-term productivity and sustainability of agro-ecosystems.

The topic will be covered in an interdisciplinary approach including nationally and internationally highly recognized experts from science and reporting. Since a strong connectivity to the commercial farming experts exist, project results will be communicated and transferred to keep the science-policy gap at a minimum.

Results

NitroAustria is divided into six work packages. WP 1 is responsible for the coordination and management of the project and for the dissemination of project results. WP 2 “Data acquisition and harmonization” collects data and provides them to WP 3 “Estimating N_2O emissions form arable soils” where the data are used to model N_2O emissions and nitrate leaching from arable soils. WP 3 performs process based modelling at site, regional and national scale. It delivers C and N budgets, N_2O emissions, data on nitrate leaching, region specific emission factors and potential mitigation options with improved agricultural management for current and future climatic conditions. The model runs at sub-daily time steps and uses data such as maximum and minimum air temperature, precipitation, radiation, and wind speed as meteorological drivers. Further input data are needed to reflect agricultural management practices, e.g., planting/harvesting, tillage, fertilizer application, irrigation and information on soil and vegetation properties for site characterization and model initialization. Using these input data, LandscapeDNDC predicts soil environmental factors such as substrate availability (C and N), soil temperature and moisture as well as partitioning of anaerobic/ aerobic micro-sites for all user defined soil layers, which are finally driving microbial N turnover processes of nitrification and denitrification and associated losses of e.g. N_2O and NO_3^-. Management according to good practice will be displayed in the model.

WP 4 “Providing data on agricultural management in Austria” is led by AGES. While at site scale, arable management data (crop cultivation, rotations, timings etc.) is obtained by experimental data from AGES field trials or observations, at regional scale such data needs to be generated using region specific proxy data such as land use and management statistics, crop cultivations and yields, crop rotations, fertilizer sales, manure resulting from livestock units etc. WP 4 provides crop rotation scenarios from arable regions and of agro-environmental measures.

Umweltbundesamt is in charge of WP 5 “Application of results and use for the GHG inventory”. The farming community only profits from NitroAustria, if model developments and results are integrated into the national emission inventory. Trade-offs between different greenhouse gas emissions and other nitrogen losses will be discussed. WP 5 will be able to show potential environmental impacts of the results gained in NitroAustria and proposes measures for a policy framework towards climate friendly farming. BFW leads WP 6 “Climate change scenarios and statistical analysis of modelling results” and performs site/regional/national LandscapeDNDC simulations considering scenarios of climate change. WP6 assesses factors that influence N_2O emissions in various Austrian regions and suggests site/region specific mitigation measures.

Conclusions

Climate smart agriculture has been defined as agriculture that sustainably increases productivity and resilience (adaptation), reduces greenhouse gases (mitigation), and enhances food security and development. Application of process based models provides a valuable tool to calculate GHG emissions and N leaching from soils. In particular modelling approaches are prerequisite to estimate N_2O emissions at various temporal and spatial scales, to assess different mitigation options and to understand and predict feedbacks of global changes (here climate, land-use and land-management changes). NitroAustria will improve estimations of soil N2O emissions by region specific modelling. It will evaluate and - if necessary - adapt existing models for gaseous nitrogen and carbon losses and make suggestions on measures for optimum fertilisation with organic and inorganic fertilizers.

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DETERMINING SPATIAL IRREGULARITIES OF NITRATE CONCENTRATIONS IN IRRIGATION RETURN FLOWS OF MEDITERRANEAN IRRIGATION SUB-CATCHMENTS

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Objectives

In order to sustain food security, irrigation and fertilization of crops are the integral part of agricultural production in arid and semi-arid countries including Mediterranean region. However, nitrate contamination of aquatic environments, such as groundwater, surface water, lagoons etc., from both rain-fed and irrigated agriculture is a common problem in many countries [1]. In this regard, irrigated agriculture induce much more negative impacts on the quantity and quality of natural resources such as land degradation by salinization and sodification and increased salt and nitrate loads in irrigation return flows (IRFs) and receiving water bodies, compared to the rain-fed agriculture. Therefore, it is necessary to know the spatial irregularities of nitrate concentrations of IRFs in the agricultural sub-catchments to take precautions. Objectives of this work were to: a) monitor nitrate concentrations of IRFs in irrigation sub-catchments, b) try to determine spatial irregularities by nitrate concentration index approach.

Method

In order to achieve the designated objectives, the work was conducted in an intensive agricultural catchment (Akarsu irrigation district, 9495 ha), located in the Mediterranean region of Turkey. Based on the drainage network of the District, five sub-catchments (DOi, i=1,5) were established for IRF sampling to determine nitrate concentrations. IRF samples were taken on daily base from the major outlet of the catchment (n=365), and biweekly samples from DOi points (n=26) in the 2015 hydrological year (HY). HY considered starting on the 1st of October of the active year and finishing at the end of September in the following year. Nitrate concentrations of IRFs were determined in the laboratory following standard procedures. Based on the cropping pattern determined for 2015 HY, wheat was the major crop (16%) grown in winter. However, first crop corn (36%) and soybean (26%) were the most dominant irrigated field crops in the District. Citrus was the only preponderant horticultural crop in the catchment. In order to determine spatial irregularities of nitrate concentrations in IRFs, "Precipitation Concentration Index (PCI)" proposed by Oliver [2, 4] was adopted for this study and dubbed as "Nitrate Concentration Index (NCI)" to figure out spatial distribution irregularities (anomalies) [3] of nitrate concentration for IRFs observed at the determined points. The necessary modifications were done on the NCI formula based on the calculation scales, i.e., daily and biweekly scales. Anderson-Darling normality test was performed to detect normality of nitrate concentration series, and the Kruskal-Wallis test was applied to compare means of nitrate concentration series for the six observation points. Mann-Whitney U-test was executed to figure out which observation point of nitrate concentrations is significantly different from the other.

Results

Descriptive statistics revealed that nitrate concentration series of IRFs observed at the DOi (i=1,5) and outlet of the catchment were characterized with a right-skewed distribution, indicating that the six groups (observation points) were not normal. Anderson-Darling normality test results proved that normality assumption for nitrate observations could not be met at all points. Nitrate concentrations were over the threshold value of 50 mg per liter during the rainy season revealing fertilizer leaching by rainfall events. During the irrigation season concentrations were generally below the value of 35 mg per liter at all the monitoring sites, except for DO5 observation point draining mostly citrus planted areas. Surprisingly, the Kruskal-Wallis One-Way ANOVA displayed a significant result indicating the presence of significant differences among 6 observation points or groups regarding nitrate concentration series of IRFs. By performing the multiple-comparison techniques, i.e., Mann-Whitney U-test, it was found that nitrate concentrations at DO1, draining only corn and soybean grown areas, was significantly different (alpha=0.05) from others including the main outlet of the basin. On the other hand, according to the “Nitrate Concentration Index (NCI)” classification [2], it was suggested that “NCI” values of less than 10 represent a uniform nitrate distribution; “NCI” values from 10 to 15 denote a moderate nitrate concentration; values from 16 to 20 denote irregular distribution and values above 20 represent a strong irregularity of nitrate concentration at the observation stations distribution over the time domain. Based on this information, “NCI” for DO1 observation point denoted nearly a uniform nitrate distribution over the observation period; in this regard, the overall variability was found the lowest (CV=57%) at the DO1 point supporting “NCI” value. On the other hand, “NCI” values denoted a moderate nitrate concentration for DO2, DO3, DO5 and main outlet of the catchment. Contrary to those, “NCI” of DO4, draining both horticultural and field crop areas (fifty by fifty), indicated irregular nitrate concentration distribution in the HY 2015.

Conclusions

Nitrate concentrations at the observation points were subject to change spatially and temporally. Normality assumptions for nitrate concentrations could not be met, therefore, nonparametric methods should be used to figure out if there exist any differences among the groups. Nitrate Concentration Index might be introduced to detect spatial irregularities in the nitrate concentration series over the time domain.

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References

[1] Nakagawa, K., Amano, H., Asakura, H., Berndtsson, R. 2016. Environ Earth Sci., 75:234.

[2] Oliver, J. E. 1980. Prof. Geogr., 32, 300-309.

[3] De Luis, M., Gonzalez-Hidalgo, J. C., Brunetti, M, Longares, L. A. 2011. Nat Hazards Earth Syst Sci., 11, 1259-1265.

[4] Longobardi, A., Buttafuoco, G., Caloiero, T., Coscarelli, R. 2016. Environ Earth Sci., 75:189.

INTERACTIONS BETWEEN TILLAGE SYSTEM, NITROGEN FERTILIZATION AND COVER CROPPING DETERMINE N_2O FLUXES

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Objectives

Agricultural soils play an important role in the global fluxes of nitrous oxide (N2O), with tillage practices, crop choice and nitrogen fertilization levels as important factors regulating the magnitude of emissions. The main objective of this study was to determine the long-term effects of a shift from conventional tillage, using ploughing, to reduced tillage with only shallow cultivation. In addition, we wanted to determine if the level of nitrogen fertilization affected the emissions and if there was interaction between tillage system and nitrogen level with regard to N_2O fluxes. We hypothesized that N_2O emissions would be larger in the reduced tillage treatment, that a higher level of N fertilization would lead to larger N_2O emissions and that the combination of reduced tillage and high nitrogen fertilization levels would cause especially high emissions.

Method

The study was carried out within a long-term cropping systems field experiment at the SITES Lönnstorp Research Station in Sweden. The experiment had been running for 18 years at the start of this study and included conventionally tilled plots (plowed, 1 ha each) and plots with reduced tillage (shallow tillage, 3 ha each). The tillage treatment plots contained response plots with different nitrogen fertilization levels, which had been in place since the start of the experiment. Measurements of N_2O fluxes were carried out in two fields cropped with cereals (winter wheat or spring barley) and in one field cropped with sugar beet. The measurements continued for three years, with new fields each year, following the crop rotation of the field experiment. Fluxes of N_2O from the soil were measured using manual static chambers. Measurements were carried out approximately biweekly, with additional measurements during periods with expected high emissions. Gas samples were analyzed using gas chromatography.

Results

Preliminary results from the first two years of the study show that for the sugar beet fields, the N_2O emissions were similar for the two systems when the N application was low (below the standard rate) but when the N rate was high (above the standard rate) the emissions were approximately double from the reduced tillage fields compared to the conventional system. When cereals were grown, the system with reduced tillage also included ley that was sown in in the spring or an oil radish cover crop that was established after harvest of the cereal and incorporated by shallow cultivation in late autumn. The preliminary results show that in the fields with reduced tillage and in-sown ley, the N_2O emissions were slightly lower than from the conventional system, while in those with reduced tillage and an oil radish cover crop, the N_2O emissions were approximately double those from the conventional system.

The N_2O emissions were generally higher when the nitrogen fertilization rate was above standard, compared to when it was below, except for the fields with conventionally grown sugar beets, where the emissions seemed not to be affected by the nitrogen fertilization rate. Some of the main emission peaks occurred in November, just after the harvest of the sugar beets and the incorporation of the oil-radish cover crop. It seems that disturbing the soil and adding leaf residues at a time when the soil is wet has profound effects on the annual N_2O emissions. The hypothesis that N_2O emissions would be particularly high when reduced tillage was combined with a high level of nitrogen fertilization seemed to be confirmed by the results from the sugar beet fields. For the fields where cereals were grown, the choice of crop following the cereal (ley or oil radish) seemed to dominate over the soil tillage treatment in determining the annual N_2O emissions.

Final results will be presented at the workshop.

Conclusions

Annual N_2O emissions varied widely with choice of crop, tillage treatments and nitrogen fertilization levels, which indicates a large potential for mitigation of N_2O emissions from agricultural land by the modification of cropping systems. Since there were large N_2O peaks after sugar beet harvest there may be scope for drastically decreasing N_2O emissions by harvesting sugar beets earlier in the autumn or by removing the harvest residues for production of biogas. From an N_2O point of view, an oil radish cover crop that is incorporated into the soil in late autumn may be unsuitable.

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OPPORTUNITIES TO REDUCE NITROUS OXIDE EMISSIONS FROM AGRICULTURAL SOILS: EMISSION REDUCTION POTENTIALS AND COSTS

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Objectives

Analysis of emissions from crop production indicates that N_2O (nitrous oxide) emissions from fertilizer application have the largest impact on global warming as compared to emissions from other production operations (Adler et al. 2007). This emphasizes the need to abate nitrogen flows from agricultural production. Various abatement options are available to mitigate N_2O emissions from agricultural soils. However, the emission reductions and associated costs of existing abatement technologies exhibit variability and analysis of current technologies are lacking. This study identifies current and prominent abatement technologies, in an effort to improve and update existing N_2O abatement options.

The objectives of this study are summarized below.

- Describe the various abatement options available to mitigate N_2O emissions from agricultural soils
- Estimate possible emissions reductions and costs from implementing the abatement options
- Develop abatement cost curves for implementation in the GAINS (Greenhouse Gas - Air Pollution Interactions and Synergies) - model

Method

GHG (greenhouse gas) emissions are not only estimated for the sake of reporting, but also with a purpose of assessing the potential of abatement opportunities to reduce emissions. A range of options are available to reduce N_2O emissions from agriculture. The GAINS model has been used to quantify such reductions from abatement options, as well as their associated costs for the years 2005 to 2050 for the 28 countries of the European Union (EU) (Winiwarter 2005, Höglund-Isaksson et al. 2013). Defining abatement options in GAINS involves continuously updating and adding mitigation measures when new knowledge and scientific evidence is available. While little additional information can be expected for the well-established abatement options, study of recent scientific literature helps to establish a better understanding of further abatement options that are expected to become available in the foreseeable future.
In this study we analyze six N_2O abatement options: • VRTs (variable rate technologies) • Crop rotations • Tillage management • Timing and mode of fertilizer application • Type of fertilizers and • Enhanced efficiency fertilizers (including traditional inhibitors). Emission reductions and costs (when available) for all the six abatement options are quantified, from evidence in recent scientific literature. Additionally, key differences, caveats in implementation (feasibility, implications on yield etc.) and uncertainty in emission reductions and costs among and within the abatement options are also discussed. This will help improve and extend the existing implementation of N_2O abatement options in GAINS.

Highlights of the methodology are summarized below

- Scope: European Union (EU) countries for current and future projections
- Data sources: Published literature
- Models used: Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model
- Approach: Develop abatement costs curves for mitigation options and implement them in GAINS

Results

This study describes six management options that could reduce N_2O emissions. Within the individual abatement options specific technologies are discussed from various individual studies and used to estimate the overall emission reduction and cost. Other scientific studies, which aggregate emission reductions without addressing specific abatement options and pathways, report N_2O emission reductions in the range of 35 to 50% (Oenema et al. 2013, FAO 2001, Davidson 2012). In this study, the aggregated emission reductions is around 40%. This is comparable to the emission reduction numbers reported in previous literature.

Among the six abatement options, the management options like tillage management, crop rotations, changing fertilizer type and changing timing and mode of fertilizer application showed mixed responses in terms of emission reductions. While some studies report a decrease in N_2O emissions from implementing the above four management practices, others show an increase in emissions. These variations are due to differences in geography, cropping systems and interaction between management practices. These differences and reasons for variation are outlined and described in detail. Costs associated with implementing the above management practices were observed to be negligible. The other two abatement options namely: VRTs and enhanced efficiency fertilizers, specifically nitrate and urease inhibitors, yield favorable emission reductions, albeit at a moderate cost. Existing evidence from 25 field studies show emission reductions of 24% and 38%, respectively, compared to conventional fertilizer application.

There are only a handful of studies available that allow to attribute cost information. Cost is also highly variable, depending on farm structure, farm size and assumption on specific farming conditions such as investments for equipment, fertilizer prices and amount of fertilizer that can be saved. Depending on the specific situation, either VRT or inhibitors may turn out to be the most cost-effective control, at specific costs between 30 and 60 €/ton CO_2-eq. Implementing this detailed information in GAINS allows to create cost curves and to compare effective GHG mitigation options within and beyond the sector agriculture.

However, it is important to note that achieving the estimated emission reductions at the calculated cost using abatement technologies described here, might pose a challenge. Firstly, choosing the mean emissions reduction from a group of contrasting estimates already renders the analysis uncertain. The emission reduction estimates may refer to only cases of successful implementation of abatement technologies. There are also huge differences in geography, cropping systems and management practices among the studies considered while calculating emissions and cost estimates. Finally, measuring and monitoring N_2O emissions are fairly difficult and highly variable in space and time. Hence even the individual estimates referenced from studies are prone to uncertainties.

Conclusions

Crop production is a source of food and is indispensable to society. However, it is a major source of N_2O emissions. International agreements to reduce agricultural emissions have not been effective, in part due to missing concepts of realistic “low- carbon” situations. This study describes N_2O abatement strategies and identifies economically viable low-carbon mitigation strategies which would be helpful for farmers, crop advisors and policy makers.

References

[1] Adler, P. R., S. J. D. Grosso, and W. J. Parton. 2007. Life-cycle assessment of net greenhouse-gas flux for bioenergy cropping systems. Ecological Applications 17:675-691.

[2] Davidson, E. A. 2012. Representative concentration pathways and mitigation scenarios for nitrous oxide. Environmental Research Letters 7:024005.

[3] FAO. 2001. Global estimates of gaseous emissions of NH_3, NO and N_2O from agricultural land. Food

and Agriculture Organization of United States and International Fertilizer Industry Association, Rome.

[4] Höglund-Isaksson, L., W. Winiwarter, and P. Purohit. 2013. Non-CO_2 greenhouse gas emissions, mitigation potentials and costs in the EU-28 from 2005 to 2050. International Institute for Applied Systems Analysis (IIASA), Laxenburg.

[5] Oenema, O., X. Ju, C. Klein, M. Alfaro, A. del Prado, J. Lesschen, and C. Kroeze. 2013. Reducing N_2O emissions from agricultural sources. Pages 17-25. Drawing Down N2O to Protect Climate and the Ozone Layer. UNEP, Nairobi.

[6] Winiwarter, W. 2005. The GAINS model for greenhouse gases-version 1.0: nitrous oxide (N_2O). International Institute for Applied Systems Analysis (IIASA), Laxenburg.

NO-TILLAGE AND MEDIUM RATES OF PIG SLURRY FERTILIZATION MITIGATE YIELD-SCALED N2O EMISSIONS IN DRYLAND MEDITERRANEAN AGROECOSYSTEMS

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Objectives

Agriculture is an important contributor to the rise of atmospheric N_2O. Agricultural management practices (e.g., tillage or N fertilization) significantly influence the emission of N_2O from soils due to changes in the production, consumption and transport of gases through the soil matrix. However, to be environmentally and economically sustainable, the selection of management practices for N_2O mitigation must take into account crop productivity. This last aspect is of capital importance in dryland Mediterranean conditions, given the limitations imposed by water scarcity. Thus, the objective of this work was to identify the best combination of tillage and N fertilization practices to mitigate N_2O emissions while maintaining yields in semiarid Mediterranean agroecosystems.

Method

The study was carried out in two experimental fields devoted to winter cereals and located in the Ebro river valley (NE Spain). In the long-term experiment (LTE) (established in Agramunt in 1996; 430 mm annual rainfall), two types of tillage (NT, no-tillage; CT, conventional intensive tillage with moldboard plough) and three mineral N fertilization rates (0, 60 and 120 kg N ha^{-1}) were compared. In the short-term experiment (STE) (established in Senés in 2010, 330 mm annual rainfall), two tillage systems (CT with disk plow and NT) and three N fertilization rates (0, 75 and 150 kg N ha^{-1}) using two fertilizer types (mineral N and organic N with pig slurry) were compared. Both experiments consisted of a randomized block design with three replications. Plot size was 50x6 m in LTE and 40x12 and 40x6 m in STE organic and mineral N plots, respectively. Measurements covered one (2011-12) and two (2011-12 and 2012-13) cropping seasons in LTE and STE experiments, respectively. N_2O emissions were measured with non-steady-state chambers every two weeks and more intensively during N fertilization applications. Cumulative N_2O emissions for each growing season were calculated with the trapezoid rule. Soil samples (0-5 cm depth) were obtained at every sampling date for the determination of the water-filled pore space (WFPS), mineral N (NH_4^+ and NO_3^-). Grain yield was harvested with a commercial combine and weighed. Finally, the yield-scaled N_2O ratio (kg of CO_2 equivalents emitted per kg of grain produced) was calculated.

Results

The NT treatment presented the highest WFPS values in most dates. Nitrogen application produced significant peaks of N_2O. The maximum N_2O fluxes measured (i.e., 1.14 mg N_2O-N m^{-2} d^{-1}) were within the range of values reported under Mediterranean conditions [1].

In LTE, the average N_2O flux was 0.137 and 0.141 mg N_2O-N m^{-2} d^{-1} for the CT and NT treatments, respectively, without significant differences, which could be explained by the improvement of soil structure under long-term NT [2]. Contrarily, in STE, greater emissions were observed under NT than CT (0.205 and 0.139 mg N_2O-N m^{-2} d^{-1}, respectively). The application of different N rates in LTE did not affect N_2O fluxes (0.113, 0.122 and 0.181 mg N_2O-N m^{-2} d^{-1} for the 0, 60 and 120 kg mineral N ha^{-1}). As a difference to LTE, in STE the application of N significanty increased N_2O emissions (i.e., 0.102 vs 0.271 mg N_2O-N m^{-2} d^{-1} for the control and the application of 150 kg mineral N ha^{-1}). For a given N rate, no differences were found between N types (mineral or organic) in the average N_2O flux.

NT significantly increased the production of grain. However, in the 2011-12 growing season, and due to a severe water deficit, yield values were very low: 246 and 1554 kg ha^{-1} under CT and NT, respectively, in LTE and 437 and 806 kg ha^{-1} under CT and NT, respectively, in STE. In contrast, grain yields in 2012-13 reached 1343 and 4886 kg ha^{-1} under CT and NT, respectively, in STE, demonstrating the benefits of NT to store more water in the soil, resulting in greater yields and N responses [3]. Similarly to LTE, in STE grain yield response to N was only observed under NT, with 3322, 4519 and 4937 kg ha^{-1} when applying 0, 75 and 150 kg N ha^{-1}, respectively. However, the use of a medium rate of pig slurry under NT appeared as the best choice for grain production, with 5933 kg ha^{-1}.

The use of NT greatly reduced the yield-scaled N_2O emissions compared with CT in LTE in 2011-12, with 0.47 and 0.04 kg CO_2 equiv. kg grain^{-1}under CT and NT, respectively. In STE tillage systems also affected the yield-scaled N_2O emissions with 0.29 and 0.18 kg CO_2 equiv. kg grain^{-1} when using CT and NT, respectively, as an average of the 2011-12 and 2012-13 seasons. Differences between N fertilization treatments in yield-scaled emissions of N_2O were only found in STE. In this experiment, the combination of NT and the application of medium rates of pig slurry resulted in the lowest yield-scaled N_2O emission (i.e., 0.09 kg CO_2 equiv. kg grain^{-1}).

Conclusions

In rainfed Mediterranean agroecosystems, the combination of long-term NT and pig slurry as N fertilizer is an efficient management practice for reducing yield-scaled N_2O emissions while maintaining or, even, increasing grain yields.

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References.

[1] Meijide, A. et al. 2009. Agric. Ecosys. Environ 132, 106-115.

[2] Plaza-Bonilla, D. et al. 2013. Geoderma 193, 76-82.

[3] Cantero-Martínez, C. et al. 2003. Field Crop Res. 84, 341-357.

SPATIAL VARIATION IN SOIL PH CONTROLS OFF-SEASON N_2O EMISSIONS

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Objectives

Long before N_2O emissions from soils became an environmental issue, Wijler and Delwiche [1] and Nommik [2] observed that the production of nitrous oxide (N_2O) relative to dinitrogen (N_2) during denitrification is higher in acid than in neutral soil. More recent work suggests that this is likely because low pH interferes with the expression of N_2O reductase in denitrifying bacteria [3][4]. We hypothesized that local pH variation in cultivated soil controls in situ N_2O emissions during periods of active denitrification, i.e. when soil moisture and supply of organic C are high. To test this hypothesis, we measured emissions and soil pH in a wheat field during off season and compared field emissions to denitrification kinetics and $N_2O/(N_2O+N_2)$ product ratios under standardized laboratory condition.

Method

As a test location, we chose a spring wheat field in Southeast Norway, previously used in a four-year fertilizer trial (just terminated), in which we identified three plots from the same fertilization treatment and with similar soil properties but with marginally different soil pH (5.4-5.9). All selected 2x8 m plots had been fertilized with 200 kg N ha^{-1} during the cropping season. We installed four permanent 50 x 50 x 20 cm aluminum frames in each plot for N_2O closed chamber measurements and monitored N_2O emissions in all 12 frames during autumn (post-harvest until snow cover) and during two periods in the spring (snowmelt and late spring prior to tillage). Soil samples were taken immediately after flux measurements on every sampling date to determine pH, NH_{4+} and NO_{3-}, and loss on ignition (LOI). At the end of the field experiment, we took replicate soil samples from each frame and determined in laboratory assays potential oxic and anoxic respiration, along with the kinetics of NO, N_2O and N_2 production during denitrification. Anoxic incubations were performed both with and without glutamate addition to explore possible confounding between C-availability and the pH response of denitrification and product kinetics. We used a robotized incubation system, which measures headspace concentrations of O_2, CO_2, NO, N_2O and N_2 at high temporal resolution. The data were used to calculate an N_2O index, I_{N2O}, which is an inverse measure of the capacity of the denitrifying community to effectively express N_2O reductase under anoxia, and hence a proxy for the soil's propensity to emit N_2O under denitrifying conditions.

Results

N_2O emissions in autumn were low (0.1-110 µg N_2O-N m^{-2} h^{-1}) and declined gradually with declining soil temperature. High emissions (up to 438 µg N_2O-N m^{-2} h^{-1}) were observed during snowmelt and soil thawing, whereas emissions during late spring were low. The plot with the highest soil pH (plot 1, pH 5.80) had the smallest emission and the plot with the lowest pH (plot 3, pH 5.48) had the greatest emission. However, there were consistent differences in N_2O emissions between the frames within each plot, and even between adjacent frames. This variations were explored by inspecting the relationship between cumulative emissions and the pH measured in the individual frames, and by inspecting the pH dependency of the $N_2O/(N_2O+N_2)$ ratio in the glutamate amended incubations (I_{N2O}). Cumulative emissions measured in the field were negatively related to pH in the autumn and the thawing period ($r = -0.662$; $p = 0.019$), but not for the late spring period. I_{N2O} varied between 0.06 and 0.32, and showed a strong negative correlation ($r = -0.754$; $p < 0.0001$) with measured pH. We hypothesized that the N_2O index is a better predictor for N_2O emissions than pH alone because the index subsumes both the direct (proximal) effect of pH and its "distal" effect (via altered microbial community composition). This was supported by a clear correlation between cumulative N_2O emissions and I_{N2O} for autumn ($r = 0.844$; $p = 0.001$) and the thawing period ($r = 0.753$; $p = 0.005$), but not for the late spring period ($r = 0.305$; $p = 0.311$). Pearson correlation suggested a high degree of collinearity between soil pH, I_{N2O}, NO_{3-}, NH_{4+} and TOC and further MLR tests confirmed the high degree of inter-correlation in the dataset.

It appears likely that emissions during autumn thawing were dominated by denitrification, driven by decomposition of fresh plant litter and high soil moisture content during the autumn, and by freeze-thaw driven release of organic substrates. We cannot exclude that spatial variation in NO_{3-} concentrations and organic carbon availability may have had some influence on the spatial variability of N_2O emission. However, spatial variation in soil pH was the strongest factor determining the spatial variation in N_2O emission during the autumn and thawing period. In contrast, we found no correlation between pH and emission for the late spring period. Our tentative explanation for this is that the low emissions during late spring are primarily from nitrification, unrestricted by oxygen because the soil was well drained and there was no recent input of fresh organic material (in contrast to the autumn period).

Conclusions

The results support our hypothesis that small-scale variation in pH is an important controller for the denitrification product ratio in cultivated soil with measurable consequences for N_2O emissions. Since off-season emissions dominate N_2O budgets in many regions, careful soil pH management by “precision liming” appears to be an effective way to reduce N_2O emissions.

References

[1] Wijler, J., Delwiche, C.C. 1954. Investigations on the denitrifying process in soil. Plant and Soil 5, 155-169.

[2] Nommik, H. 1956. Investigations on denitrification in soil. Acta Agriculturae Scandinavica 6, 195- 228.

[3] Bakken, L.R., Bergaust, L., Liu, B.B., Frostegard, A. 2012. Regulation of denitrification at the cellular level: a clue to the understanding of N_2O emissions from soils. Philosophical Transactions of the Royal Society B-Biological Sciences 367, 1226-1234.

[4] Liu, B., Frostegard, A., Bakken, L.R. 2014. Impaired reduction of N_2O to N_2 in acid soils is due to a post-transcriptional interference with the expression of nosZ. mBio 5(3): e01383-14.doi:10.1128/mBio.01383-14

NITROGEN-USE EFFICIENCY OF DIFFERENT FORAGE-BASED DAIRY PRODUCTION SYSTEMS

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Objectives

Fresh grass is the most important forage in Switzerland. In dairy farming, previous projects have compared full grazing systems (during summer) with the maize-based high yield strategy. As most Swiss farms combine indoor feeding of fresh grass with partial grazing, the new project "System Comparison Hohenrain 2" aims at comparing the full grazing system with indoor feeding of fresh grass combined with partial grazing at two different levels of concentrate supplementation IFC). The performance and effects of the three production systems on sustainability are studied and compared in a system comparison with three herds on a demonstration farm and on 38 pilot farms in different regions of Switzerland. This contribution focuses on Nitrogen (N) flows and N use efficiency (NUE) of the pilot farms. The aim is to identify structural and management parameters with respect to the NUE of the different production systems and to develop practice orientated optimization options.

Method

Together with Cantonal extension services 38 interested dairy farms from different regions of the Swiss lowlands were recruited, approx. 12 for each of the three strategies: 1) full grazing plus <300 kg concentrate (FG), 2) indoor feeding/partial grazing plus <500 kg (IFC1), indoor feeding/partial grazing plus 800-1200 kg concentrate (IFC2). The conditions for the participating farms were clearly defined. A detailed list of management and structural parameters were either regularly recorded by the farmers, surveyed in detail during regular visits or collected through a questionnaire in spring 2015. The questionnaire covered all aspects of livestock and manure management that are relevant for N flows and ammonia (NH_3) emissions. Based on this information and structural data, N flows and NUE (N in sold products in percent of N inputs) are calculated for each farm (33 farms with complete and plausible data). Ammonia (emissions were also calculated for each farm using the model AGRAMMON [1]. The results are compared to different structural and management parameters to identify the most important influencing factors and promising actions to improve the NUE.

Results

For all three groups the average farm size surpassed the Swiss average of about 18 ha agricultural surface. On average the IFC1 farms (24.0 ha) were clearly smaller than the IFC12(34.6 ha) and the FG (31.5 ha) farms. The FG farms had less arable crops (9% of agricultural surface) than the IFC1 (22%) and IFC2 (28%) farms. The average annual milk yield was 8016 kg for the IFC2 farms, 6358 kg for IFC1 and 5818 for FG. As expected, the average amount of concentrate supplementation per cow per year decreased from 1073 kg for IFC2 farms to 392 kg for IFC1 and 109 kg for FG farms. Six of the 10 FG farms did not feed any concentrate at all.

Detailed results on N-flows and NUE were not yet available at the time when this abstract was written. They will be exclusively shown for the first time at the N workshop. A primary focus will be the question of the ranking of the different strategies with respect to NUE, e.g. does the higher milk yield achieved primarily through higher concentrate supplementation improve or reduce the NUE. Most important for the participating farms and the wider applicability of the project results in farming practice will be the analysis of which are the key factors influencing the NUE of dairy farms and the most promising strategies to improve the NUE. A promising step in this direction will be the comparison of the results of this project with 1) our parallel analyses of data from representative national surveys on farming practice in 2007 (approx. 3000 farms, of which about 1050 with strong focus on dairy production) and 2010 and 2) our parallel assessment of the

NUE of pilot farm groups that have deliberately tried to improve their manure management.

From earlier studies we know that it is difficult to compare the NUE of different farms as soon as there are structural differences, e.g. the proportion of agricultural land used for crop production ([2] or the different types of livestock categories present on the farm. For our study special challenges will be questions like how to deal with farm specific specialties such as the milk use for fattening calves or the outplacement of heifers to other farms.

Conclusions

The project aims at ranking the efficiency of the different dairy production strategies and to assess their sustainability. However, it will also have to consider that farm structure, market potential and personal considerations of the farmer family often limit the choice of the best production strategy. For example, the full grazing strategy is often impeded by a limited consolidation of the grazing plots around the farm facilities or the lower demand for milk during summer months. The discussion of the results will therefore have to be placed in a holistic perception that takes into account a wide variety of issues.

Hopefully the project will provide detailed recommendations and aids for the assessment and optimization of the efficiency of dairy farms which are easily implementable under practical conditions. Support for success in this direction will be the pioneer and demonstration effect that the pilot farms of the “System Comparison Hohenrain 2” project will have thanks to on farm events and other knowledge transfer activities planned towards the end of the project.

References

Kupper, T., Bonjour, C., Menzi, H. 2015. Evolution of farm and manure management and their influence on ammonia emissions from agriculture in Switzerland between 1990 and 2010. Atmospheric Environment 103, 215-221

Menzi, H., Gregis, B., Mahrer, D., Kupper, T. 2013. Assessment of the nitrogen use efficiency of Swiss farms based on a representative farm management survey. Proc. 15th RAMIRAN Conference, Versailles June 3-5 2013, S5.03, http://www.ramiran.net/doc13/Proceeding_2013/documents/S5.03..pdf

MODELLING THE INTERACTIONS BETWEEN THE MILK C AND N FOOTPRINT FROM INTENSIVE DAIRY FARMS IN NORTHERN SPAIN.

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Objectives

To calculate the N and GHG emissions from 35 commercial dairy cattle farms in northern Spain using a framework coupling mathematical models and LCA analysis. As a sub-objective we intend to relate the milk N and C footprint (N and GHG emissions) from these farms with different sustainability attributes in relation to environmental impacts (eutrophication, acidification, water footprint...) welfare and economic indicators

Method

Management, animal welfare, economics, weather and soil data from 35 commercial dairy farms located in the Karrantza Valley (northern Spain) were collected in 2013. Dairy cattle farming represents the main economic activity in this area. The climate of this area is classified as maritime with high precipitation all year round (mean= 1500 mm) and moderate temperatures, and provides favourable conditions for grass growth and also for microbial soil processes such as denitrification potentially resulting in large N_2O emissions. Weather conditions for 2013 were wetter than the average (1677 mm), which led to conditions with high potential denitrification. Using the data from the 35 dairy farms as an input, farm and field scale nutrient modelling was coupled with an LCA analysis through the modelling framework described by [1]. Modelling was carried out in order to calculate the effect of management and weather conditions on C and N emissions, and other environmental impacts (e.g. water footprint) from the cradle to the farm gate (C and N footprint). This framework simulated the N and GHG emissions occurring at the farm level (on-farm) comprising emissions, both biogenic and non-biogenic, from the farm facilities (housed animals, manure, silage making) and grassland. The assessment also included the pre-chain emissions through purchased concentrates and forages and indirect energy use (synthesis and transportation of mineral fertilizers and purchased feed). Nitrogen losses indirectly leading to N_2O emissions (e.g. NO_3^- leaching, NH_3) were also included in the assessment and converted into N_2O emissions. The main functional unit of this analysis was 1 kg of energy-corrected milk (ECM). We also included in the analysis the amount of N and GHG emissions emitted as a function of total hectares used including farm forage area and the surface used to crop the purchased feed (i. e. concentrates). Farm N use efficiency (NUE) was calculated as the ratio between the exported and the imported N. The imported N comprised purchased feed, fertilisers, N atmospheric deposition, straw for bedding and N biological fixation and the exported N included N in milk, meat and manure.

Results

Average milk per dairy cow and year was 8300 kg ECM yr-1 (4500-11000 kg ECM yr^{-1}). The main N inputs to the farm were those related to purchased feed (73% on average, 30-95 % of total N inputs). The NUE ranged from 13% to 38% (on average 22%). Most area used to produce milk was associated with the production of concentrates and not on-farm forage area (on average, 70% of total ha used to produce 1 L of milk). Water footprint was on average 1386 L kg^{-1} ECM milk and ranged between 921 L/ kg ECM milk and 2785 L/ kg ECM milk.

On average most N losses from the N footprint were produced on the farm (65%). Ammonia (63 % on average) followed by NO_3^- leaching (31% on average) comprised almost 90% of N losses from the total N footprint. Whereas N losses from NOx and NO_3^- leaching mostly occur at the pre-farm stages (cropping systems to produce concentrates feed) (>80% on average), most NH_3 (83%) and N_2O (77%) emissions occur on-farm. Average N losses per kg ECM milk were: 19.2 g N kg^{-1} ECM milk (NH_3), 9.4 g N kg^{-1} ECM milk (NO3), 0.7 g N kg^{-1} ECM milk (N_2O), and 0.3 g N kg-1 ECM milk (NOx). Annually average N losses per total ha used (on and off-farm) were: 84 kg N ha-1(NH3), 40.7 kg N ha^{-1} (NO_3), 2.8 kg N ha^{-1} (N_2O) and 1.2 kg N ha^{-1} (NOx). A large proportion of the total GHG emissions were associated with CH4 output from rumen and manure management (64% on average), purchased feed (14%) and on-farm N2O emissions (11%).

Greenhouse gas emissions ranged from 0.64 to 2.73 kg CO2-eq kg-1 ECM milk (mean ± SD=1.2 ± 0.4), 2.9 to 8.8 t CO_2-eq ha^{-1} (mean ± SD= 5.1 ± 1.4) and 4.6 to 12.9 t CO2-eq LU-1 (mean ± SD= 7 ± 1.9), which is in the range of existing studies in Europe. The C footprint was positively correlated with on-farm N_2O emissions (R2=0.91; P<0.00001) but not to CH4 output or concentrates GHG footprint. Total GHG emissions per milk output (C-footprint of milk) and N footprint were both found to decrease in a linear fashion with increase in farm N use efficiency only if NUE included biological N fixation and atmospheric N (P<0.05). Both N and GHG emissions per dairy cow decreased with animal milk yield (R2=0.65; P<0.001). The efficiency of the farm system to transform N inputs into milk and meat was not correlated with the level of purchased feed. Almost none of the animal welfare or economic indicators (e.g. number of cows above third lactation, vet costs) were correlated with either the C or N footprint.

Conclusions

Most N emissions from the N footprint of producing milk were associated with NH_3 emissions at the farm, which suggests that to reduce the milk N footprint abatement measures to reduce NH_3 emissions should be a priority. Although methane is the largest source of GHG emissions at the life cycle of milk production, N_2O emissions seems to be the most variable GHG. Although NUE was a relatively good indicator for C and N footprint, it was not related with profitability. Animal welfare did not seem to be related to either N or GHG emissions from milk production.

References

[1] Del Prado A, Mas K, Pardo G., Gallejones. P.2013. Modelling the interactions between C and N farm balances and GHG emissions from confinement dairy farms in northern Spain. Science of The Total Environment. 465, 156-165.

MEASURES TO REDUCE THE GREENHOUSE GAS EMISSIONS FROM DAIRY FARMING AND THEIR EFFECT ON NITROGEN FLOW

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Objectives

The European Union has agreed to reduce the EU greenhouse gas emissions from sectors not included in the European Trading System (transport, domestic heating and agriculture) by 30% by 2030, with reduction targets for individual Member States varying between 0% and 40%. Although the agreement acknowledges the special status of agriculture in relation to ecosystem services and the rural economy, significant reductions in GHG emissions from agriculture will still be required.

Dairy farming is a significant source of GHGs, both direct (CH_4 and N_2O) and indirect (NH_3, NO_3^-). A range of mitigation measures are available for emission sources on dairy farms but assessing their effectiveness is complicated by the knock-on effect of their implementation on whole farm emissions and farm management. Here we use a modelling approach to assess the effectiveness of a range of GHG mitigation measures and their consequences for N flows.

Method

The FarmAC whole farm C and N simulation model (www.farmac.dk) consists of static, annual modules to describe ruminant livestock, animal housing and manure storage/biogas reactor and a dynamic, multi-year module to describe crop and soil flows (including C and N sequestration). The farm is characterised in terms of the numbers of different livestock categories present (e.g. dairy cattle, heifers) and their feed ration, where each livestock category is housed, the manure storage associated with each house, the crop sequences present and how each crop is managed.

FarmAC was used to describe a baseline scenario for the following conventional dairy farm;

72 dairy cows with 72 followers, milk production 10 000 litres year^{-1}. N fertilisation (146 and 84 kg N ha^{-1} yr^{-1} slurry and fertiliser) was sub-optimal, to allow for a yield response to measures. The livestock were housed year-round in freely-ventilated animal housing producing slurry. The slurry was stored in a slurry tank with a crust and broadcast spread. The land area was 100 ha, clayey (4 %) sandy soil, initial soil C content of 70 ton C/ha. Two crop sequences; spring barley, grass, grass, maize and maize, maize spring barley, winter wheat, winter wheat.

The mitigation measures assessed were as follows:

1. The use of grass/clover swards instead of pure grass swards (reduce pre-chain emissions).

2. The treatment of all manure in a biogas reactor, with maize silage as supplementary feedstock (reduce CH_4 emissions, replace fossil fuels).

3. The injection of slurry (reduce pre-chain emissions)

4. Combination of measures 1 to 3.

If the mitigation measure resulted in a change in the production of grass or maize, the herd size, crop rotation and fertiliser rate was adjusted to bring the roughage feed production and demand back into balance. For the biogas scenario, the area necessary to produce the maize feedstock was included. The GHG budgets were calculated for direct, indirect and pre-chain emissions. N flows were averaged over a period of 50 years.

Pre-chain GHG emissions and post-chain GHG emission savings were taken into account.

Results

The GHG emissions for the baseline were 7.31 t CO_2 eq ha^{-1} yr^{-1} (direct; 5.77, indirect; 0.35, pre-chain; 1.19). Sequestration of C in soil was 1.26 t CO_2 eq ha^{-1} yr^{-1} and the farm N surplus 131 kg N ha^{-1} yr^{-1}.

Using grass/clover increased livestock feed production (8%), reduced the fertiliser requirement (20%) and enabled an increase in livestock number of 14%. This resulted in increases of 12% in N_2O emission and 20% for NH_3 emission and of 7% in NO_3^- leaching, since the increased import of concentrate feed led to an increase in the amount of N circulating on the farm. On-farm GHG emissions increased by 15% but the increased feed import increased pre-chain emissions, so the total GHG emission increased by 14%. Farm N surplus increased by 11%.

Biogas treatment only slightly reduced the emission of CH_4 from the manure because a proportion was lost by leakage and the total production of CH_4 was much higher, due to the increased degradation of slurry organic matter in the reactor and the input of maize silage as supplementary feedstock. Manure storage NH_3 and N_2O emission was substantially reduced but the higher proportion of ammoniacal N in the slurry led to higher NH_3 emission after field application. The net result was a slight reduction in livestock feed production, requiring a small increase in fertiliser N to maintain livestock numbers. The demand for maize silage as supplementary feedstock led to a 70% reduction in exported crop products but increased soil C sequestration by 53%. On-farm GHG emissions reduced by 9% but despite increased pre-chain emissions, the displacement of fossil fuel use by the biogas mean total GHG emissions fell by 40%. Farm N surplus increased by 35%.

Injecting slurry reduced total NH_3 emission by 21% and reduced the fertiliser required but increased soil N_2O emissions by 14% and NO_3^- leaching by 6%. The livestock feed production increased, allowing a 21% increase in livestock numbers. This led to increases in the import of livestock feed and in the emissions from housing and manure storage but also to increase soil C sequestration. On-farm GHG emissions increase by 13% and total GHG emissions by 16%. Farm N surplus increased by 3%.

The effect of using all measures in combination was to allow in an increase of 23% in livestock numbers. There was a reduction of 22% in total NH_3 emission and a 68% increase in soil C sequestration but an increase of 7% in N_2O emissions and 39% in NO_3^- leaching. On-farm GHG emissions increased by 7% but when pre-chain emissions and the replacement value of the biogas was included, GHG emissions fell by 32%. Farm N surplus increased by 20%.

Conclusions

Measures that aimed to reduce GHG emissions by reducing fertiliser N inputs (grass/clover, slurry injection) and NH_3 emission (slurry injection) were effective at the point of use. However, they resulted in increased crop production, triggering an increase in livestock density and therefore an increase in concentrate feed imports (soya). This increased pre-chain GHG emissions and the additional N input increased the non-targeted emissions (e.g. N_2O or NH_3 from manure storage). The net result was an increase in both N losses and total GHG emissions. The measure not targeting N efficiency (biogas production) was successful in reducing total GHG emissions, in part by increasing C sequestration, but led to substantial increases in both NH_3 and NO_3^- losses. The combined measures reduced GHG and gaseous N emissions substantially but led to a large increase in NO_3^- leaching.

Previous work [1] found a relationship between farm GHG emissions and farm N surplus. This was not apparent in the current work, because biogas treatment specifically targets a gas that does not contain N.

This work illustrates the need for tools to assist farmers and advisors to minimise trade-offs and capitalise on synergies, when considering the measures to reduce N loss or GHG emissions and their effect on crop and livestock production.

Acknowledgements

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References

[1] Olesen, J.E., Schelde, K., Weiske, A., Weisbjerg, M.R., Asman, W.A.H., Djurhuus, J., 2006. Modelling greenhouse gas emissions from European conventional and organic dairy farms. Agriculture Ecosystems & Environment 112, 207-220.

NITROGEN EXCRETION IN PREGNANT SUCKLER COWS FED DIFFERENT ROUGHAGES AD LIBITUM

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Objectives

There is a growing concern about the N losses from beef production to the environment as the global demand for beef is expected to increase by 1.5 % per year until 2050. Therefore, N emissions have to be reduced in all parts of the beef supply chains in order for beef production to remain sustainable. Efficiency of N utilization in cows in suckler-based beef production is generally low, around 5-10% [2]. The principal driver of N excretion is N intake. Previous studies have shown that reduced N intake reduces N output, especially in urine [3], which is essential as urinary N is more susceptible to volatilization and leaching than fecal N. The objective of the experiment was to study urinary N excretion in pregnant suckler cows offered late cut roughages of different chemical composition ad libitum.

Method

Total collection of urine was made during 48 h from 36 Hereford cows that were in the beginning of their third trimester (729 ± 82 kg BW; 4.4 ± 1.5 years of age). Cows were blocked into three calving groups according to expected calving dates; early (E), medium (M) and late (L), with 12 cows per group. Within calving group, cows were randomly assigned to one of four roughage diets with three cows per diet; mixed grass silage dominated by timothy and meadow fescue (M), festulolium silage (F), reed canarygrass silage (R) and barley straw (B). Cows fed B also received 0.5 kg rapeseed meal per day (BRM). Each calving group was further divided into two subgroups (E1, E2, M1, M2, L1, and L2), with six cows and two treatments per subgroup. All grass silages were first cuts harvested at the bloom stage of maturity. To avoid N-constrain on rumen microbial protein synthesis, F and B were supplemented with urea, 6.9 and 11.3 g/kg DM respectively, in order to increase their PBV values. All animals were adapted to their experimental diet for 3 weeks before the urine collection began. Cows were fed ad libitum and feed intake was recorded. Urine was collected using harnesses in 12 h intervals and one urine sample per cow and interval was analysed for N and urea-N concentration. Feed samples were analysed for DM, N and in vitro organic matter digestibility (IVOMD) and in vivo OMD was calculated [6]. Nitrogen excretion data were analysed by ANOVA in a randomised block design using the MIXED procedure in SAS (version 9.3) with dietary treatment (M, F, R and BRM) as fixed effect, calving group (E, M and L) as random effect and sub-group (E1, E2, M1, M2, L1, and L2) as a random effect nested within calving group. The MIXED procedure was also used to analyse differences in chemical composition of the roughages with dietary treatment (M, F, R and B) as fixed effect and calving group as random effect. Differences between treatments in the F-test were considered significant at $p<0.05$.

Results

Nitrogen intake has been identified as the main driver of N excretion. Losses of N in the rumen metabolism is regarded as the major contributor of N in urine of ruminants [5] and losses occur primarily because of imbalance between degradation of N containing substrates and use of available N by the rumen microbes. In the present study, a simple linear regression showed a positive relationship between urinary N output (g/d) and N intake (g/d; $r^2=0.42$; $p<0.01$), which confirms previous findings in dairy cows [3, 4].
No differences in N intake (g/d) could be found between cows fed M (102), F (97) and R (129), which differed from cows fed BRM (67, $p<0.001$). Although similar intakes of N, cows fed R had higher urinary N excretion (92 g/d; $p<0.001$) compared to cows fed M (66) and F (63). Feeding BRM resulted in the lowest urinary N excretion (41 g/d). Cows fed R also had the largest daily excretion of urea-N ($p<0.001$), with no differences observed between the other diets. The R and B roughages had lower in vivo OMD compared to M and F ($p<0.001$). The greater excretion of N and urea-N in cows fed R was probably due to the lower

OMD and, thereby, a lower availability of ruminally fermentable carbohydrates, resulting in less efficient utilization of dietary N by the rumen microbes. The low N excretion in cows fed B could most likely be explained by the low N intake of this diet.

Several authors have reported the importance of metabolizable energy (ME) intake on N utilization in dairy cows. Kebreab et al. (2010)[4] found that ME intake had a negative effect on N output in urine when included as a covariate together with N in a multivariate meta-analysis. Cohen et al. (2006) [1] reported that milk N increased at the expense of urinary N when intake of ME increased. The importance of digestible organic matter (DOM) intake for efficient N utilization was also observed in the present study, where N excretion in urine as proportion of N intake decreased as intake of DOM (g/kg BW) increased ($r^2=0.52$; $p<0.001$). Intakes of DOM were lower for cows fed R and BRM compared to cows fed M and F. This could explain why cows fed R and BRM excreted almost 50% of their total N intake as N in urine, compared to 31% and 35% for cows fed M and F respectively. The lower intake of DOM could also be the reason why urea-N accounted for a larger proportion ($p<0.001$) of total urinary N excretion in cows fed R (68%) and BRM (60%), compared to cows fed M (47%) and F (43%).

Conclusions

Increased urinary N excretion was associated with increased N intake in suckler cows offered late cut roughages of different chemical composition. In addition, a larger intake of DOM was associated with a lower proportion of N intake being excreted as N in urine. Urinary excretion of N and urea-N was greatest for cows fed reed canarygrass, a roughage with both high N concentration and low OMD. The results indicate that both N intake and DOM intake should be taken into consideration when choosing roughage type for suckler cow feeding, in order to prevent excessive N excretion.

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References

[1] Cohen, D.C., Stockdale, C.R., Doyle, P.T. 2006. Aust. J. Agric. Sci. 57, 367-357.

[2] Estermann, B.L., Wettstein, H.R., Sutter, F., Kreauzer, M. 2001. Anim. Res. 50, 477-493.

[3] Huhtanen P., Nousiainen, J.I., Rinne, M., Kytölä, K., Khalili, H. 2008. J. Dairy. Sci. 91, 3589-3599

[4] Kebreab, E. Strathe, A.B., Dijkstra, J., Mills, J.A.N., Reynolds, C.K., Crompton, L.A., Yan, T., France, J. 2010. In: Crovetto, G.M. (ed) 3rd EAAP international symposium on energy and protein metabolism and nutrition. Wageningen, The Netherlands. p. 417-425

[5] Tamminga, 1992. J. Dairy. Sci. 75, 345-357

[6] Åkerlind, M., Weisbjerg, M., Ericsson, T., TØgersen, R., Udén, P., Ólafsson, B.L., Harstad, O.M., Volden, H. 2011. In: Volden. H. (ed) EAAP publication no .130. Wageningen, The Netherlands. p. 41-54

PROTEIN QUALITY OF FORAGES FOR RUMINANTS

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Objectives

Forage is an important protein source for ruminants but a large part of the protein in ensiled forage is already in the form of non-protein nitrogen, which partly can be excreted as urea in the urine if not rapidly available energy sources are present in the rumen, which are needed for the energy-demanding microbial protein synthesis. Of the true protein, a large part of the forage protein is degraded over time in the rumen, whereas a smaller part leaves the rumen undegraded to be utilized in the lower gut [1]. When forages are harvested, wilting and preservation cause changes in forage protein quality [4] and additives can improve silage protein quality [5]. The objectives of this study were to evaluate the effects of wilting, ensiling and silage additive on the protein quality of grass and lucerne/white clover.

Method

A grass sward was mowed on 3 June, 2010 and wilted for ca 23 hours to 350 g/kg of DM by wide spreading. Wilted forage was precision chopped and ensiled in 1.7-L silos for 125 days at Lantmännen Dairy Research Farm Nötcenter Viken, Falköping, Sweden. The forage was either untreated or treated with Kofasil Life, containing *Lactobacillus plantarum* DSM 3676 and 3677 at an application rate of 400 000 cfu/g of forage or with Kofasil Ultra K, containing sodium nitrite, hexamethylene tetramine, potassium sorbate, sodium benzoate and sodium propionate, at 2 L/ton forage (Addcon Europe GmbH).

On 26 July, 2012, a mixture of lucerne (85%)/white clover (15%) was harvested as a first regrowth, was chopped and wilted for 6 hours to 40% DM before being ensiled in 1.7-L silos for 90 days at the Rural Economy and Agricultural Society Sjuhärad, southwest Sweden. Lucerne/white clover was either untreated or treated with Kofasil Lac (*Lactobacillus plantarum* DSM 3676, 3677; Addcon Europe GmbH) at 100 000 cfu/g or GrasAAT SP (formic acid, propionic acid, sodium formate, sodium benzoate; Addcon Nordic AS) at 4 L/T.

Fresh and ensiled forages were analysed for crude protein (CP) fractions according to [3]. True protein (TP) was divided into buffer-soluble protein (BSP; B1, rapid rumen degradation), neutral detergent (ND)-soluble protein (NDSP; B2, variable rumen degradability), acid-detergent (AD)-soluble protein (ADSP; B3, slowly degraded, much escapes rumen degradation) and AD-insoluble protein (ADIP; C, indigestible). The remaining part of the CP was non-protein nitrogen (NPN; A, some instantly used as ammonia, some lost as urea in urine; [6]. RUP was calculated from the CP fractions using the model described by [2]. Data were analysed as a completely randomized design using three replicates per treatment in PROC GLM of SAS (ver. 9.3). When the *F*-value was significant at 5% level, pair wise comparisons between LSmeans of forage treatments were done using Tukey´s test.

Results

Concentrations of CP, water soluble carbohydrates (WSC) and neutral detergent fibre (NDF) in wilted grass were 143, 212 and 375 g/kg DM. I*n vitro* organic matter digestibility of wilted forage was as high as 917 g/kg. Concentrations of non-protein nitrogen (NPN), neutral detergent soluble protein (NDSP) and acid detergent soluble protein (ADSP) increased from 115, 475 and 17 g/kg CP to 175, 550 and 61 g/kg CP ($P < 0.001$), while the buffer soluble protein (BSP) decreased from 351 to 180 g/kg CP during wilting, resulting in an increase in RUP at 8%/h ruminal passage rate from 292 to 350 g/kg CP ($P < 0.001$). Wilting is beneficial as forage DM concentration is negatively correlated to proteolysis during ensiling [4]. However, when the wilted forage was ensiled without additive the NPN concentration increased to 593 g/kg CP, while the concentrations of BSP and NDSP decreased to 33 and 259 g/kg CP, respectively ($P < 0.001$), resulting in a decreased UDP8 to 210 g/kg CP during ensiling ($P < 0.001$). Addition of Kofasil Life and Kofasil Ultra K tended to increase the RUP8 of untreated silage from 210 to 233 g/kg CP ($P = 0.060$). The 11% increase in RUP8 of the additive-treated silage was achieved by a decreased NPN from 593 to 537 g/kg CP ($P < 0.05$) and a tendency to increased NDSP from 259 to 294 g/kg CP ($P = 0.080$) compared to untreated silage, with no differences between the additives.

Concentrations of CP, WSC and NDF were 201, 81 and 384 g/kg DM of wilted lucerne/white clover. During wilting of the forage the BSP decreased from 169 to 74 g/kg CP and the more nutritionally favoured ADSP increased from 26 to 72 g/kg CP ($P < 0.001$), with no increase in ADIP (54 g/kg CP). During ensiling, the B fractions of the TP decreased from 659 to 335 g/kg CP while the NPN increased from 283 to 612 g/kg CP ($P < 0.001$). GrasAAT SP decreased proteolysis during ensiling as shown by less NPN (554 vs. 612 g/kg CP, $P < 0.05$) and a tendency to more NDSP (327 vs. 270 g/kg CP, $P = 0.095$) compared to the untreated silage. No effect of Kofasil Lac was found. The decreased proteolysis by GrasAAT SP during ensiling improves protein utilisation by ruminants [4].

Conclusions

Wilting increased protein quality of fresh forage by decreasing the buffer-soluble true protein and increasing the slowly degraded acid-detergent soluble protein. Proteolysis during ensiling resulted in an increased NPN fraction as the true protein fractions decreased. Use of additives decreased proteolysis during ensiling. None of the treatments affected the ADIP concentration.

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References

[1] Givens, D.I., Rulquin, H. 2004. Utilisation by ruminants of nitrogen compounds in silage-based diets. Animal Feed Sci. Technol. 114, 1-18.

[2] Kirchhof, S., Eisner, I., Gierus, M., Südekum, K.-H. 2010. Variation in the contents of crude protein fractions of different forage legumes during the spring growth. Grass Forage Sci. 65, 376-382.

[3] Licitra, G., Hernandez, T. M., Van Soest, P. J., 1996. Standardization of procedures for nitrogen fractions of ruminant feed. Anim. Feed Sci. Technol. 57, 347-358

[4] Muck, R. E., Moster, L. E., Pitt, R. E. 2003. Postharvest factors affecting ensiling. pp. 251-304. Buxton, D.R. et al. (eds) Silage Science and Technology, Nr 42. ASA, CSSA, SSSA, Madison, Wisconsin, USA.

[5] Slottner, D., Bertilsson, J. 2006. Effect of ensiling technology on protein degradation during ensilage. Anim. Feed Sci. Technol. 127, 101-111.

[6] Sniffen, C.J., O'Connor, J.D., Van Soest, P.J., F ox, D.G., Russell, J.B. 1992. A net carbohydrate and protein system for evaluating cattle diets. II. Carbohydrate and protein availability. J. Anim. Sci. 70, 3562-3577.

UPGRADING OF ESSENTIAL AMINO ACIDS IN PLANTS THROUGH BEEF PRODUCTION FOR HIGHER NUTRITIONAL VALUE FOR HUMANS

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Objectives

Ruminants' ability to digest fibrous materials inedible to humans allows cattle production systems to be diverse and use a wide variety of feeds. In the competition of land for food or feed, semi-natural pastures and other marginal land and human inedible by-products are important feed resources to ruminants in order to convert simpler nitrogen compounds into food rich in protein to a growing population. Animal protein is dense in essential amino acids (EAA) which are important precursors for protein synthesis in humans and these needs to be supplied via the diet. The aim of the present study was to determine the quantity of human-digestible EAA in feeds and in animal products, respectively, in order to estimate the net quantity in different systems for beef production.

Method

Four types of beef production systems were designed: 1) a reference similar to typical current Swedish system; and three improved systems with target-orientated feed rations, improved genotypes and decreased mortality: 2) intensive cattle production based on maize silage; 3) intensive forage-based production; and 4) extensive production based on a maximised proportion of grazed semi-natural pastures, and forage complemented with only small amounts of concentrates. Within these four systems, calculations were performed both for beef production based on calves from dairy cows and for suckler-based beef production. Gender varied among systems. Several production models with varying feeds and weight gains were hence assumed. Feed rations and feed consumption were calculated according to NorFor [7].

The input of human-digestible EAA in the feed rations was determined by multiplication of the amount of each feed by the individual EAA concentration in that feed and by the factor of ileal digestibility. True ileal digestibility in pigs [1] was used in the calculations of input of feed as recommended for humans by Food and Agriculture Organization of the United Nations [2].

The output of human-digestible EAA in animal products was calculated similarly based on product output, individual EAA concentration in that product and ileal digestibility of the amino acids. The concentration of EAA in bone-free meat and edible offals (heart, liver, tongue and kidney) was calculated from the nutritional database of United States Department of Agriculture [6], wheras data on the composition of blood were obtained from CVB Feed Table [1].

Amount of EAA in input of feed and output of animal products were calculated per slaughtered animal including input of feeds to suckler cow, breeding bull and replacement heifer and output of carcasses from dams and sires.

All roughages were considered to be completely inedible to humans and the net quantity of human-digestible EAA was determined as the difference of input in feed minus output in animal products.

Results

Intensive beef production with dairy calves resulted in a lower output in animal products than input of EAA in feeds, due to the calves' need for a high-protein diet during their first six months. The milk they consume is partly produced from human-edible protein and so are the concentrates. However, by choosing a forage-based extensive rearing model, the amounts of EAA in feeds could be reduced to the same magnitude as the amounts in animal products.

The extensive models with suckling calves resulted in a higher output in animal products than input in feeds for all EAA. These calves suckle a forage-fed dam whose feed ration contains scarcely any human-edible protein. The intensive production models for beef calves generally resulted in an output of the same magnitude as the input for most EAA.

Forage-based models generally resulted in higher net quantity of digestible EAA than models based on maize silage, due to the need for extra protein feed in addition to the starch-rich, but protein-poor, maize in the latter.

Net quantity of EAA was much lower in the reference system than in all corresponding improved systems except for replacing a reference grazing beef heifer with an intensively maize-fed one. Reference bulls would enhance their protein efficiency by 20-40% with a change to the improved intensive systems. Dairy bulls changing to extensive systems would double their output in relation to input. Hence, better precision in cropping, feed ration formulation, animal performance and survival rate would result in increased EAA efficiency.

We assumed that human-edible digestible EAA were absent from all forages, which biased the results towards decreased competition between human food production and animal feeds, especially in the forage-dominated systems. It can be argued that arable land in these systems is used for production of forages, when it could be used for cultivation of grain for human consumption. However, cultivation of leys is an important part of the crop rotation and may sometimes increase carbon sequestration in the soil [5]. Furthermore, in areas with poor conditions for grain cropping, grasslands and forage is often not only the sole realistic alternative agricultural use of land, but also superior from a protein efficiency perspective. Grazed semi-natural grasslands are not just a nutritional resource, but often of great importance for preserving a varied agricultural landscape with high amenity and cultural values, biodiversity and ecosystem services [3, 4]. Conclusively, future animal production systems ought to be based on human-inedible feeds where ruminants' extraordinary ability to digest and thrive on fibrous feeds makes them especially important in a resource-efficient perspective, especially where they not only upgrade protein but contemporary also manage valuable grasslands of societal interest.

Conclusions

Forage- and pasture-based beef production models may result in upgrading of EAA compared with using the plant materials directly as human foods, especially in suckler-based beef production.

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References

[1] CVB Feed Table. 2011. Chemical compositions and nutritional values of feed materials (ed. C. Veevoederbureau). PDV, Zoetermeer, Netherlands.

[2] Food and Agriculture Organization of the United Nations. 2013. Dietary protein quality evaluation in human nutrition. FAO food and nutrition paper 92. FAO, Rome, Italy.

[3] Ihse, M., Norderhaug, A. 1995. Int. J. Heritage Studies 1, 156-170.

[4] Jerrentrup J.S., Wrage-Monnig N., Rover K.U., Isselstein, J. 2014. J. Appl. Ecol. 51, 968-977.

[5] Soussana J.F., Allard V., Pilegaard K., Ambus P., Amman C., Campbell C., Ceschia E., Clifton-Brown J., Czobel S., Domingues R., Flechard C., Fuhrer J., Hensen A., Horvath L., Jones M., Kasper G., Martin C., Nagy Z., Neftel A., Raschi A., Baronti S., Rees R.M., Skiba U., Stefani P., Manca G., Sutton M., Tubaf Z. and Valentini R. 2007. Agric. Ecosyst. & Environm 121, 121-134.

[6] United States Department of Agriculture. 2015. National nutrient database for standard reference, release 27 (revised). Retrieved on 5 May 2015 from http://ndb.nal.usda.gov/.

[7] Volden H. 2011. EAAP publication No. 130. Wageningen Academic Publishers, Wageningen, Netherlands.

EFFECT OF ORGANIC FERTILIZATION ON N_2O EMISSIONS AND WHEAT CROP YIELD AND QUALITY

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Objectives

Nowadays, mineral nitrogen fertilization is the most commonly used in intensive agriculture systems. Having in mind the high prices that synthetic fertilizers are reaching and the necessity to manage and reuse organic residues such as manure or slurry, the interest of using organic fertilizers and predicting their effects on crops yield and quality have increased. Organic fertilization has positive effects on soil quality, since the application of organic matter improves soil properties, increasing soil's nutrients and its physical and biological functions. However, the effects of these applications on greenhouse gases emissions, such as N_2O, remain to be determined at the different edafoclimatic conditions.

The aim of this study was to determine the effect of the application of cow slurry and sheep manure on the emissions of N_2O along a wheat crop cycle as well as on crop yield and grain quality under humid mediterranean conditions.

Method

The work was conducted at the Llanada Alavesa (Basque Country) in 2014-2015 during a whole winter wheat crop cycle period, from sowing in November 2014 to sowing of the next crop in September 2015. A randomized complete block factorial design with four replicates was established, with an individual plot size of 32 m^2. Four different treatments were assayed. One of the treatments did not receive any fertilizer, in order to serve as control. The other three treatments received 120 kg N ha^{-1} at the growth stage of stem elongation, but also different fertilizers were applied at previous stages. Two of them received a basal dressing before sowing with cow slurry (40 t ha^{-1}) and with sheep manure (40 t ha^{-1}), respectively, and the third one received a dose of 40 kg N ha^{-1} of mineral fertilizer at the stage of tillering. So finally, control, slurry plus mineral, manure plus mineral and only mineral fertilization treatments were stated. The background dose of 40 t ha^{-1} of organic fertilizer per hectare was chosen as one commonly used by farmers in the region. However, after the analysis of organic fertilizers, the effective N dose applied to each treatment was calculated as 0, 160, 158 and 210 kg N ha^{-1} for control, mineral, slurry and manure treatments.

N_2O emissions were measured using a close chamber technique during the whole experimental period, with a frequency of three days per week after fertilizer applications and decreasing this frequency gradually to one or two times per week. Samples were analysed by gas chromatography (GC) (Agilent, 7890A) equipped with an electron capture detector (ECD) for N_2O detection. N_2O standards were stored and analysed at the same time as the samples. Cumulative N_2O emissions during the sampling period were estimated by averaging the rate of emission between two successive determinations, multiplying that average rate by the length of the period between the measurements, and adding that amount to the previous cumulative total.

At harvest a surface of 1.5 x 8 m per plot was harvested for grain yield determination. Grain N content was analyzed by the Kjeldhal procedure.

Results

Cumulative N_2O losses in the unfertilized treatment reached 0.57±0.07 kg N_2O-N ha^{-1}. The mineral fertilizer increased N_2O losses up to 0.85±0.08 kg N_2O-N ha^{-1}, while the organic amendments induced significant higher losses. The manure showed losses of 2.15±0.04 kg N_2O-N ha^{-1} and the slurry losses of 1.64±0.16 kg N_2O-N ha^{-1}, being these losses concomitant to the effective N dose received by the treatments. The mineral fertilizer emissions appeared to be slightly higher than in the control treatment, but the differences were not significant. By the contrary, the manure application increased N_2O emissions into a greater extent than the slurry application. This could be ascribed to the difference between the organic matter quantity provided by the manure (28.9%) compared to that of the slurry (7.4%). This, coupled with the also higher content of total N in the manure (susceptible to be mineralized to ammonium), seems to have been the reason for the strong enhancement in N_2O emissions.

Fertilizer application induced a significant increase in grain yield, since the control treatment without fertilizer yielded 4,119±138 kg ha^{-1} whereas the grain yield of all fertilized treatments was around 8,200 kg N ha^{-1}, whithout significant differences between them. The same was observed for grain N content, ranging from 1.19% in the non-fertilized treatment to around 1.56% in the fertilized ones, again with no statistical differences between them. This meant that the application of a basal dressing of either 40 t ha^{-1} of slurry or 40 t ha^{-1} of manure produced the same effect as the application of 40 kg N ha^{-1} of mineral fertilizer at tillering. So, although the slurry treatment received part of its effective N before sowing, the crop could use it in an efficient way, reaching the mineral treatment yield and quality values. However, in the case of manure, its application was less efficient since although providing 52 kg more of efficient N per hectare than the mineral treatment, its application led to the same yield and quality parameters.

Conclusions

It was possible to obtain the same wheat grain yield and N content when applying a basal dressing of 40 t ha^{-1} of sheep manure or cow slurry as when applying 40 kg N ha^{-1} of mineral fertilizer at tillering. However, the amount of N_2O emitted was 170% higher when applying manure pre-sowing and 100% higher in the case of slurry with respect to the N_2O released after the mineral fertilization at tillering. This effect was probably due to the stimulation of the release of this gas due to the contribution of the organic carbon and nitrogen supplied to the soil by both organic fertilizers.

Acknowledgements

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EVALUATION OF CARBON DIOXIDE EMISSION FACTOR FROM UREA APPLIED IN PADDY SOIL DURING RICE CULTIVATION

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Objectives

Fertilization with urea can lead to a loss of carbon dioxide (CO2) that was fixed during the industrial production process. The extent of atmospheric CO2 removal from urea manufacturing was estimated by the Industrial Processes and Product Use sector (IPPU sector). On its basis, the Intergovernmental Panel on Climate Change (IPCC) has proposed a value of 0.2 Mg C per Mg urea (available in 2006 revised IPCC guidelines for greenhouse gas inventories), which is the mass fractions of C in urea, as the CO2 emission coefficient for the agricultural sector. Notably, due to the possibility of bicarbonate leaching to waters, all C in urea might not get released as CO2 to the atmosphere. Hence, in order to provide an accurate value of the CO2 emission coefficient from applied urea in the rice ecosystem.

Method

Based on the recommendation level of N fertilizer for rice in Korea (90 kg N ha^{-1}), four different levels (0, 45, 90 and 180 kg N ha^{-1}) of urea treatments were arranged in the experimental plots (10 m x 10 m) following randomized block design with three replications.A closed-chamber method was used to investigate the CO_2 flux from the soil during rice cultivation. Opaque acryl chambers of 20 cm in diameter and 25 cm in height were placed in each plot between rice hills without rice plant. Same level of ^{13}C labelled urea $[(NH_2)_2{}^{13}CO]$ (Sigma Aldrich, 99.99%) with that of each treatment was applied inside the closed chamber to characterize the emission rates of CO_2 induced from urea. Gas was sampled three times a day (08:00, 12:00, and 16:00 hours) during the rice cropping season.A Shimadzu QP 2010 Plus GC/MS equipped with a silica capillary column (SH-Rt-Q-BOND, 30 m x 0.32 mm x 10 µm film thickness) in the splitless mode was used to separate the gaseous components. The detector operated at 1.10^{-5} torr and 70 eV. The GC oven program was isothermal at 120°C. Using the single ion monitoring mode, the detector was able to simultaneously quantify $^{12}CO_2$ ($m/z = 44$) from $^{13}CO_2$ ($m/z = 45$). CO_2 quantification was based on standards (Supelco Inc., Bellefonte, Pa.) and serial dilutions prepared therefrom.

Results

Total CO_2 fluxes and rice grain yields increased significantly with increasing urea application (110-130 kg N ha^{-1}) and thereafter, decreased. However, with increasing ^{13}C-urea application, a significant and proportional increase of the $^{13}CO_2$-C emissions from ^{13}C-urea was also observed. From the relationships between urea application levels and $^{13}CO_2$-C fluxes from ^{13}C-urea, CO_2-C emission factor from urea was estimated to range between 0.0143 and 0.0156 Mg C per Mg urea. Thus, CO_2-C emission factor of this study is less than that of the value proposed by IPCC.

Conclusions

During rice cultivation soil respiration patterns were mainly influenced by soil temperature changes, irrespective of the urea application levels. Total CO_2 fluxes increased significantly with increasing urea application levels by 115-122 kg N ha^{-1}, and thereafter, decreased. However, CO_2-C emissions from urea increased significantly and proportionally with increasing urea application levels. From the relationships between urea application levels and CO_2-C fluxes from urea, CO_2–C emission factor from urea was estimated to 0.0143–0.0156 Mg C per Mg urea, which is supposed to be less than the emission factor prescribed in the revised

2006 IPCC guideline (0.2 Mg C per Mg urea). Merely 1.43-1.56% of the applied urea-C got emitted as CO_2 from the soil during rice cultivation. Therefore, CO_2−C emission factor from urea given in the revised 2006 IPCC guideline for greenhouse gas inventories (0.2 Mg C per Mg urea) could be updated to 0.0143-0.0156 Mg C per Mg urea for rice cultivation in Korea.

DIFFERENT RESPONSES OF NITROGEN FERTILIZATION ON METHANE EMISSION IN RICE PLANT INCLUDED AND EXCLUDED SOILS DURING CROPPING SEASON

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Objectives

Since nitrogen (N) fertilization is most powerful practice to increase rice productivity, N fertilizer consumptions have continuously increased in the world wide, and the effects of N fertilization on CH_4 emission characteristics were numerously studied. However, no consistent conclusions to N fertilization on CH_4 cycles have been drawn so far.

Method

The experimental field consisted of 12 plots, each 100 m^2, and was laid down in a randomized block design. We installed four treatments with different levels of urea fertilization (0, 45, 90 and 180 kg N ha^{-1}. Thirty day old seedlings (3 or 4 plants per hill) of rice (*Dongjinbyeo* cultivar, Japonica) were transplanted with a spacing of 30 cm × 15 cm by hand in the late May, 2014 and 2015.

A closed-chamber method was used to estimate CH_4 fluxes during rice cultivation period. In order to estimate the CH_4 fluxes from rice plant included and excluded soils during the cropping season, two different types of chambers were installed in each plot. To monitor the rates of CH_4 emissions in rice plant included soils, a six hexahedron transparent acrylic chamber (width 62cm, length 62cm, and height 112cm) was set up permanently on the flooded soil after rice transplantation. Three acrylic chambers that could accommodate eight rice plants inside each were used. Besides these chambers, to evaluate the rates of CH_4 emissions from rice plant excluded soils, sets of acrylic column chambers (20 x 20 cm), were placed on the soil surface between rice

A closed-chamber method was used to estimate CH_4 fluxes during rice cultivation period. In order to estimate the CH_4 fluxes from rice plant included and excluded soils during the cropping season, two different types of chambers were installed in each plot. To monitor the rates of CH_4 emissions in rice plant included soils, a six hexahedron transparent acrylic chamber (width 62cm, length 62cm, and height 122cm) was set up permanently on the flooded soil after rice transplantation. Three acrylic chambers that could accommodate eight rice plants inside each were used. Besides these chambers, to evaluate the rates of CH_4 emissions from rice plant excluded soils, sets of acrylic column chambers (24 x 20 cm), were placed on the soil surface between rice plants. After chamber placement, gas samples were collected with 50 ml gas-tight syringes. The collected gas samples were immediately transferred into 30 ml air-evacuated glass vials sealed with a butyl rubber septum for gas analysis. The collected gas was analyzed with gas chromatograph equipped with FID detector.

Results

Seasonal CH_4 fluxes were differently responded to N fertilization between rice plant included and excluded soils. In rice plant excluded soils total CH_4 fluxes significantly increased with increasing N fertilization levels. However, in rice planted soils seasonal CH_4 fluxes were changed with a quadratic response model. Total CH_4 fluxes increased with increasing N fertilization by 115-137 kg N ha^{-1}, but thereafter, clearly decreased. The difference of seasonal CH_4 fluxes between two soils might be caused by rice rhizospheric activities, and then this difference could be defined as minimum CH_4 oxidation potentials of rice rhizosphere. This CH_4 oxidation potential significantly increased with increasing N fertilization levels, and highly correlated with total biomass, straw and root biomass productivities.

Conclusions

Total CH_4 fluxes during cropping season responded differently to N fertilization between the rice plant included and excluded soils. In rice plant excluded soils, seasonal CH_4 fluxes significantly increased with increasing N fertilization. However, in rice plant included soils, its fluxes changed with a quadratic response. The difference of seasonal CH_4 fluxes between two soils might be caused by rice rhizospheric activities, and this difference could be defined as the minimum CH_4 oxidation potentials of rice rhizosphere. The minimum CH_4 oxidation potential significantly increased with increasing N fertilization levels, and highly correlated with total biomass, straw and root biomass productivities. Therefore, the decrease of CH_4 fluxes by high levels of N fertilization in rice plant included soils might be caused by N fertilization-induced CH_4 consumption.

REAL TIME ANALYSIS OF DAIRY SLURRY FOR PRECISE FERTILAZATION– PERFORMANCE OF AN ON-LINE NEAR INFRARED REFLECTANCE SYSTEM

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Objectives

There is a large variation in the concentrations of dry matter and plant nutrients in cattle and dairy cow slurries. For more precise fertilization application, quantification and monitoring of available plant nutrients prior to spreading is required.

Analyzing the slurry quality on-line with a sensor while spreading or filling the spreader would be advantageous for representative sampling and variation monitoring. Near infrared reflectance spectroscopy (NIR) is a measurement technology commonly used in laboratories and on-line in agricultural and food industries. Different chemical bonds absorb light at different bands, resulting in reflectance spectra with information about the sample composition.

In this study, we explored analyzing slurries passing a NIR-sensor while circulating through a pipe. We also compared the precision for predicting dry matter (DM), total nitrogen (tot-N, ammonia (NH4) and total phosphorous (tot-P) with an on-line system to a lab grade instrument with less noise and a broader band with.

Method

In this study, an on-line NIR sensor equipment from Tec5 (Oberursel, Germany; tec5.com) was used. It was equipped with a Carl Zeiss PGS-NIR1.7 (Carl Zeiss AG, Germany) detector measuring reflected light in the 960-1700 nm region with a resolution of <5 nm. The instrument was equipped with a fiber optic connected to a NIRON II measuring head including a light source and a shutter for white reference and black current measurements. The measuring head was mounted on a 100 mm pipe connected to a tank for 50-100 l samples. The slurries were circulated through the pipe to simulate the flow in a real spreader. In addition, two replicate samples were taken from the tank and analyzed with a ASDI Field Spec Full Range instrument (Boulder Colorado; asdi.com) in the lab. This instrument collected spectra from the visible (350-780 nm) to the full near infrared (780-2500 nm) with a similar resolution as the Tec5 instrument, but with less noise.

For the study, 35 dairy slurries collected from different farms were analyzed. Each slurry was analyzed in the test rig at three different pump rates to make calibrations more robust for future use on data from real spreaders where the flow rate will also vary and will not be adjusted to exactly the same as in the test rig. After NIR measurements, three 1 l samples of each slurry were taken while still circulating. One was sent to the laboratory for reference analysis of DM, tot-N, NH4-N and tot-P. From these data, PLS prediction models were calibrated. The two others were used for NIR analysis in the lab.

Evaluation of the calibrations was performed with cross validation with as many segments as unique samples. Residual mean square errors (RMSE), correlation coefficients (R2) and the ratio of predicted to standard deviation (RPD; SD/RMSE) were calculated. In this presentation only prediction results from the average spectrum of the three circulation rates are presented.

Results

In the reference analyses the slurries demonstrated a fairly large variation. The average and standard deviation for DM, tot-N, NH4-N and tot-P was 7.7 (±1.6) %, 3.8 (±0.7) kg/ton, 2.0 (±0.3) kg/ton and 0.5 (±0.1) kg/ton, respectively. The corresponding ranges were: 3.8-10.3, 2.2-5.0, 1.1-2.6 and 0.35-0.75.

Calibration performance in the cross validation ranked DM > tot-N > tot-P > NH4-N with R2 ranging from 0.89 to 0.39 and RPD's from 3 to 1.2, DM and NH4 being the best and worst, which is regarded as very good and poor, respectively. The corresponding values for tot-N and tot-P were intermediate; 1.6 and 1.5.

In contradiction to the expected the differences between calibrations based on on-line measurements with the shorter spectral range and the spectra collected in the lab with less noise and the full visible and near infrared spectral range was very small or nonexistent. In some cases on-line measurements were actually slightly better. The reason for this is not known, but a hypothesis is that sample presentation in the on-line system was more representative. It can be expected the rapid sedimentation can occur in the lab setup even though the probe was dipped in a very shallow sample in 10 replicates for each sample.

Conclusions

Calibration results for DM are very promising, while the results for especially NH_4-N is somewhat disappointing. However, 35 samples are very few and requires a large degree of interpolation and in some cases extrapolation from the calibrations. More samples are on their way, which will possibly improve results to some degree. The fact that the comparably cheaper and more robust on-line instrument can compete with a lab-grade instrument despite more noise and a shorter range was regarded as very advantageous.

GROWTH, WATER AND NITROGEN USE EFFICIENCY UNDER DRIP IRRIGATION ON WHEAT GROWN ON ARID REGION

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Objectives

Objectives: Improve the grain yield and nitrogen use efficiency under drip irrigation intervals with application of different nitrogen sources fertilization. Also, determine soil nitrate concentration in the different layers with different levels of drip irrigation and nitrogen fertilization.

Method

The experiment was laid out in split block design with eight treatments, two application of irrigation at 80 % and 40% from field capacity and four rate of nitrogen fertilizer application from two sources of nitrogen, each treatment was replicated thee time under drip irrigation. Distance between laterals 1 m, distance between drippers is 35 cm. Drippers discharge is 4 l/h. Number of drippers are 12000. Wheat (*Triticum aestivum*, cv Giza 168) was sown on 20 November 2009 until 10 April 2010 a seed rate of 70 kg fed.-1 with 1m cm row spacing. Water was applied by drip irrigation. Phosphorus and potassium was applied in the form superphosphate and potassium sulfate at rate of 15 kg fed.-1 P_2O_5 and 24 kg fed.-1 K_2O, respectively. Also, 20m^{-3} fed FYM was addition to all plots at the time of preparing soil. Also, nitrogen fertilizer as source of ureaformaldehyde was applied at the time of sowing, while urea was applied with irrigation at different stages of growth up to 100 days after sowing. The experiment was laid out in a split–plot design. The whole plot factors were two irrigation treatments (I1 and I2) the main plots however, eight N treatments which included a combination of two N sources (urea and Ureaformaldhyde) and four N rates (0, 40, 60 and 100 kg N fed-1) sub plot. At maturity, one meter square area selected randomly from each plot was used to determine the number of spikes per unit area. Plant height (cm), number of tillers/plant, weight of 1000 grains per (g) and grain yield ton fed^{-1}. Water use efficiency was calculated as the ratio of the grain yield (kg ha") to the total water applied in m^3 per fed. **(Hussain and Al-Jaloud, 1995).** Soil water content at different depths (from 0.10 m to 0.80 m) was made using gravimetric soil water sampling.

Results

It worth to mentioned that at high rate (100 kg N fed-1) of ureaform with I2 level of irrigation gave the lower values compared with at the same rate with urea. These results may be attributed to under the low soil moisture the mineralization of nitrogen from ureaform was low because the release of nitrogen depends on soil moisture and microbial activity thus lowering the N availability. **(Paramasivam and Alva 1997).**also the emission of ammonia by volatilization was usually reduced when moisture content increase.These results may be due to that sandy soil is very low water holding capacity and high nutrient leaching losses. **Hanafi et al. (2002)** reported that the uncoated compound fertilizer such as urea gave significantly higher amounts of nutrients loss compared to slow release N fertilizer. **Zeidan and El kramany (2005)** found that the use of slow release nitrogen fertilizer increased grain yield of wheat compared with other nitrogen sources.

Conclusions

This approach also provides an efficient way of applying nitrogen to such soils to increase the efficiency of N application and to minimize leaching as well as to prevent environmental pollution by the excess of nitrogen in the soil.

LAND USE EFFECTS ON C AND N DYNAMICS IN AN AREA NEAR BRAUNSCHWEIG, NORTH GERMANY

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Introduction

Soils play an important role within the global cycles of carbon (C) and nitrogen (N). Storage and dynamics of soil organic carbon (SOC) and total nitrogen (N_{tot}) besides climate, texture and other factors depend mainly on the land use system. Most of the studies related to SOC and N_{tot} under different land use either focus on total stocks, or available fractions, or transformation rates of C and N [1]. In the current study, we compared land use-specific C and N storages with results from selected extraction and incubation procedures. The specific objectives of this study were to enumerate the effect of land use on i) SOC and N_{tot} stocks in soils ii) available fractions such as hot water-soluble C (C_{hws}) and N (N_{hws}), iii) N mineralization potentials and iv) nitrification capacities.

Method

Two locations (Hordorf and Warmbüttel) near Braunschweig (North Germany), exhibiting almost similar soil parent materials and soil types, were sampled in October 2013. According to [2] the soils in Hordorf and Warmbüttel are characterized as Stagnic or Haplic Cambisols, respectively. Soil development has occurred on pleistocene sand overlying glacial till. At each location, three sites representing long-term established land use systems (arable land, grassland, deciduous forest) were selected. Under each land use, soil samples were taken with five replicates in a 20 x 40 m area with an auger from 0-60 cm depth, divided in 10 cm increments. Samples from each increment were combined to a mixed composite sample. For SOC and N_{tot} stock calculation, the soil bulk density was determined in defined depths with undisturbed soil cores of a volume of 100 cm^3.

Besides SOC and N_{tot} storage in 0-60 cm depth, hot water-soluble C (C_{hws}) and N (N_{hws}), N mineralization potential and nitrification capacity with and without addition of NH_4^+ fertilizer were determined for the surface soil horizons (Ah and Ap). Soil organic carbon and N_{tot} were measured simultaneously with a Carlo Erba NA 1500 CNS Analyzer. Hot water-soluble C and N_{hws} were determined according to [3] at 80°C and 100°C, respectively. The long-term-incubation experiment on nitrogen mineralization was conducted for 177 d at 35°C according to [4] with modifications by [5]. The incubation experiment on nitrification (25°C; only Hordorf location) was conducted by following a standard procedure, using NH_4^+ fertilizer plus a zero NH_4^+ treatment.

Results and discussion

Stocks of SOC (0-60 cm) amounted to 81 Mg C ha^{-1}, 90 Mg C ha^{-1} and 188 Mg ha^{-1} for Hordorf arable land (Ha), grassland (Hg) and forest (Hf), and to 54.8 Mg C ha^{-1} for arable land (Wa), 46.2 Mg ha^{-1} for grassland (Wg) and 83.2 Mg ha^{-1} for forest (Wf) in Warmbüttel, respectively. Total nitrogen (0-60 cm) accounted for 8.1 Mg N ha^{-1} (Ha), 8.8 Mg N ha^{-1} (Hg) and 12.6 Mg N ha^{-1} (Hf) in Hordorf, and 4.1 Mg N ha^{-1} (Wa), 4.3 Mg N ha^{-1} (Wg) and 6.3 Mg N ha^{-1} (Wf) in Warmbüttel, respectively. These data confirmed that C and N stocks under (near-) natural vegetation are higher compared to agricultural land (arable and grassland). There were positive correlations of C_{hws} and N_{hws} with SOC and N_{tot}. The three land use types differed significantly ($P<0.05$) from each other in their potentials to mineralize N. However, the N mineralization patterns at the two locations were not uniform on a concentration basis (µg N g^{-1} soil). The amounts of N mineralized (µg N g^{-1} soil) after 177 d followed the order Hf > Hg > Ha and Wg > Wf > Wa. In contrast, amounts of N mineralized on an area basis (kg N ha^{-1},) at both locations followed a uniform pattern (Hg > Ha > Hf and Wg > Wa > Wf). Mineralized N of both, the readily available N fraction (N_a*k_a) as well as the resistant fraction (N_r*k_r) was positively correlated with C_{hws} and N_{hws}. The results of the experiment on nitrification with addition of $(NH_4)_2SO_4$ fertilizer (100 mg N kg^{-1} soil) showed that the highest amounts of NO_3^--N after 7 d of incubation were produced under Ha, followed by Hg and Hf, indicating a strong correlation between nitrification and soil pH.

Conclusions

Our results showed that the amounts of SOC and N_{tot} present in soil are strongly dependent on land use. Among the three sites investigated, C and N stocks at both of the locations were highest in the forest soil, suggesting an immense potential for C and N sequestration through forest regrowth on both grassland and arable land. There were different patterns concerning N mineralization potentials on a concentration basis (µg N g^{-1} soil) compared to the area basis (kg N ha^{-1}). The latter may be more appropriate under an ecological point of view. Compared to the arable soil, nitrification activity following N fertilizer application was more limited under forest than grassland. Nitrification is strongly linked to pH and thus limited under the soil conditions of the forest. According to our results, the current land use seems to have a more pronounced influence on the nitrification capacity compared to the N mineralization potential.

References

[1] Nieder, R., Benbi, D.K. 2008. Carbon and nitrogen in the terrestrial environment. Springer, 430 pp.

[2] IUSS Working Group WRB. 2015. World Reference Base for Soil Resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106.

[3] Ghani, A., Dexter, M., Perrott, K.W. 2003. Hot water-extractable carbon in soils: a sensitive measurement for determining impacts of fertilization, grazing and cultivation. Soil Biology and Biochemistry 35, 1231-1243.

[4] Stanford, G., Smith, S.J. 1972. Nitrogen mineralization potentials of soils. Soil Science Society of America Proceedings 36, 465 - 472.

[5] Nordmeyer, H., Richter, J. 1985. Incubation experiments on nitrogen mineralization in loess and sandy soils. Plant and Soil 83, 433-445.

SIMULATION OF NITROGEN MIGRATION AND LOSS IN THE RETURN WATER OF NINGXIA IRRIGATION DISTRICT

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Objectives

Based on the sustainable development of agriculture and water quality safe in the Yellow River Irrigation District, the combination methods of network soil column experiment and field study were used to simulate nitrogen migration and loss characteristics during the return water of the Irrigation Area of Upper Yellow River.

Method

The study area is located at the second station of Lingwu Farm in Ningxia Province. The main soil type is anthropogenic-alluvial soil which formed by long-term irrigation of the Yellow River water. The main cropping pattern is rice-wheat rotation in one harvest a year. Its main crops are rice, spring wheat and corn.

The plexiglass column was 130 centimeter high and 30 centimeter in diameter. Six sampling holes were set up in the unilateral of each column. The each of the sampling hole was made of screw mouth, and the pore size was 1.2 centimeter.

The area of paddy field plot was 60 square meters (6m×10m).The independent irrigation and drainage system was provided, cement ridge of 1.2 meter in depth was repaired all around. And double plastic film was used to prevent water and fertilizer leakage. The conventional irrigation was 22500 cubic meters per hectare. The conventional fertilization was 105 kilograms phosphorus pentoxide (P_2O_5) per hectare, 60 kilograms potassium oxide (K_2O), and 300 kilograms urea per hectare. Three treatments were set, which were rice growth, no rice growth and controlled treatment (only irrigation without fertilization). Each treatment has three repeats. Rice was transplanted in May 11, 2010 and harvested in September 11, 2010.The rice varieties was 96D10 in 30 centimeter row spacing and 10 centimeter column spacing.

The 105 kilograms phosphorus pentoxideper hectare and 60 kilograms potassium oxide was applied once as a base fertilizer in May 9, 2010. Nitrogen fertilizer was applied at four different stages， and the ratio of fertilizer application was 4:3:2:1 in May 9th（two days before transplanting), May 31st (twenty days after transplanting), June 22nd (forty-two days after transplanting) and July 22nd (sixty-three days after transplanting). The soil solution at the depth of 30, 60, 90, 120 centimeters was collected regularly by soil solution extractor. Soil bulk density, soil texture, soil porosity， total nitrogen(TN)， ammonium nitrogen(NH_4^+-N) and nitrate nitrogen(NO_3^--N) was measured. Meteorological data such as rainfall, relative humidity, temperature, wind speed, sunshine duration, etc. were monitored at the same time.

Results and discussion

Nitrogen in the surface water of network soil column was mainly ammonium nitrogen. The peaks of nitrate nitrogen concentration appear later than that of NH_4^+-N, only when the peak appeared at three to five days after basal dressing and three days after the first topdressing. The changes of NH_4^+-N and total nitrogen concentration with time were accord with logarithmic decrement. NO_3^--N was not the main form of nitrogen loss of farmland at the beginning of fertilization.

Nitrogen in the leakage water of network soil column was mainly NH_4^+-N. In addition to TN, NH_4^+-N and NO_3^--N concentration of leakage water at the depth of 120 centimeter in no rice growth soil column between basal dressing and the first topdressing was higher than that of rice growth soil column, NO_3^--N and TN concentration at the other depth in rice growth soil column was higher than that of no rice growth soil column after three fertilization. And NH_4^+-N concentration was close to each other. NH_4^+-N and TN concentration of leakage water at different depths of rice growth soil column was higher than that of no rice growth soil column, but its NO_3^--N concentration was lower than that of no rice growth soil column.

Nitrogen in the surface water of paddy field was mainly NH_4^+-N, and NH_4^+-N concentration was much higher than that of NO_3^--N. The change trends of NO_3^--N and NH_4^+-N concentration of surface water in paddy field were basically the same. The concentration was maintained a high concentration about one week after per fertilization, but the change of NO_3^--N concentration was relative moderate, the time of concentration peak was later one to three days than that of NH_4^+-N.

The change trends of NO_3^--N and TN concentration of leakage water at different depths during the rice growth stages were basically the same. NH_4^+-N concentration peaks occur after per fertilization, and then NH_4^+-N concentration declines to stabilization gradually.

NH_4^+-N and NO_3^--N concentration was close to each other at the shallow soil in paddy field, and the leaching of nitrogen at the deeper soil was mainly NO_3^--N. The leakage of soil water in paddy field was the most serious during the tiller stage, and the excessive irrigation was the main cause of serious water leakage. Nitrogen leakage occurs mainly at the early stage of rice growth, and the main form was NO_3^--N. It occupied about 80% of the loss of TN, but the proportion of NH_4^+-N was very small.

Conclusions

The dynamic variation of nitrogen concentration with time and depth in the surface water and the leakage water was revealed by soil column experiment and rice field study. It has less effect to seepage loss of nitrogen whether rice growth or not. The leakage of soil water in paddy field is the most serious during the tiller stage. Nitrogen leakage occurs mainly at the early stage of rice growth. Controlling the nitrogen loss within one week after fertilization could reduce the probability of water body pollution. There is a pressing need for improving experimental device to reduce the leakage loss.

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References

[1] Gooday, R., Anthony, S., Fawcett, L. 2008. A field scale model of soil drainage and nitrate leaching for application in nitrate vulnerable zones. Environmental Modelling & Software 23,1045-1055.

[2] Wang, M., Chen, Z., Yang, J., et al. 2009. Measurement difference in paddy field nitrogenleakage by using different type lysimeters. Chinese Journal of Applied Ecology 20(5), 1236-1242.

[3] Li, Y., Yang, L.,Yin, G. 2010. Experimental study on nitrogen leaching in a direct-seeding rice paddy of Taihu Lake Basin. Plant Nutrition and Fertilizer Science 16(1), 99-104.

SIMULATING N_2O EMISSIONS USING THE STICS SOIL-CROP MODEL IN LOW-INPUT CROPPING SYSTEMS IN SW FRANCE

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Objectives

Nitrous oxide (N_2O) is a powerful greenhouse gas (GHG) with a global warming potential 265 times greater than carbon dioxide (CO_2), making agriculture a major actor in the emission of this GHG [1]. The use of models is a key strategy for evaluating N_2O emissions from different cropping systems at different scales, given their capacity to integrate the processes that regulate N_2O emission [2]. In this work we tested the ability of the soil-crop model STICS, able to deal with complex rotations, to simulate the emissions of N_2O in low-input cropping systems.

Method

The performance of the model STICS v.8 to simulate N_2O emissions was evaluated using observed data of the MicMac experiment testing innovative low input cropping systems (Auzeville, SW France). In that experiment, 3-year alternatives to the traditional durum wheat-sunflower rotation were compared for decreasing N fertilizer and pesticide inputs. For each 3-yr rotation, N_2O emissions were measured using automatic chambers (0.70 x 0.70 x 0.30 m, 3 replicates). N2O concentration was quantified using automatic chambers. Other key variables were also measured (e.g. soil water and mineral N contents, soil temperature, and bulk density). Plant and soil input parameters of the model were calibrated and validated as reported by [3].

Results

Our preliminary results show a fairly good capacity of the STICS model to simulate N_2O emissions from the soil to the atmosphere, in different cash crop and cover crop phases of a rotation in a low-input cropping system. Basically, STICS simulates emissions of the same data range than the observed values and seems able to capture the main trends of emissions. However, our first work shows that some aspects remain to be improved. Firstly, the model seems to be too sensitive to N fertilizer application, simulating some N_2O peaks that were not observed under field conditions with dry soil surface. Secondly, the model is highly sensitive to soil bulk density. In its current status, STICS takes soil bulk density – and concomitantly, porosity – as a static soil property during the crop cycle, fact that hinders the ability to mimic the dynamic soil structure measured under field conditions. Observed and simulated N_2O peaks showed the same order of magnitude, although with a short delay which highlights the need to improve the simulation of temporal dynamics of porosity and gas diffusion within soil structure [2], [4].

Conclusions

Our preliminary results show the potential of the STICS soil-crop model to simulate the range of values of N_2O emissions of such complex crop rotations with cover crops without great time investments in calibration, which is satisfactory. However, some formalisms and parameterization still need to improve the dynamic of emissions and obtain more precise estimations of the impact of agricultural management practices and cropping systems on N_2O emissions.

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References

[1] IPCC. 2013. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Climate Change 2013: The Physical Science Basis. Cambridge University Press, Cambridge, United Kingdom and New York NY, USA.

[2] Doltra, J., J.E. Olesen, D. Báez, A. Louro and N. Chirinda. 2015. European Journal of Agronomy 66, 8-20.

[3] Plaza-Bonilla, D., J.M. Nolot, D. Raffaillac and E. Justes. 2015. Agriculture, Ecosystems and Environment 212, 1-12.

[4] Blagodatsky, S and P. Smith. 2012. Soil Biology and Biochemistry 47, 78-92.

AMMONIA EMISSIONS FROM TWO NATURALLY VENTILATED CATTLE BUILDINGS IN IRELAND

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Objectives

Ammonia (NH_3) gas emission represents a substantial economic loss of nitrogen for farmers and is also environmentally detrimental. Agriculture contributes 98% of the total NH_3 emissions in Ireland with 48% of agricultural emissions coming from animal housing and slurry storage which are estimated to arise. However, current NH_3 emission estimates for Irish cattle housing are based on UK derived emission factors. There is a need to create country specific emissions factors to improve the accuracy of Ireland's NH_3 emission inventory. In particular, there is a lack of data relating to cattle buildings with slatted floors, as the UK studies have primarily focused on solid floor cubicle and straw bedded cattle buildings. The objective of this study therefore was to quantify NH_3 emissions and emission factors from two cattle buildings with solely slatted floors in Ireland.

Method

This study was conducted on two commercial livestock farms (building "A" and "B") in the south of Ireland. The two buildings consisted of a solid floor feeding alleyway with slatted floor pens on either side of the feeding alleyway. Both buildings were roofed with a combination of concrete and Yorkshire boarding perimeter walls. The external dimensions of building A were 19.1 m × 13.2 m with a roof height of 5.5m. The external dimensions of building B were 14.4 m × 12.9 m with a roof height of 4.7 m. Building A contained, on average, 41 livestock units (lu: 1 livestock unit = 500 kg liveweight) during the measurements, while building B contained 31 lu. The livestock were a mixture of suckler cows, dairy heifers (6-12 mths) and suckler weanlings (6-12 mths). The diet of the livestock primarily consisted of grass silage with small amounts of straw and mixed rations.

Measurements were conducted on each building on seven occasions over two consecutive winters (Nov to March: 2015 and 2016). Ammonia emission measurements for both buildings were made using passive flux samplers (Ferm tubes) [1]. Samplers were distributed evenly across the building openings and contained two NH_3 acid traps which captured NH_3 as it entered and exited the buildings. Samplers were exposed on the buildings for 24 h for each measurement. Following exposure, the amount of NH_3 collected in each acid trap was determined by extracting with deionised water over 16 h, followed by analysis for ammonium. The net flux from the buildings (kg NH_3-N d^{-1}) was calculated as described by Pereira *et al. (2010)* [2].

Ammonia emissions factors (g NH_3-N lu^{-1} d^{-1}) were calculated by dividing the daily fluxes by the number of livestock units in the building on each measurement day. The emission factor as a percentage of total N excreted was calculated using standard values of N excretion for different livestock categories (S.I No. 31 of 2014). Climatic data such as air temperature, wind speed and wind direction were recorded during each measurement inside and outside the buildings.

Results

Daily NH_3 emissions varied over time in both buildings. Mean emissions (kg NH_3-N d^{-1}) were 1.49 from building A and ranged from 0.52 to 2.52. Daily emissions (kg NH_3-N d^{-1}) from building B were four-fold lower than building A with a mean of 0.35 and ranged from 0.06 to 0.63. The larger livestock numbers (generating more urine and dung) and greater emitting surface area associated with the larger building was the most likely cause for the higher emissions from building A. The emissions from each side and the roof of the buildings were not uniform. In building A the largest contributor was the east side (56%) followed by the north side (16%), west side (15%), south side (7%) and roof (6%). The high proportion of emissions form the east side of the building was due to the westerly wind directions experienced during these measurements, with is typical of Ireland's climate. Building B was slightly different to building A with the largest contributor being the east side (31%) followed by the south side (24%), west side (16%), north side (15%) and roof (14%).The wind direction was much more variable during the measurements on building B, which resulted in less dominance of the east and north side of the building.

The NH_3 emission factors (g NH_3-N lu^{-1} d^{-1}) varied over time and between buildings and ranged from 13.4 to 54.3 on building A (mean: 34.0, S.D.: 15.7) and from 1.8 to 18.4 on building B (mean: 11.2, S.D.: 5.8). The overall mean emission factor from the study was 22.5 g NH_3-N lu^{-1} d^{-1} or 12.8% of total N excreted. This was somewhat lower than the mean emission factors (34.3 g NH_3-N lu^{-1} d^{-1}) reported for buildings with cubicles and scraped alleyways but similar to those reported for straw-bedded buildings (23.1 g NH_3-N lu^{-1} d^{-1}) in the UK [3]. Total ammonium N is assumed to accounts for 60% of total N excreted in the calculations used in Ireland national NH_3 inventory. Using the same assumption the results of this study suggests an overall emissions factor of 21.4% of TAN excreted in this study. It is also lower than the currently applied emission factor of 32% of TAN excreted indoors in the Irish NH_3 inventory.

Conclusions

The results of this study represent the first direct measurements of NH_3 emissions from cattle buildings in Ireland, which can be used as a starting point in the generation of robust country specific emissions factors to improve Ireland's national NH_3 inventory. The overall mean emission factor from the study was 22.5 g NH_3-N lu^{-1} d^{-1}, which is lower than the currently used emission factor for Ireland. The results of this study also add to the limited available datasets on NH_3 emissions from cattle buildings with solely slatted floors.

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References

[1] Scholtens, R., Dore, C.J., Jones, B.M.R., Lee, D.S., Phillips, V.R., 2004. Measuring ammonia emission rates from livestock buildings and manure stores-part 1: development and validation of external tracer ratio, internal tracer ratio and passive flux sampling methods. Atmospheric Environment 38, 3003-3015.

[2] Pereira, J., Misselbrook, T.H., Chadwick, D.R., Coutinho, J., Trindade, H., 2010. Ammonia emissions from naturally ventilated dairy cattle buildings and outdoor concrete yards in Portugal. Atmospheric Environment 44, 3413-3421.

[3] Misselbrook, T.H., Gilhespy, S.L., Cardenas, L.M., Williams, J., Dragosits, U., 2015. Inventory of ammonia emissions from UK agriculture, 2014. Inventory submission report to Defra as part of project SCF0102.

Ammonia and Nitrous Oxide Losses from Mechanically Turned Cattle Manure Windrows: a Regional Composting Network

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Objectives

A cattle manure composting network exists in the Basque Country (northern Spain), in which solid manure produced by 82 farmers is composted at farm level. All compost windrows are mechanically turned according to a previously agreed calendar and the end product is sold to regional crop producers. This network let farmers reduce on-farm waste volume whereas regional nutrient surplus is balanced. Despite these benefits, manure composting is related to N gaseous losses into the atmosphere. Ammonia (NH_3) is usually lost within the first month after the heap establishment. Nitrous oxide (N_2O) losses occur during the mesophilic phase of the process. The objective was to assess NH_3 and N_2O emissions from turned cattle manure composts windrows, which were managed in "real-life" conditions and differed in their origin (deep litter and solid fraction) and maturity (fresh and mature piles).

Method

Gaseous N losses (NH_3 and N_2O) were monitored from 4 windrows before and after 1 to 3 turning operations in spring/summer 2012. Three deep litter derived piles were studied at 2 cattle farms (beef and dairy). Cereal straw was used as bedding material (8 kg cow^{-1} d^{-1}) in all cases. The windrow heaped at beef cattle farm (BDL) had been established outdoors in December 2011. Windrows with different maturities had been heaped at dairy farm: DDL_m in December 2011 and DDL_f in March 2012. All windrows showed a similar shape (115 m length, 3 m width and 1.3 m height). The fourth windrow (SMS), which was obtained after solid-liquid slurry separation, had been heaped in a second dairy cattle farm. The solid fraction had progressively been heaped in 3 windrows from March 2012 onwards (30 m length, 3 m width and 1 m height). BDL, DDL_m, DDL_f and SMS windrows were mechanically turned by a self-propelled turner (4300SP Menart). The first turning in BDL, DDL_m and DDL_f was conducted in 13th April 2012, whereas the second turning was performed in 17th May 2012. Finally, the third turning, which was monitored in SMS, was conducted in 10th August 2012.

Ammonia emissions were measured by the open chamber technique [1]. Three PVC chambers (6.75 L) were randomly placed on all the piles. Measurements were conducted during 5 days after the windrow turnings. Chambers were daily repositioned for representing the spatial variation. Ammonia measurements were monitored from 10.00h to 15.00h by a photoacoustic analyser (Bruel & Kjaer 1302). Nitrous oxide was measured by the closed chambers technique [2]. Sampling was daily performed during 1 week after the turning operations and twice per week during the rest of the experimental period. Four PVC chambers (20 cm diameter, 15 cm height) were inserted in each windrow. Gas samples were taken 0, 20 and 50 min after the chamber closure and introduced in GC vials. Nitrous oxide concentration was quantified by GC (Agilent 7890A). Finally, all the windrows were analyzed for total N (TN) and ammonium-N (NH_4^+-N). Atmospheric and windrow temperatures were also monitored.

Results

Negligible NH_3 losses were monitored before the first mechanical turning in BDL, DDL_m and DDL_f, and the third turning in SMS windrows. These results agreed with previously reported data [3], in which NH_3 was mostly emitted within the first 2 weeks after heaping the windrows. The maturity of BDL, DDL_m and DDL_f and SMS heaps (> 1 month) would have limited NH_3 losses. The low NH_4^+-N pool in all the windrows (< 5% TN) suggested that N immobilization was held by the microbial flora. The effect of the mechanical turnings was not uniform on NH_3 emission pattern. Emission was not affected by the first turning in BDL, DDL_m and DDL_f composts, while it was released at low levels after the second turning in BDL and DDL_f (< 2.0 mg m^{-2} d^{-1}). This effect could be related to the warmer atmospheric conditions during the second turning operations (≈ 20ºC). Atmospheric temperature was around 10ºC during the first turning works. A similar mean NH_3 peak was observed in SMS windrow after the third turning process in August 2012 (atmospheric temperature > 20ºC). All these results agreed with the available literature, which showed that turning of mature composts had little effect on NH_3 volatilization [3]. According to the best management practices in the region, the first turning operations should have been conducted in January 2012 for BDL and DDL_m. However, the adverse weather conditions in winter delayed the field works.

In relation N_2O losses, low mean emission rates were recorded in all the heaps during the monitoring period (< 50 mg m^{-2} d^{-1}). This emission rate was close to data reported in the literature for mature manure-derived piles [3]. Above mentioned N immobilization would have contributed to the low N_2O emissions. Nitrous oxide emission increased significantly after the turning works, especially in DDL_f and SMS with 253.0 and 326.8 mg m^{-2} d^{-1}, respectively. These peaks were observed 3 days after the second and third turning works in DDL_f and SMS (windrow temperature, 30-40ºC), respectively. This delay would support that N_2O losses from turned windrows arise due to microbial activities rather than the physical turning. The lack of response of BDL and DDL_m was attributed to windrow temperatures below 20ºC.

Conclusions

The present study concluded that two turning operations in mature compost windrows have not significant effect on NH_3 and N_2O losses. An additional third turning, which is required for well-humificated composts, may be a suitable option in mature windrows without increasing significantly NH_3 and N_2O losses. In contrast to the performance of gaseous losses in experimental systems, losses from “real-life” manure composting- turning networks are dependent on (i) the manure management practices at farm level (e.g. heaping compost windrows in winter instead of in warmer seasons); and (ii) regional climatic conditions (e.g. altering theoretically best management practices for turning during the composting process).

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References

[1] Merino, P., Arriaga, H., Salcedo, G., Pinto, M., Calsamiglia, S. 2008. Agriculture Ecosystems and Environment 123, 88-94.

[2] Merino, P., Estavillo, J.M., Pinto, M., Rodríguez, M., Duñabeitia, M.K., González-Murua, C. 2001. Soil Use and Management 17, 121-127.

[3] Parkinson, R., Gibbs, P., Burchett, S., Misselbrook, T. 2004. Bioresource Technology 91, 171-178.

Further development and appraisal of the Geological Survey of Ireland's Potentially Denitrifying Bedrock map

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Objectives

Eutrophication is the principal threat to surface water quality in Ireland. In some situations, groundwater represents a significant pathway for nutrient transport to surface water. Nitrate is usually the principal limiting nutrient responsible for eutrophication in estuarine and coastal waters [1]. In addition, groundwater plays a role in indirect greenhouse gas emissions, transferring dissolved nitrogen from terrestrial ecosystems to the atmosphere via the aquatic pathway [2].

The Geological Survey of Ireland (GSI) developed a Potentially Denitrifying Bedrock map [3] to allow the Environment Protection Agency (EPA) and other decision makers to better assess the risk of surface water eutrophication from groundwater sources [4] as part of the implementation of the E.U. Water Framework Directive (WFD) (2008/98/EC).

This study aims to appraise and to further develop the GSI's Potentially Denitrifying Bedrock map in order to improve estimates of nitrate fluxes from groundwater to surface waters.

Method

In certain hydrogeological settings in Ireland, denitrification can occur. Denitrification reduces nitrate to nitrogen gas, or where the process is incomplete, the greenhouse gas nitrous oxide may be released. The GSI's Potentially Denitrifying Bedrock map [3] focuses on the denitrification of nitrate which occurs in the *bedrock* making use of electron donors present within the bedrock. This is in contrast to denitrification occurring in the subsoils and shallow groundwater which has been shown to be significant in some settings in Ireland [5].

The GSI's Potentially Denitrifying Bedrock map identifies bedrock units which are likely to contain electron donors such as organic carbon or metal sulphides (e.g. pyrite). Data for the map came from a number of sources: (i) the descriptions of the bedrock units from the published GSI 1:100,000 scale bedrock maps (GSI, various); (ii) evaluations of the GSI's draft Aggregate Potential maps [6]; (iii) hydrogeological field experience of pyrite occurrence or hydrogen sulphide containing groundwater; (iv) geological knowledge of experienced geologists; and (v) other knowledge of pyrite occurrence. These data sources were combined to produce a Geographical Information System Potentially Denitrifying Bedrock map. The new version of the map, currently under development, will benefit from updated GSI bedrock and aggregate potential mapping; as well as recent research results, such as [5], [7] and [8].

Groundwater nitrate data have been collected in Ireland since the 1970s. Typically, measurements in the 1970s and 1980s were conducted during the course of different projects implemented by the GSI or local authorities (LA). In the 1990s, the EPA took responsibility for groundwater monitoring in Ireland and set up a national monitoring network for groundwater quality and levels. In recent years, and particularly in response to the implementation of the WFD, the groundwater monitoring network in Ireland has been updated and expanded considerably. Cross-correlation between groundwater nitrate data and potentially denitrifying bedrock, taking into account pressures (e.g. nitrogen inputs) and pathway factors, will be appraised and used to evaluate and constrain the Potentially Denitrifying Bedrock map.

Results

The current Potentially Denitrifying Bedrock map [3] includes bedrock units which are rich in organic carbon or metal sulphides (e.g. pyrite) and will hence potentially reduce nitrate levels through microbially-assisted oxidation of the electron donor substances. The potential for denitrification is qualified through a scoring schema within the map, ranking bedrock units from "definitely containing compounds with the potential to denitrify" (1a) to "almost certainly not containing compounds that have the potential to denitrify" (2b).

The Dinantian Lucan and Ballysteen shaly limestone Formations; the Namurian Clare Shale Formation and the Silurian Tramore Shale Formation were identified as the formations with the greatest potential for denitrification. Devonian Old Red Sandstone, Dinantian Pure Limestones, Dinantian Sandstones and the Dinantian Cork Group (mudstones and sandstones) were identified as having least potential for denitrification.

The new version of the map, currently under development, will benefit from updated GSI bedrock and aggregate potential mapping, as well as recent research results. In addition, the bedrock units identified as potentially denitrifying are being appraised with respect to groundwater nitrate data from the GSI, EPA and Local Authorities. Groundwater nitrate data from monitoring points within different denitrifying settings will be investigated with respect to pressure layers (including land cover, fertiliser application rates, livestock and septic tank density) and pathway layers (including soils, unconsolidated deposits, bedrock geology, aquifer type and climate data). The cross-correlation between nitrate data and bedrock data (taking pressures and pathways into account) will be appraised and used to constrain and evaluate the potentially denitrifying bedrock map.

Conclusions

This further development of the Geological Survey of Ireland's Potentially Denitrifying Bedrock map will strengthen its role in assessing the groundwater element of the nitrogen cycle in Ireland. The map will provide information for good decision making regarding catchment management and WFD objectives.

References

[1] Neill, M. 2005. A method to determine which nutrient is limiting for plant growth in estuarine waters—at any salinity. Marine Pollution Bulletin 50, 945–955

[2] Jahangir, M.M.R. et al. 2012a. Groundwater: A pathway for terrestrial C and N losses and indirect greenhouse gas emissions. Agriculture, Ecosystems and Environment 159, 40–48.

[3] Geological Survey of Ireland, 2011a. Bedrock units with the potential for denitrification. Unpublished report and map.

[4] Environmental Protection Agency. 2013. A Risk-Based Methodology to Assist in the Regulation of Domestic Waste Water Treatment Systems. Available from www.epa.ie

[5] Jahangir, M.M.R. et al. 2012b. Denitrification potential in subsoils: a mechanism to reduce nitrate leaching to groundwater. Agriculture, Ecosystems and Environment 147, 13–23.

[6] Geological Survey of Ireland, 2011b. 1:100,000 Draft Aggregate Potential map. Available from www.gsi.ie

[7] Orr, A. 2014. Hydrogeological influences on the fate and transport of nitrate in groundwater. Doctor of Philosophy thesis, School of Planning, Architecture and Civil Engineering, Queens University Belfast.

[8] McAleer, E., Mellander, P.E., Coxon, C.E., Richards, K.G. and Jahangir, M.M.R. 2015. Groundwater denitrification in two agricultural river catchments: influence of hydro-geological setting and aquifer geochemistry. Proceedings of the EGU General Assembly. Available from http://adsabs.harvard.edu/abs/2015EGUGA..1712889M

MYCORRHIZAL INOCULUM EFFECTS ON NITROGEN UPTAKE AND LEACHING IN ENERGY CROP SPECIES FERTILIZED WITH DIGESTATE LIQUID FRACTION IN MESOCOSM CONDITION

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Objectives

Large amounts of chemical fertilizers are generally applied in conventional agriculture, with potential nutrient losses, such as nitrogen (N) and phosphorus (P), which are among the top environmental threats of pollution to ecosystems worldwide. Organic fertilizer such as digestate, byproduct of biomasses anaerobic digestion, is an alternative to mineral ones. Arbuscular mycorrhizal fungi (AMF) are a very widespread communities of soil fungi, which play an important role in the nutrient cycling processes. It has been shown that AMF could reduce N and P leaching losses and increase plants nutrient uptake, they can promote sustainable nutrient cycling but the effects on N cycling are context dependent [1]. The aim of the trial was to evaluate the effect of AMF inoculum on N uptake and leaching in six annual and perennial herbaceous crops fertilized with digestate liquid fraction (DLF) in mesocosm condition.

Method

The trial conducted at the Experimental Farm "L. Toniolo" (45°20' N; 11°57' E), began in 2014 and it is still ongoing. The experimental design is a split-plot with AMF inoculation as the main-plot, and plant species as the sub-plots replicated four times, which consists of 6 species (Giant reed, Miscanthus, Jerusalem artichokes, Lolium, Corn and Sorghum) for a total 48 concrete growth boxes (2x2 m side). The growth boxes were installed with the top surface at 1.3 m above ground level, to avoid water table influence, the bottom open to allow water percolation and were filled with fulvi-calcaric Cambisol. Before the experiment started, ceramic suction plates were installed in 18 growth plots at a depth of 0.90 m and connected to a suction system to sample percolation water.

DLF, obtained from anaerobic digestion of cattle slurry and manure, maize silage and flour, was distributed on soil surface (April 1st 2014 and March 19th 2015) at dose of 250 kg N ha^{-1} box^{-1}. AMF (*Glomus* spp.) inoculations were carried out during transplanting or sowing at dose of 500 propagules m^{-2}. The perennial species were transplanted on February 2014, lolium was sowed on April 2014 while sorghum and corn on April 2014 and 2015. Plants were harvested cutting all boxes total aboveground biomass as follows: one or two cuts for Jerusalem artichokes, three cuts for sorghum, two cuts for lolium and one cut for giant reed, miscanthus and corn. Biomass dry weight was obtained in a thermo-ventilated oven at 65 °C, until the constant weight was reached. A CNS Macrovario combustion analyzer (Elementar Analysensysteme GmbH, Germany) was used to determine the biomass N content. During the trial percolation water samples were taken, at 3 different times, in the 60 days after DLF spreading in 2014 and in the 45 days after DLF spreading in 2015 (spring period); and 5 times after the first growing season from December 2014 to 2015 DLF spreading (winter period). 181 percolation water samples were collected and analyzed to detect TKN, NO_3-N and NH_4-N concentrations in spring samples and TKN and NO_3-N concentrations in winter ones.

Results

AMF inoculation significantly (ANOVA $p<0.05$) increase (+23.7%) giant reed (22.8±1.5 Mg ha^{-1}) and decrease (-16.7%) sorghum (36.6±4.3 Mg ha^{-1}) dry biomass production. No significant effect AMF inoculation exert for the other species with an average yield of 32.0±1.7, 28.9±5.9, 19.0±2.0 and 7.9±0.9 Mg ha^{-1} for corn, Jerusalem artichoke, miscanthus and lolium, respectively. AMF inoculation did not show any significant effect on N-uptake (32.6±12.5 and 30.8±14.0 g N m^{-2} with and without inoculation, respectively). On the average of AMF inoculation and cuts, the N-uptake for sorghum (42.3±8.1 g m^{-2}), Jerusalmen artichokes

(41.6±20.4 g m^{-2}) and corn (38.0±2.0 g m^{-2}) was not significantly different among them, but significantly (ANOVA $p<0.05$) higher than giant read (26.6±7.1 g m^{-2}), lolium (22.0±3.4 g m^{-2}) and miscanthus (19.1±2.6 g m^{-2}). The high standard deviation in Jerusalem artichoke is due to the different N-uptake between the plots managed with one (23.3±6.6 g m^{-2}) or two cuts (59.9±6.1 g m^{-2}). Except for lolium, miscanthus and Jerusalem artichoke, managed with one cut, the other crops have N uptake higher than that supplied with DLF (25 g m^{-2}). In 2015 spring TKN and NH_4-N concentration in percolation water were significantly (Mann-Whitney test $p<0.05$) lower (0.7 times) and higher (1.7 times), respectively, than 2014. AMF inoculation didn’t show effect on N content in the percolation water during 2014-spring season, probably due to the short time after experiment beginning. Instead, in 2015, AMF inoculation showed a significant (Mann-Whitney test $p<0.01$) lower NH_4-N (-52.2%) and higher NO_3-N (+73.8%) concentrations, than in the un-inoculated plots, which presented median values of 2.42 and 17.30 mg L^{-1} for NH_4-N and NO_3-N, respectively. In spring 2014, we detected in the percolation water the lowest (0.71 mg L^{-1}) and the highest (2.26 mg L^{-1}) NH_4-N content for giant reed and lolium, respectively. Opposite trend was observed for NO_3-N with 33.31 mg L^{-1} for giant reed and 14.58 mg L^{-1} for lolium. During winter season, the lowest NO_3-N concentration in the percolation water was found with lolium (1.40 mg L^{-1}), whereas the highest one with corn (27.72 mg L^{-1}). AMF inoculation significantly (Mann-Whitney test $p<0.001$) increases (2 times) the NO_3-N percolation compared un-inoculated boxes (14.05 mg L^{-1}). Evaluating the effect of cuts number on N percolation for Jerusalem artichoke, no effect was observed during winter season for both TKN and NO_3-N. Whereas in spring 2015 the percolation water from the boxes managed with two cuts showed a significant (Mann-Whitney test $p<0.05$) lower concentration for TKN (-38.8%) and NH_4-N (-51.6%), than in boxes managed with one cut (median concentration of 4.29 and 2.54 mg L^{-1} for TKN and NH_4-N, respectively). No effect was observed considering NO_3-N with a median concentration of 24.40 mg L^{-1}.

Conclusions

AMF inoculation increase giant reed and decrease sorghum dry biomass production, whereas no effect exerts on the others species. AMF inoculation had no clear effect on plants N-uptake, whereas after the first growing season significantly increase the NO_3-N concentration in percolation water. After the first DLF application AMF inoculation did not influence the N content in the percolation water although, after the second digestate distribution, it decrease NH_4-N and increase NO_3-N. The latter result seems confirm that AMF symbiosis favorites N uptake as NH_4 rather than NO_3 as previously reported by [1], [2] and [3]. The two cuts management of Jerusalem artichoke determine lower TKN and NH_4-N leaching, whereas no effect exerted the management on NO_3-N percolation. The results are undoubtedly interesting, but they have to be considered with caution since that they were obtained only during the first cropping season therefore further results are needed to confirm our findings.

Acknowledgment

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References

[1] Bender, F.S., Conen, F., Van der Heijden, M.G.A. 2015. Soil Biology & Biochemistry 80, 283-292

[2] Govindarajulu, M., Pfeffer, P.E., Jin, H., Abubaker, J., Douds, D.D., Allen, J.W., Bücking, H., Lammers, P.J., Shachar-Hill, P. 2005. Nature 435, 819-823.

[3] Tanaka, Y., Yano, K. 2005. Plant, Cell & Environment 28, 1247-1254.

SIMULATIONS OF NITROGEN DYNAMICS AND LOSSES IN AGRICULTURAL SOILS IN LOMBARDY REGION UNDER DIFFERENT CROPPING SYSTEMS

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Objectives

In order to assess the impact of the Italian requested derogation (Nitrate directive) on water quality, nitrogen losses to groundwater from the main agricultural systems in the specific conditions of the Lombardy region have been estimated through the ARMOSA simulation model.

Method

ARMOSA [1] is a model developed to define a methodology for the assessment of soil quality and nitrate vulnerability in arable systems in Lombardy plain; it was calibrated and validated through a large set of data observed in six monitoring sites [2]. The aim of the model is to simulate water and nitrogen dynamics in the soils representative of the Po valley agricultural areas, under different climatic conditions, crops and management practices, in order to have an instrument to extend the results of field trials to larger areas and to perform scenarios analysis.

Simulations have been provided using the model ARMOSA to compare the environmental performance of 3 different maize-based agricultural systems:

1. Silage maize (late maturing maize, class FAO 700);

2. Silage maize (class FAO 600) + Italian ryegrass;

3. Silage maize (late maturing maize, class FAO 700)+ wheat + sorghum + winter cover crop

The aim of these simulations was to compare the nitrogen outputs (N uptake, leaching and volatilisation) under different manure management and to evaluate the impact on the environment. These 3 scenarios were considered:

- scenario 1: application of 170 kg N ha-1 year-1 from manure;

- scenario 2: application of 250 kg N ha-1 year-1 from manure;

- scenario 3: application of 300 kg N ha-1 year-1 from manure.

Scenarios rely on the assumptions that despite an increase in the level of nitrogen from livestock manure, the total amount of nitrogen applied to the field does not vary (365 kg N ha-1 year-1) increasing the theoretical nitrogen efficiency (0.5, 0.6, 0.7) of manure.

These cropping systems have been simulated and compared considering four different soils, characteristic of Lombardy and Piedmont regions:

Soil 1: Luvisol (WRB, 2006), (87) representative of the central and high plain, with a coarse loamy texture;

Soil 2: Luvisol (WRB, 2006-462) representative of older surfaces with a coarse silty texture;

Soil 3: Cambisol (WRB, 2006-112) representative of the medium plain with a loamy texture;

Soil 4: Vertic Cambisol (WRB, 2006-144) representative of the low plain of Lombardy with a silty clay loamy texture.

Results

The simulation results show that despite an increase of nitrogen from livestock manure distributed to crops, the nitrogen losses (average values) through leaching or volatilisation processes notably decrease between the scenario 1 (application of 170 kg N ha-1 year-1 from manure, NVZ) and the scenarios 2 (application of 250 kg N ha-1 year-1) and 3 (application of 300 kg N ha-1 year-1).

The percentage distribution of nitrate concentration (mg l-1) in drainage water resulted to be affected by the level of fertilisation with organic N: globally, cases with a nitrates concentration higher than 50 mg l-1 are about 50% in scenario 1 (application of 170 kg N ha-1 year-1 from manure) and decrease to 30% in scenario 3 (application of 300 kg N ha-1 year-1).

The ANOVA pointed out the high significance of correlation between the crop rotation and the N losses, with a better environmental performance where soils are covered all year round by crops.

The effect of the crop rotation is confirmed also through the shape of the curves obtained by the correlation between the N leaching (kg ha-1 year-1) and the water inputs (rain + irrigation mm): the slope of the curve strongly decreases from the "maize" rotation to the "maize-wheat-sorghum-cover crop" rotation (confirming a lower trend to leach), with an additional small reduction going from scenario 1 (application of 170 kg N ha-1 year-1 from manure) to scenario 3 (application of 300 kg N ha-1 year-1).

The balance between nitrogen inputs and outputs was also evaluated for the different crop rotations and scenarios to allow the analysis of the increasing or decreasing of the soil N content in organic matter over the years of simulation. Nitrogen sequestration rates were estimated by calculating the mean difference between the final and initial organic N, using soil data to a depth of 40 cm from the latest year of simulations.

Simulation results suggest that scenarios where the soil is fertilised with high amount of organic N (250-300 kg N ha-1 year-1) are more stable with respect to soil organic carbon levels, while low input of manure (170 kg N ha-1 year-1) could lead to a loss of carbon and nitrogen (about 10-15 kg N ha-1) from the soils, in particular where maize is a monoculture or the prevalent crop, as it is in the intensive cropping systems of the Lombardy and Piedmont plain. On the other side, the apparent accumulation of nitrogen (30-50 kg N ha-1) under the other rotations seems to be consistent with the initial simulated low organic matter content (<2%) of soils.

Conclusions

The ARMOSA simulation results highlighted that scenario 3 with high organic N can be considered as an interesting solution to Lombardy soil. In fact, the greater amount of manure does not improve nitrogen losses, the leaching decrease from 55.99 (scenario 1) to 41.04 kg N ha-1 year-1 (scenario 3).

Silage maize in a double-cropping system with Italian ryegrass or silage maize in rotation with wheat, sorghum and cover crop had an high N uptake and it decrease of the N losses in winter season.

Finally, management adopted under scenario 3 can help improving the efficiency of manure use and reducing the use of mineral fertilizer by the farmer.

Reference

[1] Acutis M., Ducco G., Grignani C., 2000. Stochastic use of the LEACHN model to forecast nitrate leaching in different maize cropping systems. European Journal of Agronomy, 13: 191-206

[2] Perego A., Giussani A., Sanna M., Fumagalli M., Carozzi M., Alfieri L., Brenna S., Acutis M., 2013. The ARMOSA simulation crop model: overall features, calibration and validation results. Italian Journal of Agrometeorology 3:23-38.

EFFECT OF INTEGRATED FERTILIZATION AND COVER CROPPING ON N2O LOSSES IN AN IRRIGATED MEDITERRANEAN MAIZE FIELD

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Objectives

Agronomical and environmental benefits are associated with replacing winter fallow by cover crops (CC). Yet, the effect of this practice on nitrous oxide (N_2O) emissions remains poorly understood. The objective of this study was to evaluate the effect of two different CC species (barley and vetch) and fallow on N_2O emissions during the CC period and during the following maize cash crop period in an Integrated Soil Fertility management (ISFM) system. We also aimed to study the contribution of synthetic fertilizer and other N sources to N_2O emissions through a parallel ^{15}N labelled fertilizer experiment.

Method

The study was conducted at "La Chimenea" field station, located in the central Tajo river basin near Aranjuez (Madrid, Spain), where an experiment involving cover cropping systems and conservation tillage has been carried out since 2006. Soil at the field was a Typic Calcixerept with a silty clay loam texture and basic pH (8.2). The area has a Mediterranean semiarid climate, with a mean annual air temperature of 14 °C. Twelve plots (12m × 12m) were randomly distributed in four replications of three cover cropping treatments (seeded in October 2013), including a cereal and a legume: 1) barley (B) (*Hordeum vulgare* L., cv. Vanessa), 2) vetch (V) (*Vicia sativa* L., cv. Vereda), and 3) traditional winter fallow (F). The cover cropping phase finished on March 2014, with an application of glyphosate, and all the CC residues were left on top of the soil. Thereafter, a new set of N fertilizer treatments was set up for the maize cash crop phase. The fertilizer treatments consisted of ammonium nitrate (AN) applied on 2nd June at three rates: 170, 140 and 190 kg N ha^{-1} in F, V and B plots, respectively, according to ISFM practices. For the calculation of each N rate, the N available in the soil, the expected N uptake by maize crop, and the estimated N mineralized from V and B residues were taken into account. In order to determine the amount of N_2O derived from the N fertilizers, double-labelled AN ($^{15}NH_4{}^{15}NO_3$, 5 % atom ^{15}N) was applied on 2m x 2m subplots established within each plot at a rate of 130 kg N ha^{-1}. Nitrous oxide was sampled using opaque manual circular static chambers and measured by gas chromatography. Stable ^{15}N isotope analysis of N_2O contained in the gas samples was carried out on a trace gas analyzer (using cryo-trapping and cryo-focusing) coupled to a 20/22 isotope ratio mass spectrometer at Rothamsted Research North Wyke. Soil mineral N concentrations, soil temperature and moisture, dissolved organic carbon and GHG fluxes were also measured during the experiment.

Results

The ISFM resulted in low cumulative N_2O emissions (0.57 to 0.75 kg N_2O-N ha^{-1}) and N surplus (31 to 56 kg N ha^{-1}) for all treatments. The presence of CCs increased N_2O emissions during the intercrop period compared to F (1.6 and 2.6 times in B and V, respectively), but the intercrop period had a low impact in annual N_2O losses (8, 10 and 21% of total cumulative emissions in F, B and V, respectively). Average topsoil nitrate (NO_3^-) was significantly higher in V, which was the treatment that led to the highest N_2O emissions during this phase. Legumes such as V are capable of biologically fixing atmospheric N_2, thereby increasing soil NO_3^- content with potential to be denitrified.

The ISFM resulted in similar cumulative emissions for the CCs and F at the end of the maize cropping period. Barley-residue plots had higher N_2O emissions than fallow or V-residue plots (at the 10% significance level). The higher C:N ratio of the B residue led to higher DOC contents in these plots and a greater proportion of N_2O losses from the synthetic fertilizer in these plots, when compared to V. Taking into account the whole intercrop-maize cycle, the N_2O Emission Factor ranged from 0.2 to 0.6% of synthetic N applied, which were lower than IPCC default value of 1%.

The replacement of bare fallow by CCs, in combination with an ISFM, did not increase soil N_2O emissions in the overall CC-cash-crop cycle. This fact should be taken into account since the potential of CCs to reduce indirect losses (through the abatement of NO_3^- leaching) and to increase C sequestration has been demonstrated in previous studies.

Conclusions

Our study confirmed that the presence of CCs (particularly V) during the intercrop period increased N_2O losses. Conversely, by employing ISFM, similar N_2O emissions were measured from CCs and F treatments at the end of the whole cropping period, with low N surpluses. Our results highlight the critical importance of the cash crop period on total N_2O emissions, and demonstrate that the use of either legume or non-legume CC combined with ISFM offers an opportunity for N_2O mitigation.

STATISTICAL MATCHING TO OBTAIN BETTER ESTIMATES AT REGIONAL SCALE

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Objectives

Within the research of the Dutch Minerals Policy Monitoring Program (LMM) insight is desirable for combinations of farm types and (sub-)regions into long term developments of the use and surpluses of nitrogen and phosphate. This information is also useful for regional policies and the EU-Water Framework Directive. LMM can be seen as a subsample of the Dutch Farm Accountancy Data Network (FADN). To improve the reliability of the estimates not only firm data of LMM-farms are needed but also of all farms in the FADN being part of the LMM sample population.

A stratified, disproportional random sample is used for the firm choice for the FADN [1] and LMM to achieve smaller standard errors in the estimates. This type of sampling needs weighing for reliable judgements concerning specific farm types or regions. To improve the weighing a technique for inclusion of additional information is applied.

Method

Data on use of nitrogen and phosphate and the surpluses on the soil balance were derived from FADN and LMM. The Agricultural Economics Research Institute (LEI Wageningen UR) continuously collects economic, technical and environmental data at farm level in the FADN. For this research data from the period 1991-2013 were used. The datasets of surveys such as FADN and LMM are mainly used to generate statistics for the whole population. Based on the observations and a set of weights an estimate can be made for the population. When making estimations for smaller areas or specific groups the number of sample elements belonging to a region or group can be limited. This results in estimates with a low reliability.

To increase the reliability of estimates additional information can be used for example from the agricultural census. The agricultural census gives a complete list of the population of farms but the amount of information in this census is limited. By an imputation procedure (statistical matching via nearest neighbour) for each farm in the population a set of farms in the FADN sample is selected which resembles the farm as closely as possible [2]. Variables, which are used to decide whether a farm resembles a sample farm (called imputation variables), have been determined before with multiple regression analysis. The imputation variables should be known for all farms in the sample and the population. Based on these variables the distances between all possible combinations are calculated. The sample farm with the smallest distance is regarded as the farm that resembles the population farm as closely as possible. For each farm in the population, 3 most similar farms are selected from the sample to avoid underestimation. These best fits are recorded together with the distance measures.

Based on these best fits, estimates can be made for a set of goal variables, which are known in the sample, but unknown for all population farms. To judge the results of statistical matching compared to not weighing and the standard weighing in FADN the representativeness and the validity of the results are considered.

Results

Within LMM four soil regions are distinguished: sand, clay, peat and loess. Besides four farm types are considered: arable, dairy, pigs/poultry and other which results in sixteen possible combinations of region and farm type. Because of very limited numbers in the agricultural census pigs/poultry is only considered for the sandy region and in the peat region only dairy is taken into account.

Regression analysis provided for dairy farms the imputation variables distance (in km), farm size (in Dutch Size Units (DSU)), DSU per ha utilized area, percentage livestock units (LSU) pigs/poultry of total livestock units, percentage grassland in utilized area and LSU young stock per dairy cow. For most soil regions DSU/

ha was the most important imputation variable. In the case of arable farms the imputation variables were distance (in km) and the shares of different crops in the utilized area. Distance (in km) and LSU/ha utilized area resulted as imputation variables for pig/poultry farms in the sandy region whereas distance (in km), farm size, LSU/ha and share of grassland turned out to be the imputation variables for farms of other type.

For eleven combinations of farm type and soil region the imputation was run. Nitrogen soil surpluses on arable farms decreased from about 150 kg N per ha in 1991 to about 100 kg N per ha in 2013. For dairy farms the decrease was about 130 kg N per ha: from just above 300 to just below 200. Pig/poultry farms realized smaller decreases, about 20 kg N per ha from 170 to 150. Other farms realized decreases comparable to those of arable farms: from about 240 kg N per ha in 1991 to about 190 kg N per ha in 2013. Main source of the decreases was less use of artificial/chemical fertilizer.

Both on representativeness and validity the use of statistical matching performed better than when using the standard weighing in FADN and much better compared to not weighing. Relative difference compared to relative standard error [1] and comparison of sample results with population averages (for the imputation variables) showed good outcomes for statistical matching. The sensitivity (fluctuation in weighing factors) was only slightly higher for statistical matching due to the fact that statistical matching uses more imputation variables than are used for the stratification in the FADN sample. In the FADN sample only farm type and farm size are used. A leave one out test (the values of a sample farm are estimated by imputing values from one or more other sample farms that are very similar) showed no significant differences between the estimated and the real values for statistical matching.

Conclusions

In the period 1991-2013 farms in the Netherlands considerably reduced their nitrogen soil surpluses. Main contributor to this reduction was less use of artificial/chemical fertilizer. Comparison of different methods to calculate these nitrogen soil surpluses for specific farm types or regions showed that statistical matching produced the most representative and valid results. The slightly higher sensitivity in the case of statistical matching is a point of attention: it can be reduced for instance by setting a maximum on the weighing factor a sample farm can get.

References

[1] Veen, H.B. van der, Ge, L., Meer, R.W. van der, Vrolijk, H.C.J. 2014. Sample of Dutch FADN 2012, LEI Wageningen UR, The Hague, report 2014-027

[2] Vrolijk, H.C.J., Dol, W., Kuhlman, T. 2005. Integration of small area estimation and mapping techniques - Tool for Regional Studies. LEI, The Hague, Report 8.05.01

PROVISION OF DICYANDIAMIDE IN SUPPLEMENTARY FEED AS A TARGETED NITROGEN MITIGATION STRATEGY FOR GRAZING CATTLE: PROOF-OF EFFICACY

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Objectives

Urine deposition by cattle results in localised patches of high soil nitrogen (N) levels that are the major contributor to N losses from grazed pastures. Dicyandiamide (DCD) is a chemical compound that has shown to be an effective mitigation technology to reduce urinary-N losses from soil. A method to specifically target individual urine patches is by administering DCD directly to grazing ruminants for excretion in the urine. One practical delivery method could be to administer DCD with supplementary feed to grazing cattle.

This paper reports on a series of studies that examined the effect of administering DCD to cattle via grass silage (as a supplementary feed source) on (1) excretion of DCD in urine, (2) efficacy to inhibit nitrification in soil, (3) deposition of DCD in urine patches under grazing and, (4) persistence of DCD in grass silage during storage.

Method

1. Animal feeding study: Five non-lactating dairy cattle were housed in individual stalls with standard harnesses attached for separate collection of urine and faeces over a 10 day measurement period. The five cows were allocated 2 kg dry matter (DM) of ryegrass silage each morning followed by 8 kg DM of fresh cut pasture with actual intakes recorded daily (total of 10 kg DM offered cow^{-1} day^{-1}). The grass silage was amended with granular DCD (30 g DCD cow^{-1} day^{-1}) and a small amount of molasses was used to ensure the DCD adhered to the silage. The cows had free access to water during the entire study with urine and faeces collected from individual cows daily and the DCD concentration determined. Associated measurements included: water intake, N excretion in urine and faeces, animal live-weight and animal welfare.

2. Laboratory soil incubation study: Urine collected from DCD-treated cattle in the feeding study was compared with urine from non-treated cattle spiked with varying rates of DCD (ranging from the equivalent of 0-100 kg DCD ha^{-1}) and a control. These treatments were added to a volcanic ash derived soil (*Typic vitrandept*) and incubated at 20^{o}C for 104 days. Soil samples were extracted at regular intervals and analysed for ammonium-N, nitrate-N and DCD concentration.

3. Grazing study: Seventeen non-lactating dairy cattle consecutively grazed fenced pasture plots (each 714 m^{2}) over a seven day period. The cattle were also supplemented with grass silage (4 kg DM cow^{-1} day^{-1}) and had free access to water. An aqueous DCD solution was applied to the silage to potentially achieve a targeted daily DCD intake of 50 g DCD cow^{-1} day^{-1}. Individual urine patches were soil-sampled over a 6-hour period (0900-1500 h) on four occasions to determine the rate of DCD deposited in urine patches.

4. Baled silage storage study: Aqueous DCD solution was applied to rowed silage immediately prior to being ensiled in plastic (4 replicates). There were also two control (nil-DCD) silage bales. The silage bales were sampled at regular intervals over a 286-day storage period and analysed for DCD concentration and pasture quality parameters.

Results

The animal feeding study showed that the concentration of DCD in urine from cattle fed DCD-treated pasture silage (30 g DCD cow^{-1} day^{-1}) markedly increased within the first two days and thereafter remained relatively constant at about 900 mg DCD L^{-1}. The daily recovery of DCD in urine averaged 82% of that administered with 10% in faeces across cattle and measurement days (excluding the first two days). Sampling of individual urinations over a 24 h period showed a diurnal pattern in the concentration of DCD in urine, which peaked at about 9 h after commencing DCD administration. The associated laboratory soil incubation study showed that the DCD voided in urine prolonged the retention of urinary-N in the ammonium-N form in soil at a similar temporal inhibitory pattern to DCD applied directly to soil at a rate of 50 kg DCD ha^{-1}. This finding infers no effect of animal feeding on DCD efficacy in soil.

Analyses of soil samples from the 172 urine patches collected in the grazing study revealed that the rate of DCD deposited in urine patches was variable, which showed a positively skewed distribution. The application rate of DCD in urine patches was typically in the range of 20-60 kg DCD ha^{-1}.

The concentration of DCD in stored silage bales decreased over time to approximately 30% of that initially applied after 286 days. The degradation of DCD in grass silage bales was primarily attributed to the high temperatures and low pH associated with ensiled silage that would have denatured the compound.

Conclusions

These studies have demonstrated that provision of DCD in a supplementary feed source (grass silage) to non-lactating cattle resulted in a large amount (averaged 82% of that administered) being voided in the urine that effectively inhibited nitrification of urinary-N in soil. Under grazing, the rate of DCD deposited in urine patches was variable with the majority of urine patches having an equivalent field application rate in the range of 20-60 kg DCD ha^{-1}. Administration of DCD to grass silage should be undertaken prior to feeding since degradation of DCD occurs when grass silage is stored for a long period (e.g. 280 days). This research highlights the viability of delivering DCD to cattle via supplementary feed as a targeted mitigation strategy to potentially reduce urinary-N losses from grazed pastures.

DETERMINING THE ROLE OF FUNGI AND BACTERIA IN CO-DENITRIFICATION

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Objectives

Emissions of N_2O, a greenhouse gas, and N_2 may derive from classical denitrification, nitrifer-denitrification, and co-denitrification [1]. Co-denitrification may be significant and has been reported to be responsible for more than 90% of nitrogen gas emissions in grazed grassland [2]. A more detailed knowledge on the fate of applied nitrogen is required to improve nitrogen use efficiency and to provide an understanding for N_2O mitigation options.

The objective of this experiment was to reveal the contribution of fungi and/or bacteria to N_2O and N_2 fluxes following bovine urine deposition to a pasture soil.

Method

A sandy loam pasture soil was collected (43°38'33.73"S, 172°27'40.38"E) and sieved (2mm). Moistened soil was then placed in jars, 240 single jars (250ml) at a 50% water holding capacity. Jars were divided into six treatments x 5 replicates x 8 sampling times (30 jars each sampling time. Six treatments consisted of a control, urea, urea + streptomycin + penicillin, urea + cycloheximide, urea + captan, urea + streptomycin + penicillin + cycloheximide). Urea was enriched with 15N at 50 atm% and applied at a rate of 1000 kg N/ha to simulate bovine urine deposition. During the experiment the jars were stored in an incubator at 23°C and 55% relative air humidity. At each sampling time (day 1, 7, 13, 19, 25, 31, 40, 49) a set of jars was 'inhibited' as determined by treatment. During the experiment daily gas samples were taken to determine the N_2O-flux rates of all jars and the 15N enrichment of N_2O and N_2. Measurements of surface pH and CO_2-fluxes were also made. Subsamples of the inhibited soils and controls were taken to measure the amount of NH_4^+, NO_3^-, NO_2^-, the dissolved organic carbon and the total carbon/nitrogen ratio in the soil.

Results

Soil chemistry, fluxes of N_2O and N_2, as affected by treatment, will be presented over time along with their 15N enrichments and their relative contributions to the total flux.

The role and implications of co-denitrification will be further explored with respect to the microbial contributions to the total N_2O and N_2 emissions.

Conclusions

Preliminary data analysis indicates, differing contributions of fungi and bacteria to the production of gaseous nitrogen compounds.

References

[1] Spott, O., Russow, R., Stange, C. F. 2011. Soil Biology & Biochemistry 43, 1995-2011

[2] Selbie, D. R., Lanigan, G. J., Laughlin, R. J., Di, H. J., Moir, J. L., Cameron, K. C., Clough, T. J., Watson, C. J., Grant, J., Somers, C., Richards, K. G. 2015. Scientific Reports 5, 17361, PMC4663629

N-\$mart^{TM} SUSTAINABILITY MODEL: THE SCIENCE BEHIND IT

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Objectives

Applied fertiliser is both the biggest input cost and the biggest contributor to GHG's emanating from cropping. The ***N-\$mart^{TM}*** software model provides farmers with a suggested optimal fertiliser application rate based on their yield goal and current fertiliser application regime; as well as the opportunity to simulate different practice change scenarios to explore maximum profit versus lowest environmental impact combinations.

It appears that the current fertiliser recommendation models in Australia may not do justice to the multi-faceted approach that is required to optimise fertiliser management, including recognising that profitability is also a strong sustainability driver for growers.

Farmers need a simple nitrogen management interface whereby they can explore all the different practice change scenarios and outcomes, and it is anticipated that the N-\$mart tool meets these requirements. It is the aim of this paper / presentation to highlight the scientific principles that underlies the methodology of the model.

Method

Industry consultation guided the structure and outcomes of the model:

Founding Principles:

- An industry / farmer level tool - approximately 15 minutes for N assessment
- Utilises data inputs available at farm level, including soil test reports
- Site and crop specific, incorporating various 'environmental' factors
- Four outputs: Gross profit/ha, carbon footprint/unit, progress (%/unit) and yield/ha
- Graphic output in declining yield curve with optimum fertiliser rate
- Web-based software with customising and scenario planning capability
- Determines progress made in environmental impact improvements (%) through adoption of practice changes

Research shows there are three main factors that have a significant effect on crop nitrogen use efficiency, namely soil mineralised N contributions, crop uptake N / yield conversion ratios and fertiliser application losses (Rochester, I., J. 2011).

Fertiliser derived N normally comprises less than 50 per cent of cotton crop N uptake, therefore we need to maximise N mineralisation in the soil as a 'cheaper' and perhaps less vulnerable N source. Accordingly, a major component of the model is a comprehensive mineralisation module which estimates the amount of nitrogen that will be 'manufactured' during the growing of the crop, given certain environmental parameters.

Research in Australia has shown that optimum uptake N requirement for cotton is approximately 250 kg N per hectare. However, extensive field trials showed that at a common 250 N uptake level, actual yields can vary from 6 bales per hectare to 13 bales, or conversely an N uptake requirement per bale ranging from 13.6 N to 34 N at a common 9 bale yield level. It is therefore important that this conversion efficiency factor is taken into consideration prior to estimating fertiliser N application losses.

None of the commonly applied fertiliser recommendation models in Australia allow for the type of N applied or the method with which it will be applied, and no published information was available. Our research has shown that N application losses can vary between 20% (N26 water run) to 70% (broadcast urea) of total N applied amongst different product / practice combinations. It is therefore important that these distinctions be made in nitrogen modelling.

Results

For the distinction between fertiliser type and application practice N losses, the following 7 combinations were tested and quantified for N_2O fluxes / losses in field trials:

- Urea broadcast - Dry
- Urea broadcast - Irrigated
- Urea incorporated / banded - Irrigated
- Entec broadcast - Irrigated (denitrification inhibitor)
- Entec incorporated / banded- Irrigated
- N26 - With irrigation
- Anhydrous ammonia liquid - with irrigation
- Control: Nil N, irrigated

The following are the main observations; specific loss factors were determined after further laboratory tests on the effect of soil types, and post facto soil tests and ammonia volatilisation losses at the field trial sites:

- Temperature has marked effect on emission rates
- Limited losses from urea on dry soil surface (including dew), response only came with significant rainfall
- Similar response from urea broadcast irrigated, liquid N 26 with water and anhydrous with water.
- Losses from incorporated urea significantly lower than broadcast urea at first, response only came after second watering event and rain, but then at similar rate of increase.
- Two Entec variations (broadcast and incorporated) were outstanding with near zero emission losses, again with the broadcast variance being higher.
- Control showed surprisingly flat response to the moisture and temperature variations.

Typically fertiliser recommendation models incorporate limited in crop N mineralisation contributions, or exclude it. However, zero N cotton field trials in Australia have shown crop uptake levels of up to 150 units of N per ha. A thorough search of the literature and extensive consultations revealed that there was no industry level broad acre mineralisation simulation model available that could be incorporated into the *N-$mart™* model. The most applicable tool was the Solvita soil CO_2 respiration kits but these parameters had not been adapted for Australian conditions. It was therefore decided to develop a customised forecasting tool based on soluble C and N values linked to validated soil respiration data and resulting mineralisation, based on actual cotton field trials in all the cotton growing regions. Further in crop mineralisation fieldwork will take place during this year's crop. An interim mineralisation methodology has been developed.

It is clear that precision crop N management is a complex and multi-facetted area, with many intre-related factors to consider. To calculate the nitrogen requirement of the crop, the model follows the following 6 sequential steps in order to deal with all the variables is a logical manner:

- 1) Farmer set the target yield: - i.e bales of cotton /ha
- 2) Estimate N/yield conversion: - N uptake / yield efficiency ratio
- 3) Estimate total soil N contribution: - soil mineralisation plus ‘starter’ N
- 4) Estimate fertiliser application losses (%): - for different products & practices applied
- 5) Calculate fertiliser balance to apply: - (1*2-3)/4

Conclusions

Sustainability is recognised as a process of continuous improvement, however, growers need to be empowered with fit-for-purpose tools whereby they can track their progress and explore financially viable alternatives to guide their decision-making.

The scientific credentials and robustness off the *N-$mart*^{TM} tool is an ongoing process as the results of further field trials and published data are incorporated into back-end of the model. Further, ‘sustainability needs to pay to be sustainable’, which required establishing all the economic parameters pertaining to the 15 different cotton growing regions in Australia.

Tools that require farmers to complete a lengthy spreadsheet are doomed to fail, this was successfully addressed by pre-populating the different grower regions with defaults data sets. The model guides the user to customise the parameters for each paddock/crop, taking the environmental and soil conditions into account, within a time frame of 15 minutes.

Growers are encouraged to run different scenarios: tracking the effect of parameter changes on yield and sustainability outputs at different N levels; including the corresponding gross margins. It is particularly important to consider the types of fertilisers and application practices undertaken by growers as these have significant effects on N losses. Likewise uptake N/yield conversion is an important aspect. As indicated above, the difference between a good and a poor conversion efficiency can be 20 units of N per bale which amounts to a relative loss of 200 units of N at a yield of 10 bales per hectare, which could overshadow fertiliser application losses.

N_2O EMISSIONS OF IRRIGATED MAIZE MANAGED UNDER DIFFERENT SOIL TILLAGE SYSTEMS AND N FERTILIZATION RATES IN A MEDITERRANEAN AGROECOSYSTEM

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Objectives

Soil nitrous oxide (N_2O) emissions resulting from agricultural management practices, increase the atmospheric concentrations of N_2O, contributing to global warming. The aims of this work were: i) to quantify the emission of N_2O and maize yields according to different soil management practices and N fertilization rates and ii) to analyze the impact of environmental and soil variables on the emissions in a semiarid area recently transformed to irrigation under Mediterranean conditions.

Method

The study site was located in Agramunt (NE Spain; mean annual precipitation: 430 mm). A long-term tillage and nitrogen experiment (established in 1996) under dryland barley production was transformed to irrigated maize with solid set sprinklers in 2015. Three types of tillage (no-tillage, NT; reduced tillage, RT and conventional intensive tillage, CT) and three mineral N fertilization rates (0, 200, 400 kg N ha^{-1}) were compared. The NT treatment consisted of weed control with a non-selective herbicide while the CT treatment consisted of one pass of subsoiler to 35 cm depth followed by one pass of a disk plough to 20 cm depth. Finally, the RT treatment consisted of one pass of a strip-till implement on the sowing line to 30 cm depth reducing the surface tilled to a 20 %. The experiment was laid out in a randomized block design with three replications. N fertilization rates were split in one pre-sowing and two top-dressing applications. Soil N_2O fluxes were measured weekly during the growing season (April to November), being more intense during fertilizer applications (i.e. 24 h. prior and 3 h. and 72 h. after) using non-steady state static chambers [1]. Gas samples were taken at 0, 20 and 40 min after the closure of the chamber and stored in vials, being subsequently analyzed by a gas chromatography system equipped with an ECD detector. Gas fluxes were calculated taking into account the linear increase in the N_2O concentration inside the chamber with time (40 min) and correcting the values for the air temperature. On each sampling date and close to each chamber, soil mineral N (as ammonium and nitrate), temperature and volumetric soil water content of the 0-5 cm depth were also quantified. The water-filled pore space (WFPS) was calculated with soil bulk density, which was quantified monthly. Grain yield was harvested with a commercial combine, dried and weighed. Finally, the yield-scaled N_2O emissions, expressed as kg of CO_2 equivalents emitted per kg of grain produced, were calculated taking into account a global warming potential of 265 [2].

Results

Soil N_2O emissions were significantly affected by tillage, N fertilization, sampling date and their interactions. Mean N_2O fluxes decreased in the order NT > RT > CT, being 0.305, 0.171 and 0.095 mg N_2O-N m^{-2} day^{-1}, respectively. Increasing N fertilizer rates led to a significant increase in the emissions, i.e. 0.02, 0.16 and 0.40 mg N_2O-N $m^{-2}d^{-1}$ for the 0, 200, 400 kg N ha^{-1} treatments, respectively. A significant tillage x nitrogen interaction was found on N_2O fluxes. While the control and the 200 kg N ha^{-1} treatments led to similar N_2O emissions between tillage systems, the application of 400 kg N ha^{-1} led to greater values in NT, followed by RT and CT (0.65, 0.33 and 0.19 mg N_2O-N $m^{-2}d^{-1}$, respectively).

The WFPS was affected by tillage and N fertilization treatments. Mean WFPS was 50%, 36% and 31% for the NT, RT and CT treatments, respectively. No-tillage presented greater WFPS than CT in most sampling dates. This result was probably due to: (i) lower soil structural stability under long-term CT compared to NT [3] which could have reduced water infiltration due to soil crusting, as a consequence of organic matter and aggregate stability reduction and (ii) greater water storage under NT compared to CT [4]. The sampling date affected significantly the dynamics of NO_3^- and NH_4^+ in the soil, which was influenced by N fertilizer applications. Those applications led to punctual increases in soil mineral N, which produced N_2O emission peaks, especially under NT, as a consequence of a a greater WFPS. Similar results were observed by Sánchez-Martin et al., 2010 [5].

Grain production was greater in NT and RT than in CT, with 11406, 9548 and 5594 kg ha^{-1}, respectively. The lower amount of water in the soil in CT as a result of a reduced infiltration of irrigation water would have caused a severe hydric stress to maize, reducing its yield. Also, significant differences on grain production were found between N fertilization treatments with greater values when applying 200 kg N ha^{-1} compared to the control treatment (10394 and 7705 kg ha^{-1}) and intermediate values when applying 400 kg N ha^{-1} (8448 kg ha^{-1}). The application of 200 kg N ha^{-1} under NT led to the highest production (12747 kg ha^{-1}) without being significantly different than the rest of treatments.

Only the N fertilization treatments affected significantly the yield-scaled N_2O emissions, with greater values when increasing the N fertilizer rate: 0.001, 0.012 and 0.035 kg CO_2 equiv. kg grain^{-1} for the 0, 200 and 400 kg N ha^{-1} treatments, respectively. Contrarily, no differences on the yield-scaled N_2O emissions were found between tillage systems or the interaction between tillage and N fertilization treatments.

Conclusions

The results of this study show that NT led to higher emissions of N_2O to the atmosphere than RT and CT. N fertilization increased N_2O emissions when a high rate of mineral N was used and, especially, just after the application of N fertilizer. The use of NT increased the production of grain, while the use of CT led to very low yields. However, only the N fertilizer treatments affected significantly the yield-scaled N_2O emissions, which increased at increasing N rates. Our preliminary data shows that tillage and N fertilization have a profound effect on N_2O emissions and maize production in recently transformed to irrigation Mediterranean agroecosystems.

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References

[1] Hutchinson and Mosier. 1981. Soil Sci. Soc. Am. J. 45, 311-316.

[2] IPCC. 2013. Fifth Assessment Report (AR5) of the IPCC.

[3] Plaza-Bonilla et al. 2013. Geoderma 193-194, 76-82.

[4] Cantero-Martínez et al. 2007. Ann. Appl. Biol. 150, 293-305.

[5] Sánchez-Martín et al. 2010. Eur. J. Soil Sci. 61, 710-720

UREASE ACTIVITY AND POTENTIALLY MINERALIZABLE NITROGEN INFLUENCED BY DIFFERENT SOIL MANAGEMENT SYSTEMS

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Objectives

The objectives of this work were: (1) to study the impact of long term tillage systems and crop rotation on some parameters directly related to N availability like urease activity and potentially mineralizable nitrogen (PMN), and (2) to evaluate the correlations among the studied parameters (urease activity, PMN, total soil nitrogen (SN) and soil mineral nitrogen).

Method

The study was conducted in a field trial located in Alcalá de Henares, Spain (40° 32'N, 3° 20'W; 600 m.a.s.l.). Soil was classified as a Calcic Haploxeralf and the area is characterized by low and irregularly distributed rainfall (353 mm year-1). The experimental design was established on 1994 and consisted in a split plot with four randomized blocks. The main factor was tillage system (Conventional Tillage (CT), Minimum Tillage (MT) and No Tillage (NT)). The secondary factor was the cropping background, either a wheat monoculture or a four-year crop rotation: fallow-wheat-vetch-barley. Soil sampling was conducted in October 2013, one week before seeding. 24 subplots out from the whole 60 were sampled, 12 from the wheat monoculture and 12 from the rotation after barley harvest and before the fallow period. Two separated depths were collected, 0-7.5 and 7.5-15 cm. Total soil nitrogen was determined by the Kjeldahl method. Soil mineral nitrogen was extracted by shaking 5 g soil with 50 mL of a KCl solution (2M) during 30 min. NH4+ and NO3- were measured with the respective cassettes of a FIAstar 5000 Analyzer (FOSS). Potentially mineralizable nitrogen (PMN) was estimated by an anaerobic soil incubation for 7 days [1]. The extraction and measurement of the ammonia was performed as above. PMN was calculated as the difference between NH4 produced during the incubation minus the initial soil NH4 content. Extracellular urease activity was estimated following the non-buffered incubation method [2], [3]. Briefly, 5g of fresh soil were incubated with 2.5 mL urea solution (0.08M) at 37ºC. After 2h, ammonia was extracted with the addition of 50 mL of an acidified KCl 1M (HCl 0.01M) solution and shacked during 30 min. Control solutions were prepared as above with 2.5 mL distilled water, the urea being added after the incubation and immediately before the addition of the KCl/HCl solution. The resulting suspensions were filtered and NH4+ was colorimetrically determined with a FIAstar 5000 Analyzer (Foss). Variance analysis was performed with the GLM procedure of SAS and mean separation was tested with the least square means option.

Results

Soil water content (SWC) at sampling in October 2013 was close to that of field capacity and did not vary neither with depth, tillage nor rotation. Mean value of SWC was 128 g kg-1. Results showed that except for SWC and N-NH4, the studied parameters varied significantly with depth. Those differences occurred mainly under NT and MT plots due to the accumulation of crop residues on the surface, whereas under CT, mouldboard ploughing buried crop residues every year resulting in a homogenized soil layer until 20-30 cm depth. Differences in crop residues placement and tillage intensity led to differences in Soil Organic Matter (SOM) content and localization, affecting other soil properties. PMN content in the surface of NT plots accounted to 51.4 mg N-NH4 kg-1 7d-1, whereas in the deeper layer PMN was significantly lower, only 14.7. Mean PMN content under CT plots was 20.4 mg N-NH4 kg-1 7d-1. On the other hand, urease activity in the surface of NT plots was 69.1 mg N-NH4 kg-1 2h-1 whereas in the deeper layer 26.2. Mean urease activity under CT plots reached 37.7 mg N-NH4 kg-1 2h-1.

NT plots showed significantly higher PMN and urease activity than CT plots, mainly in the soil surface. In the first 7.5 cm, PMN was a 55 % higher under NT than under CT, and urease activity a 35 %. A higher N immobilization or reduced mineralization rate under NT plots may explain the higher PMN founded. Differences between subplots under wheat monoculture compared to those subplots from the crop rotation were significant only in the case of urease activity. Unlike other authors findings [4], we found significant higher values of urease activity in the surface of the monoculture subplots (61.1 mg N-NH4 kg-1 2h-1) than under the rotation subplots (49.9). Those differences might be the result of long fallowing every four years under the subplots from the crop rotation. Including fallow periods in the rotation limited not only C input but also the rizosphere activity resulting in reduced microorganism activity.

As expected, both PMN and extracellular urease activity significantly correlated with SN ($p<0.0001$). PMN is the result of the net mineralization of several easily decomposable organic matter pools, whereas urease is related to the terminal N-cycle, in which soil organic nitrogen is transformed into ammonia [5]. PMN and urease activity were also highly correlated ($r2=0.92$, $p<0.0001$). We expected PMN or urease activity to correlate with N-NH4 content but neither of them did. In our study N-NH4 represented around a 1.5% of SN, being the majority of SN organic nitrogen. Ammonia expected suppression effect on urease activity was not noticeable under the semiarid conditions of the study.

Conclusions

This study was our first attempt to understand some different steps of the N biogeochemical cycle in semiarid soils. Managing and understanding N availability indices is critical in order to improve soil natural fertility and reducing N fertilization in agro-ecosystems.

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References

[1] Drinkwater, L.E., C.A. Cambardella, J.D. Reeder, and C.W. Rice. 1996. Potentially mineralizable nitrogen as an indicator of biologically active soil nitrogen, pp. 217-229, In J. W. Doran, and A. J. Jones, eds. Methods for Assessing Soil Quality, SSSA, Madison, USA.

[2] Kandeler, E., and H. Gerber. 1988. Short-term assay of soil urease activity using colorimetric determination of ammonium. Biol. Fertil. Soils. 6: 68-72.

[3] Kandeler, E. 1993. Kolorimetrische Bestimmung der Urease-Aktivität, pp. 186-189, In F. Schinner, R. Öhlinger, E. Kandeler, R. Margesin, eds. Bodenbiologische Arbeitsmethoden. Springer-Verlag, Berlin, Germany.

[4] Acosta-Martinez, V., J. Moore-Kucera, J. Cotton, T. Gardner, and D. Wester. 2014. Soil enzyme activities during the 2011 Texas record drought/heat wave and implications to biogeochemical cycling and organic matter dynamics. Appl. Soil Ecol. 75: 43-51.

[5] Caravaca, F., G. Masciandaro, and B. Ceccanti. 2002. Land use in relation to soil chemical and biochemical properties in a semiarid Mediterranean environment. Soil Till. Res. 68: 23-30.

FERTILISER N RECOVERY AND MINERALISATION SUPPLY IN A MEDITERRANEAN MID-TERM COVER CROP-MAIZE ROTATION SYSTEM

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Objectives

The use of cover crops is increasing mainly because of environmental benefits, but also because of economic and agronomic advantages. Cover crops reduced nitrate leaching in many regions and they are an important tool reducing nitrate leaching risk. Moreover, cover crops can increase organic matter, water retention capacity, soil aggregate stability, nutrient supply and soil erosion control. But controversial effects on the yield and N uptake of the following main crop have been reported depending on the cover crop species, the region or the management.

The main goal was to study the effect of replacing fallow with cover crops in a long-term maize production system under limited N fertilisation supply. The specific objectives were to determine the effect on (i) the crop yield and N uptake, and (ii) the recovery of ^{15}N fertiliser applied to maize.

Method

The study was conducted during 2 years (08/10/2012 to 25/09/2014) in a silty clay loam in Aranjuez (Spain), Mediterranean semiarid. Plots were included in a mid-term experiment based on three winter cover crop treatments sowed every year since October 2006. The treatments were barley (*Hordeum vulgare* L.), vetch (*Vicia sativa* L.) and fallow, and the design corresponded to four replications randomly distributed in twelve plots (144 m^2). Cover crops were sown in early October and killed in late winter (Glyphosate 2% and straw chopped when dry), allowing planting of maize (*Zea mays* L.) on the entire trial in early April, and harvested by the end of September. One microplot (2 m x 2 m) was established within each plot to monitor ^{15}N-labeled fertiliser uptake, recovery and fate. Each microplot received 130 kg N ha-1 as ammonium nitrate enriched (5.0 % excess ^{15}N), when corn had 4-6 leaves. The rest of the experimental area received the same N application but with no-labelled fertilizer. Irrigation, weed control and fertilizer application followed the agricultural practices of the area.

At maize maturity a central square of 1.5 m x 0.75 m was harvested from each microplot, threshed on plant components (grain, and rest of aerial biomass), dried, weighed and ground. All samples were analysed for total N and ^{15}N concentration, as described by Gabriel and Quemada [1]. For each microplot, plant N uptake (N_t) and labelled-fertilizer recovery (NR) were calculated for each plant component, and added up to obtain values for the whole plant. The NR from fertiliser was calculated as the percentage of total plant N derived from ^{15}N fertiliser ($NRF=100 \cdot NR/N_t$). The N from other sources (NOS) was calculated as the difference between N_t and NR.

Soil samples to a depth of 0-1 m at 0.2 m intervals were also collected from all microplots at maize sowing and harvest, with an Eijkelkamp® helicoidal auger as described by Gabriel and Quemada [1]. Control soil samples without labeled fertiliser were also collected. Subsamples were taken for determination of total N and ^{15}N concentration. Soil N content and NR were calculated for each layer.

Results

The barley covered faster the soil than the vetch, but differences disappeared during the winter and the vetch covered the ground better than the barley by the time of cover crop killing, including N uptake and biomass differences. Maize biomass and yield were not affected by treatment, averaging 13.8 Mg ha^{-1} of grain, but N content was. The maize after the vetch uptake 264 kg N ha^{-1} in the total aerial biomass. After barley and fallow took up only 192 and 228 kg N ha^{-1} respectively. The N harvest index remained constant for all treatments but not during years (around 0.68 and 0.75 kg N grain per kg N total aerial biomass during 2013 and 2014, respectively). The maize after vetch also increased the N concentration in the grain respect to the fallow and barley (13.1 g N kg^{-1} versus 11.6 and 10.6, respectively) and in the remaining aerial biomass (5.4 g N kg^{-1} versus 5.0 and 4.5, respectively).

The NRF was the same for all treatments, averaging 62.3 and 70.6% in 2013 and 2014 respectively. More ^{15}N was recovered in the grain both years than in the rest of the aerial biomass (51.9 and 68.8 kg N ha^{-1}, during 2013 and 2014 respectively, versus 28.5 and 23.0), but there were no differences between treatments. Differences between treatments in N uptake appeared then because NOS. Maize from the vetch treatment uptake on average 68 kg NOS ha^{-1} more than the barley and 38 more than the fallow. Cover crop aerial biomass and N uptake were not related with NOS, being in this case a bad indicator for estimating possible fertiliser reduction.

The amount of NRF in the soil after maize harvest did not differ between years or treatments. In all cases it was around 42 kg N ha^{-1} (equivalent to 32% of the fertilizer applied) with the same distribution by layers between treatments and years. Only during 2014 in the 20-cm upper layer after barley there was a NRF increment. Most of the NRF in the soil profile was found in the upper 40-cm layer (from 65.9 to 84.6%) and only small fraction below 80-cm (from 3.5 to 11.7%). Combining ^{15}N recovered in the maize biomass and in the soil, the estimated direct losses from the fertilizer were in the order of 5 kg N ha-1 with no differences at 0.95 between treatments or years.

The N_{min} profiles showed that barley reduced N_{min}, but these differences disappeared after maize. Moreover, the vetch increased apparent N mineralisation (42 kg N ha^{-1} with respect to the fallow treatment, with the barley in between), difference sometimes larger than the N content of the cover crop residue.

Conclusions

Reducing N fertilization led to low soil available N throughout the experiment, enhancing N fertilizer use efficiency and controlling losses. But it also increased the risk of pre-emptive competition with the subsequent cash crop, mostly after the barley and the fallow. In these conditions, cover crops affected N uptake (mostly in the grain N content and higher after vetch and lower after barley), but did not have an effect on the subsequent yield, biomass or C/N translocation to grain.

The low N fertiliser supplied allowed a high NRF, averaging 66.5%. There were no differences between treatments, even when the legume incorporated atmospheric N_2 fixation into the system. Soil ^{15}N recovery was mostly retained in the upper layers (suggesting that the ^{15}N was substituting ^{14}N in a fairly stable organic fraction) and was the same in all treatments. Only during 2014, there was an increase at the 0-20 cm in the fertiliser recovered in the barley treatment, probably due to immobilization. N_{min} profiles after maize growth were low for all treatments, but barley also increased pre-emptive competition reducing N_{min} content before maize planting, without affecting NRF. The capacity of the soils to supply N presented a cumulative effect after seven years of cover cropping.

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References

[1] Gabriel, J.L., Quemada, M. 2011. Eur. J. Agron. 34, 133-143

EFFECTS OF MYCORRHIZAL INOCULUM AND DIGESTATE FERTILIZATION ON TRITICALE (×*TRITICOSECALE* WITTMACK) PRODUCTION USING FUNGICIDES COATED SEEDS

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Objectives

Fertilization with organic wastes represents an alternative to mineral fertilization for sustainable agriculture [1]. In this context the agricultural reuse of digestate, organic waste products of biogas plants, should be considered. Symbiotic mycorrhizal fungi, such as arbuscular mycorrhizal fungi (AMF), are a significant component of the soil microbial population influencing its fertility, crops yield and ecosystem sustainability with positive roles in the agro-ecosystems such as nutrient mobilization from organic substrates [2]. Fungicides are extensively used in crop system to control fungal phytopathogens, but their application also can affect the soil beneficial microorganisms such as AMF [3]. The aim of the trial was evaluated the effect of AMF inoculation and digestate fertilization on triticale (×*Triticosecale* Wittmack var. Cosinus) bio-agronomics features and soil CO_2 emission using fungicides coated seeds.

Method

The experiment was carried out in 2014-2015 in North-Easter Italy (45°20' N; 11°57' E) in open field conditions adopting a split-plot experimental design. AMF inoculum was the main factor (inoculated (AMF-Y) and not-inoculated (AMF-N)) and fertilization the sub-plots (no fertilization (NF), mineral fertilization (MF), digestate liquid fraction (DL) and digestate solid fraction (DS)) randomly distributed and replicated three times. Each plot had a size of 16 m^2 (4x4m). DL and DS were supplied before sowing, at rate equivalent to 140 kg N ha^{-1}. Due to their chemical composition, 88 kg K ha^{-1} and 15 kg P ha^{-1} and 109 kg K ha^{-1} and 105 kg P ha^{-1} were also provided respectively with DL and DS. MF has been distributed in three times: before sowing 40 kg N ha^{-1}, 65 kg K ha^{-1} and 65 kg P ha^{-1}, after sowing, 50 kg N ha^{-1} on 20 February and 20 April 2015 were distributed. Triticale was sown on 28 October 2014, at a rate of 220 kg ha^{-1} seeds coated with fungicides. AMF inoculation, with a commercial inoculum based on *Glomus* spp., was applied at the sowing mixing it with the seeds in the hopper at a dose of 1.2 kg ha^{-1}. On 26 March 2015 a second AMF inoculation was performed at a dose of 1 kg ha^{-1}. During the growing season, soil temperature and moisture in the first 7.5 cm layer and CO_2 emissions were measured seven times (from 78 to 178 days after sowing (DAS)), NDVI index four times (from 143 to 178 DAS) and root percentage AMF colonization [4] three times (from 114 to 222 DAS). Triticale aerial biomass was harvested at dough stage on 8 June 2015 and dry weight was determined at 65°C. Furthermore, at the harvest, shoot stature and shoot density in each subplot were detected. Bio-agronomics data were analyzed using ANOVA and the comparison between means was made using Fisher LSD test. Soil CO_2 emission was analyzed with Kruskal-Wallis and Mann-Whitney nonparametric tests. Correlation between soil temperature and moisture with CO_2 emissions were evaluated using Spearman Rank correlation.

Results

Root percentage AMF colonization was not significantly different between inoculated and not inoculated plots with values ranged from 0.0% to 11.6% suggesting that inoculation was not effective. Roots colonization could be due to the soil AMF that have been naturally selected over time considering that the soil was managed in the previous years under conventional agronomic techniques using fungicide coated seeds. Among fertilization treatment roots AMF colonization was significant ($p<0.05$) higher in DS treatment (6.0%) than other ones (1.2%).

AMF inoculation did not show significant effect on monitored bio-agronomic parameters except for shoot density at the harvest time ($p<0.05$) with higher density in AMF-N (461.3 shoot m^{-2}) than AMF-Y (396.0

shoot m^{-2}). MF treatment showed a significant ($p<0.05$) higher plants height (130.2 cm) than NF one (120.2 cm). No significant different plants height was found between DL and DS treatments with an average value of 125.3 cm.

Dry biomass production was significantly ($p<0.05$) higher in the MF treatment (21.8 ± 1.04 Mg ha^{-1}) compared to DS or DL ones (17.5 ± 1.12 and 16.9 ± 0.64 Mg ha^{-1}, respectively). The lowest dry biomass production (14.5 ± 0.7 Mg ha^{-1}), as expected, was found in sub-plots without fertilization. NDVI index was significantly ($p<0.05$) influenced by fertilization with the highest value in MF (0.729) and the lowest one in NF (0.551). No significant difference was found between DL and DS plots with an average value of 0.644. No effect was detected for fertilization treatments on soil CO_2 emission with a median value of 447.3 mg m^{-2} h^{-1}. In the average of treatments soil CO_2 emissions were positively correlated with soil temperature (Spearman R = 0.617; $p<0.001$) whereas no correlation was found with soil moisture (Spearman R = -0.015).

Considering that P and K supplied with MF was in the range or lower than DS and DL, the lower yield of these last is probably due to both the N distribution time (all N pre-sowing in DL and DS treatments, in three times in MF treatment) and the lower N fertilization value of digestate (e.g. ammonia volatilization [5]). However, the higher MF biomass production should be considered taking into account the environmental aspects of mineral fertilization. In fact, considering the macronutrients (N, P_2O_5, K_2O) supplied, and using the $CO_{2(eq)}$ specific emission factors for mineral fertilizers production [6], the indirect emission was +863.8, -674.4 and -1121.2 kg $CO_{2(eq)}$ ha^{-1} in MF, DL and DS treatments, respectively.

Conclusions

Limited effect of AMF inoculation was observed, probably due to seeds coating with fungicides. Although low in absolute value, interesting appears for further research development the colonization capacity of soil AMF because it could be due to naturally selected fungicides resistant AMF. MF determined the highest biomass production (+21% respect digestate treatments), but it should be considered taking into account the environmental (e.g. $CO_{2(eq)}$ emission) and economical (e.g. fertilizer and distribution costs) aspects. On the basis of the previous considerations, triticale fertilization with digestate can be an interesting alternative in sustainable agriculture. Furthermore, the biomass produced can be used in biogas reactors building a closed cycle. Although results are interesting they were obtained in only one cropping season therefore further experiments are needed.

Acknowledgment

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References

[1] Morra, L., Pizzolongo, G., Baiano, S., Pentangelo, A. 2013. Italian Journal of Agronomy, 8(4), 25.

[2] Finlay, R.D. 2008. Journal of experimental botany, 59(5), 1115-1126.

[3] Channabasava, A., Lakshman H.C., Jorquera M.A. 2015. Journal of Soil Science and Plant Nutrition, 15 (1), 35-45

[4] Trouvelot, A. 1986. In: Gianinazzi-Pearson, V., Gianinazzi, S. (Eds.) p. 217–221.

[5] Quakernack, R., Pacholski, A., Techow, A., Herrmann, A., Taube, F., Kage, H. 2012. Agriculture, ecosystems & environment, 160, 66-74.

[6] Capponi, S., Fazio, S., Barbanti, L. 2012. Renewable energy, 37(1), 45-52.

MANAGEMENT MATTERS: TESTING A MITIGATION STRATEGY OF NITROUS OXIDE EMISSIONS ON MANAGED GRASSLAND

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Objectives

The magnitude of greenhouse gas (GHG) exchange between managed grasslands and the atmosphere largely depends on management practices. While natural or extensively managed grasslands are known to function as GHG sinks intensively managed grasslands are often characterized by substantial nitrous oxide (N_2O) emissions and therefore act as net GHG emitters. One potential approach to mitigate N_2O emissions is a decrease in fertilizer inputs by replacing the needed N input by biological nitrogen fixation via legumes. However, the effect of legumes on nitrous oxide fluxes is still uncertain. In this study we aim at quantifying net GHG fluxes from two management strategies under field conditions in relation to the productivity of the fields (yield estimates). Furthermore, we aim at revealing direct drivers of N_2O exchange and developing suggestions for a more sustainable grassland management in the future.

Method

We conducted an ecosystem-scale experiment to compare GHG fluxes from an intensively managed Swiss grassland site. The experimental approach consisted of a control parcel representing conventional management with up to 6 harvests and subsequent organic fertilizer application (total N input > 250 kg ha^{-1}) per year as well as an adjacent treatment parcel where common organic fertilizer N inputs are replaced by biological nitrogen fixation via legumes. We measured the net exchange of the three major GHGs, nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) with the eddy covariance technique in 2015. GHG flux measurements were accompanied by measurements of commonly known driver variables such as water filled pore space, soil temperature, soil oxygen concentrations, pH and mineral N to disentangle the soil meteorological influence of N_2O fluxes from human drivers.

Results

We measured enlarged peaks in N_2O fluxes emissions following organic fertilizer application in the control site and unchanged N_2O emissions in the treatment site. We observed peaks in N2O emissions also on the treatment parcel. Mostly these could be attributed to rain events. Net annual fluxes were about one third lower at the experimental parcel. Annual yields were 19% lower at the experimental parcel compared to the control parcel. Relatively dry conditions during the growing season affected plant growth and the timing of the management events.

Conclusions

Significantly lower nitrous oxide fluxes under experimental management compared to conventional management indicate that nitrous oxide emissions can be effectively reduced at very low costs with a clover-based management. Dry weather conditions are regarded as adequate to reflect future climate at the site. In order to get insights into effects under more common (i.e. wetter) weather conditions, further measurements are required. In addition, implications of the experimental management on animal feed need to be evaluated.

MODELING WATER-NITROGEN-CARBON FEEDBACKS ON PLANT BIOMASS ACCUMULATION UNDER ELEVATED CO_2 USING A COUPLED HYDROLOGICAL-PLANT GROWTH MODEL

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Objectives

Soil nitrogen and atmospheric carbon dioxide (CO_2) are major variables for potentially enhanced plant growth under climate change. It is hypothesized that increasing CO_2 may work as a fertilizer for crops by increasing biomass production [1]. However, this effect on plant growth can be limited by subsequent nitrogen limitation known as 'Progressive Nitrogen Limitation hypothesis' [2]. Coupled models that allow for investigations of the multiple feedback mechanisms between biogeochemistry, plant growth and atmosphere are powerful tools to evaluate hypotheses and to investigate the potential effects of carbon-nitrogen interactions on crops.

We aim at 1) testing and improving the representation of carbon-nitrogen interactions in the coupled hydrological-plant growth model PMF–CMF, 2) investigating the resulting parameter uncertainty. This revised model set up will help to analyse our current system understanding and identify possible missing links in our process representation of the effects of nitrogen supply and elevated CO_2 on biomass accumulation.

Method

A coupled hydrological-plant growth model using the Catchment Modeling framework (CMF) and the Plant growth Modeling Framework (PMF) will be set up. Both frameworks are flexible and integrative tools, allowing for site specific simulations of plant growth and water transport in the soil [3]. The newest version of PMF includes a response functions of stomatal conductance and biomass accumulation to elevated CO_2, i.e. an increase of atmospheric CO_2 simulates stomatal closure by increasing stomatal resistance and accelerates biomass production by enhancing the radiation use efficiency factor. Nitrogen acquisition is simulated by passive and active uptake, whereby the latter occurs if the passive nitrogen uptake does not match the nitrogen demand. For a reasonable representation of nitrogen-carbon impacts we will test incorporated nitrogen processes and select and implement further crucial processes of the soil nitrogen cycle and link them to effects of elevated CO_2.

The further developed, coupled PMF-CMF model will be confronted with field data of a Free Air Carbon dioxide Enrichment (FACE) experiment, where crops are cultivated in CO_2-emitting rings at different nitrogen fertilization levels. To investigate the parameter space as well as parameter and model uncertainty we will conduct a Monte Carlo based generalized likelihood uncertainty analysis (GLUE) considering RMSE, R^2 and bias as objective functions using the recently developed SPOTpy package [4]. To increase the performance of Monte Carlo sampling the Latin Hypercube algorithm will be applied.

Results

First results indicate that hydrological feedback mechanisms of the coupled PMF-CMF model are satisfying. Furthermore, simulations considering the new CO_2 response mechanisms lead to adequate results. Currently, we are testing the new carbon-nitrogen-water feedbacks. We will present the structure of the further developed PMF and show first results of the simulated combined effect of elevated atmospheric carbon dioxide and soil nitrogen availability on biomass. Furthermore, we will show the effect of the model further development on parameter and model uncertainty.

Conclusions

[1] Ainsworth, E.A., Long, S.P. 2004. New Phytologist. 165, 351–372

[2] Luo, Y., Su, B., Currie, W.S., Dukes, J.S., Finzi, A., Hartwig, U., Hungate, B., Mc Murtrie, R.E., Oren, R., Parton, W.J., Pataki, D.E., Shaw, M.R., Zak, D.R., Field, C.B. 2004. BioScience 54, 731-739

[3] Houska, T., Multsch, S., Kraft, P., Frede, H.-G., Breuer, L. 2014. Biogeosciences, 11, 2069–2082, doi:10.5194/bg-11-2069-2014

[4] Houska, T., Kraft, P., Chamorro-Chavez, A., Breuer, L. 2015. PLOS, DOI: 10.1371/journal.pone.0145180

NITROGEN EMISSIONS FROM ARABLE LAND WITH DIFFERENT NITROGEN FERTILIZATION

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Objectives

Nitrogen (N) losses from fertilization are non-desirable and options for reductions are needed as N losses pose an economic loss for farmers and cause harmful effects to the environment. In order to reduce N losses from arable fields we have to understand the fate of the applied fertilizer. The overall objective of our project is to provide completely closed N budgets for typical Swedish arable fields on clay soil, fertilized with either mineral or organic N fertilizer. The specific aims of the project are:

- Investigate how fertilization rate affect the gaseous and leaching N losses;
- Compare the N flows between treatments with fertilization with biogas residue, more organic rich animal slurry and mineral fertilizer;
- Provide a closed budget for fertilizer N in typical Swedish agricultural conditions.

Method

The project is conducted at the Lanna Research Station, which is situated on a large agricultural plain in south-western Sweden having a clay soil. Lanna is representative for agricultural crop production on clay soils in Sweden and is the only Northern agricultural ecosystem station within the European GHG network ICOS. We investigate three different rates of mineral N fertilizer (0, 100 and 200 kg N ha^{-1} yr^{-1}) as well as biogas residues (digested slurry) and animal (pig) slurry (equivalent to 100 kg NH_4^+-N ha^{-1} yr^{-1}).

During 2014-16, a range of field flux measurements are conducted in order to quantify three main N loss pathways: leaching losses of nitrate/nitrite and total dissolved N, emissions of nitrous oxide and ammonia volatilization from organic fertilizers. Measurements are conducted on 20 existing leaching plots (20x21m; four per fertilizer treatment) with separate drainage systems supplied with flow-proportional automatic sampling. From these plots, nitrous oxide emissions are permanently monitored using automatic chambers coupled to a laser spectrometer. Ammonia volatilization is measured following fertilization with dynamic chambers.

Results

The largest N export from the field occurs via crop harvest. Leaching losses showed little variation among treatments, but were 25-40 % higher from plots receiving high mineral fertilizer rate compared to all other treatments. About 10 % of the N applied as pig slurry was lost in the form of ammonia and from the biogas residue about 8 %, which is lower than the typical range reported for animal manure. Nitrous oxide emissions were low from all treatments, ranging between 0.3 and 0.6 kg N ha^{-1} over the growing season (152 days), suggesting annual losses in the order of 1 - 1.5 kg N ha^{-1} yr^{-1}. Consequently, the nitrous oxide emission factor (emission divided by applied fertilizer) was in all cases below 1 %, most likely in the range 0.4 - 0.7 %, being lower than the IPCC default value.

Conclusions

Overall, the fertilized soils, with the exception of low mineral N fertilization, showed preliminary a surplus N balance, while the unfertilized soil showed a negative N balance. However, this N balance so far does not consider N2 emissions, which will be investigated by ^{15}N tracer studies for completing the N budget of the arable fields.

Acknowledgments

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SHORT TERM EFFECTS OF POLYACRYLAMIDE AND DICYANDIAMIDE ON C AND N MINERALISATION IN A SANDY LOAM SOIL

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Objectives

The conditioners anionic polyacrylamide (PAM) and dicyandiamide (DCD) are added to soils to respectively reduce soil erosion and nitrogen loss.

Should PAM and residue application improve microbial biomass and conditions, it is possible mineralisation and nitrification activity would increase, in which case simultaneous DCD application could be advantageous in preventing N loss.

A 27-day incubation study was set up to gauge their interactive effects on the microbial biomass, carbon mineralisation and nitrification activity of a sandy loam soil in the presence or absence of maize straw. The objectives were to ascertain whether:

- PAM stimulated the soil decomposition of native and added C residues
- PAM increased soil nitrification when applied with $(NH_4)_2SO_4$ with or without the nitrification inhibitor DCD
- Ammonium sulphate application, with or without DCD, significantly affected the soil microbial biomass
- There are interactive effects of maize straw application and N fertilisation on C mineralisation and the soil microbial biomass

Method

Soil was collected from the top 30 cm of a maize field, sieved (< 2 mm) and stored at 5º C for one month prior to the experiment beginning. PAM-amended soils received 308 or 615 mg PAM/kg (Stockosorb® 500, Evonik Stockhausen GmbH, Krefeld, Germany), respectively representing 100 or 200 % of the recommended application rate. N-fertilised soils were amended with 1800 mg/kg $(NH_4)_2SO_4$, with or without 70 mg DCD/kg. Maize leaf/stem straw was added to soil at the rate of 4500 mg dry matter/kg.

The incubation experiment took place for 27 days at 22º C with all samples (100 g dry weight) adjusted to 50 % water-holding capacity in 1 L glass jars. All of the following treatments were carried out in replicates of five:

(1) control

(2) ammonium sulphate (NH_4)

(3) ammonium sulphate plus dicyandiamide (NH_4 + DCD)

(4) 100 % PAM (100 PAM)

(5) 100 % PAM plus $(NH_4)_2SO_4$ (100 PAM, NH_4)

(6) 100 % PAM plus $(NH_4)_2SO_4$ + DCD (100 PAM, NH_4 + DCD)

(7) 200 % PAM (200 PAM)

(8) 200 % PAM plus $(NH_4)_2SO_4$ (200 PAM, NH_4)

(9) 200 % PAM plus $(NH_4)_2SO_4$ + DCD (200 PAM, NH_4 + DCD)

Evolved CO_2 during the incubation was absorbed in alkali traps containing 1.0 M NaOH solution. Traps were removed from all jars after 2, 5, 12, 20 and 27 days prior to being back titrated with 0.1 M HCl after addition of 5 mL saturated $BaCl_2$ solution. Quantities of evolved CO_2 were used to calculate cumulated CO_2-C (CC) and the metabolic quotient ($q$$CO_2$, CO_2-C evolved per unit of microbial biomass C per day).

Microbial biomass C (MBC) was determined by fumigation extraction at the end of the incubation period, while aliquots of the non-fumigated soil extracts being taken for determination of NH_4^+ and NO_3^-. At the end of the experiment, subsamples from each jar were refrigerated and later air-dried prior to pH determination.

Results

Maize straw application increased soil microbial biomass and respiration. PAM stimulated C mineralisation, as evidenced by significant increases in evolved carbon dioxide (CO_2) concentrations. In treatments receiving PAM and NH_4 without DCD, nitrate concentrations were markedly greater, and ammonium concentrations decidedly lower, than in the corresponding treatment without PAM, indicating a stimulation of nitrification by PAM. PAM-stimulated nitrification and C mineralisation are likely to have been effected by the PAM improving microbial conditions (enhanced aeration, water permeability and cationic nutrient retention) and partially being utilised as a substrate, with the latter being indicated by a PAM-induced significant increase in the metabolic quotient. PAM did not reduce the microbial biomass except in one treatment at the highest application rate. Therefore it could have a detrimental effect on soil microbial biomass, despite the normally beneficial effect of residue additions, if PAM has accumulated or is applied excessively.

Ammonium sulphate stimulated nitrification and reduced microbial biomass; the resultant acidification of the former is likely to have caused the latter. The metabolic quotient of the treatments revealed DCD to have caused reduction relative to the control which indicated suppression of nitrifying bacteria. N fertilisation may also have induced short-term C limitation in the soil which impacted on microbial growth and respiration. In our relatively short-term experiment, it is possible the expected stimulatory effect of N addition was dependent on release of C from more recalcitrant components of the native and added residue after exhaustion of easily degradable (soluble) C and was therefore not evident in our results.

The extractable nitrate and ammonium results showed that the DCD in all PAM treatments was effective at inhibiting nitrification and keeping nitrate concentrations lower than those in the control. The nitrification inhibitor DCD reduced the negative impacts on microbial biomass of $(NH_4)_2SO_4$. As well as the DCD reducing nitrification and the resultant microbe-stressing acidification, this could also have arisen as a result of preferential bacterial immobilisation of NH_4^+ to NO_3^-.

Conclusions

In our 27-day incubation experiment, soil C mineralisation rates proved to be stimulated by PAM addition. This arose as a combination of improved microbial conditions and PAM partially being utilised as a microbial substrate. PAM also stimulated nitrification when applied with $(NH_4)_2SO_4$; this effect could be nullified with concurrent DCD application. Ammonium sulphate application had negative impacts on microbial biomass C. This effect arose due to soil acidification following nitrification and was reduced with simultaneous DCD application. Maize straw application increased soil microbial biomass C but this increase was not as marked if applied with N fertilisers or excessive amounts of PAM. This was probably a short-term C-limitation effect following exhaustion of easily degradable C. DCD is an effective soil amendment to reduce nitrification under conditions where mineralisation is increased by addition of PAM and/or residue incorporation. Therefore concurrent PAM and DCD application is recommended in nitrate vulnerable zones where erosion-threatened soils are amended with fertilisers or manures.

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CAN NITRIFICATION INHIBITORS AND MANURE TMING IMPACT NITROUS OXIDE EMISSIONS FOLLOWING FIELD INJECTION OF LIQUID MANURE?

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Objectives

The main objective of this research was to investigate nitrous oxide (N_2O) emission reduction strategies in an annual cropping system receiving the liquid manure application. This research compared N_2O emissions from two contrasting manure injection times (fall vs. spring), examined the effectiveness of nitrapyrin and 3, 4–dimethylpyrazole phosphate (DMPP) and identified the key biophysical controls on N_2O flux in Alberta cropping systems.

Method

From fall 2014 to fall 2015, two split-plot field experiments were initiated in Alberta, Canada (Edmonton and Lacombe sites). Liquid manure (dairy or swine) was injected with or without nitrification inhibitors (nitrapyrin and DMPP). N_2O flux measurements, soil temperature, soil water content as well as plant aboveground biomass and N uptake were measured following the fall and spring manure injections. Field flux measurements were done during the frost free periods using manual static chambers (weekly or twice per week following major rainfall or manure injection). Composite (at least 3) disturbed soil samples were collected after manure injections and some of them were collected by the band and inter-band area separately when necessary.

Results

At both sites, the amount of annual cumulative N_2O emissions generated from the fall manure without NIs was about two times than that from the spring manure without NIs. This differential N usage derived from the timing of manure injection was also observed in the crop N uptake in Lacombe. The N uptake in the spring-manured only treatment was significantly higher than the fall-manured only. All manure injections resulted in a significant increase in N_2O emissions compared to the controls without manure ($Ps < 0.05$). The increasing N_2O emissions from manure applications could be reduced by incorporating the NIs. At the Lacombe site, fall-applied DMPP and nitrapyrin reduced by 81.0 and 57.8% annual total N_2O emissions compared to the treatment with manure without NIs. These reductions by NIs were also observed for spring-applied DMPP and nitrapyrin treatments but they were less pronounced. For the fall-manured soils, more than 67% of annual cumulative N_2O emissions were derived from the emissions observed during the early spring after snow-melt and soil thawing. In addition, the annual N_2O emissions from either fall-manured or spring-manured soils without NIs in Lacombe were about triple than that in Edmonton. This was likely due to the drier soil condition in Edmonton than Lacombe.

Conclusions

The spring manure injection could become a N_2O mitigation strategy in the areas with similar climatic and edaphic conditions as Alberta, Canada; because the spring manure injection resulted in lower annual N_2O emissions and higher crop N uptake than the fall manure injection. Nitrification inhibitors could reduce N_2O emissions associated with liquid manure application. With respect to the N_2O reduction results, DMPP was more efficient than nitrapyrin. The performance of inhibitors, however, might be restricted under a dry season or soil condition. Additional studies are recommended to address knowledge gaps such as the impacts by different levels of soil moisture content and temperature on NIs effectiveness. It appears that soil moisture content could be the key driver for the N_2O emissions as evidenced by the peak N_2O emissions following the snow-melt in the early spring and the lower annual N_2O emissions in the Edmonton site.

EFFECTIVENESS OF NITRIFICATION INHIBITORS AND CONTRAST OF FIELD VERSUS INCUBATION EXPERIMENTS ON SOIL NITROGEN KINETICS AND NITROUS OXIDE EMISSIONS

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Objectives

The main objectives of this study are to evaluate the potential amount of nitrous oxide (N_2O) emissions reduced by nitrification inhibitors, to contrast the effectiveness of the nitrification inhibitors, to examine how well the N_2O production measurements in the laboratory incubation compare to the N_2O in the field, and to assess the first- and second-order kinetic models in describing the soil mineral N transformations.

Method

The soil sampling site was located in Edmonton, Alberta. The liquid dairy manure was applied in the early fall of 2014 and in the spring of 2015 with a rate of 74.14 m^3 ha^{-1}. Two types of nitrification inhibitors were used in this project --- nitrapyrin and 3, 4–dimethylpyrazole phosphate (DMPP). They were independently mixed with the manure at a rate of 0.5 kg a.i. ha^{-1}. Seven treatments were conducted in this project, including control with the manure injector disturbance (CT), fall manure without any inhibitors (FW), fall manure with DMPP (FD), fall manure with nitrapyrin (FN), spring manure without any inhibitors (SW), spring manure with DMPP (SD) and spring manure with nitrapyrin (SN). Flux measurements were conducted both in fields and in a laboratory incubation (28 days). Composite disturbed soil samples for the incubation were all collected one day after the spring manure injection in the same manner. Band and interband soil samples were collected from SD, SN, SW and CT treatments. Field flux measurements were done using manual static chambers (weekly or twice per week following major rainfalls or manure injections). The incubation gas production measurements were done by using mason jars with a rubber septum. The frequency was twice a week during the first two weeks of the incubation, and once a week for the following three weeks. Soil ammonium and nitrate were analyzed once a week throughout the incubation.

Results

For the spring manure treatments, the manure with DMPP and nitrapyrin reduced cumulative N_2O flux by 32% and 42%, respectively, compared to the treatment with manure only in the incubation. However, the inhibitors did not reduce soil N_2O production in the fall manure treatments. The highest cumulative N_2O flux was for the fall manure with DMPP treatment (0.31 kg N ha^{-1}). This is because the N retained by the DMPP since the fall was rapidly transformed leading to intense N_2O production once the soil with the fall DMPP additive was incubated under optimal conditions [i.e., temperature of 20.4°C and 60% water-filled pore space (WPFS)]. In addition, a remarkably higher cumulative N_2O fluxes happened in the spring manure band soils. This clear spatial banding effect can be directly explained because the band zones had significantly higher initial $NH4^+$-N and NO_3^--N concentrations. The difference in N_2O emissions between the incubation and the field was compared. For the fall treatments and the control treatment, the N_2O output in the incubation has the same sequence of that in the field but it had much higher N_2O emissions compared to the field. This is because both the temperature and the volumetric water content in the incubation were higher than those in the field, stimulating the activities of denitrifiers and nitrifiers. The increased N_2O emissions in the incubation for the fall-manured and control treatments were also observed after accounting for the effect of temperature by normalizing the cumulative N_2O production based on thermal time. This result showed that the soil moisture content was the key driver to the N_2O production in the incubation. However, the incubation N_2O production result was lower than in the field for the spring-manured treatments. This might be due to the disturbance of aggregates when field sampling and manipulating the soils and establishing the laboratory incubation. Compared to the first-order kinetic model, the second-order model in general could better describe faster soil ammonium transformations as shown by lower p-values and higher R_2 values.

Conclusions

Both types of nitrification inhibitors reduced N_2O emissions. Compared to the nitrapyrin, DMPP seemed to be more effective when applied at the same active ingredient rate. Both high concentration of substrates and high soil water content could potentially produce high N_2O emissions. It can be noted that the disturbance of soil aggregates could lead to underestimation the amount of N_2O produced in laboratory incubation in particular for the recently-manured soils. Rapid ammonium transformations in soils can be better described by the second-order kinetic model compared to the first-order model.

DEPOLYMERIZATION AND MINERALIZATION - INVESTIGATING THE RATE LIMITING STEP BY A NOVEL ^{15}N TRACING MODEL

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Objectives

Depolymerization of soil organic matter (such as proteins and peptides) into monomers (e.g. amino acids) is currently thought to be the rate limiting step for the terrestrial N cycle. The production of free amino acids (FAA) is followed by FAA mineralization, which is an important fraction of the total N mineralization. Accurate assessment of depolymerization and FAA mineralization rates is important to gain a better understanding of the N cycle dynamics.

Method

We combine for the first time two parallel ^{15}N tracing experiments, in which soil is separately amended with ^{15}N labelled ammonium or an amino acid mixture. For data analysis, we further developed the numerical ^{15}N tracing model Ntrace to explicitly account for FAA turnover, in order to simultaneously quantify gross depolymerization, gross FAA mineralization and total gross N mineralization in forest soils. With this approach a more robust and coherent rate assessment and a more accurate calculation of microbial amino acid nutrient use efficiency (NUEFAA) is achieved. Soil was sampled from two forests at the Skogaryd Research Catchment (SITES; Swedish Infrastructure for Ecosystem Studies, www.fieldsites.se), situated in southwest Sweden (58° 23’N, 12° 09’E; 60 m above sea level).

Results

We present an extended numerical ^{15}N tracing model *Ntrace* which incorporates the FAA pool and related N processes to 1) provide a more robust and coherent estimation of production and mineralization rates of FAAs; 2) expand the experimental time-frame to get more realistic FAA mineralization rates; and 3) suggest a realistic microbial N use efficiency of amino acids (NUE_{FAA}) in soils.

Conclusions

We compare analytical and numerical approaches for two forest soils, suggest improvements of the experimental work for future studies and conclude that: i) FAA mineralization might be an equally important limiting step for gross N mineralization to depolymerization, because about half of all depolymerized N is further mineralized; and that ii) FAA mineralization and FAA immobilization rates should be used for assessing NUE_{FAA}.

RESIDUAL EFFECT OF DIFFERENT NITROGEN FERTILIZATION ON REED CANARY GRASS, (PHALARIS ARUNDINACEA L.) IN MONOCULTURE AND IN MIXTURE WITH GOAT’S RUE, (GALEGA ORIENTALIS, LAM.)

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Objectives

Reed canary grass (RCG) harvested in spring is a potential energy carrier as a solid fuel or as a feed stock for biogas production. The RCG also has a potential as a recipient crop for municipal residues such as sewage sludge and ash from incineration of biofuels. Previous studies have shown no or small differences between fertilization treatments for RCG in monocultures or intercropped with legumes [1]. This study was conducted to further investigate the impacts of fertilizing regimes for these crops. The main questions asked were: What are the effects on harvest and lodging of omission of nitrogen fertilization on biomass production and the competition between reed canary grass and goat’s rue in the intercrop? Can sewage sludge pellets replace mineral fertilizers as a nitrogen source?

Method

The experiment was established in Ås in Jämtland in 2008 on moraine clay (clay 19 %). It was designed to study reed canary grass/legume intercrops under different fertilization regimes for three production years (2009-2011) before this extra experiment was conducted 2012. The original experiment was a split plot experiment with three fertilization treatments (A) Full NK fertilization (average 70 kg N ha-1), B) half N plus K (average 35 kg N ha-1), or C) half N (average 35 kg N ha-1) plus sewage sludge (1200 kg=35 kg N ha-1) on the main plots and the different species mixtures as sub plots. N fertilization was used in the intercrops as a means to control the legume content by increasing RCG biomass. In the current experiment, conducted 2012, plots with either monoculture RCG, established together with barley or as sole crop or RCG intercropped with goat’s rue where two different sowing densities of goat’s rue were used. Goat’s rue was used since it has been successfully intercropped with RCG in i.e. [2]. There were no significant differences related to establishment technique after the first harvest year. Further details are found in Lindvall et al. [1]. Two plots with the same species composition in each main plot were randomly assigned to either continuation of the previous fertilization treatment or omission of the mineral N and NK fertilization. The N-fertilization treatments (A1) 60 kg N ha-1) B1) 30 kg N ha-1, C1) 30 kg N ha-1 + 35 kg N ha-1 as sewage sludge, A0) and B0) no fertilization and C0) 35 kg N ha-1 as sewage sludge) were conducted on four plots of reed canary grass monoculture and four plots of reed canary grass/goat’s rue intercrop. The botanical composition was assessed by sorting biomass from 50*50 cm subplots in August to sown species plus weeds. Lodging was graded before harvest. The plots were harvested by a Haldrup harvester in September 6 2012. Dry matter content was determined by drying subsamples in 60oC. The NCSS general linear model ANOVA and Dunnet’s one sided tests were used for statistical analysis.

Results

The ANOVAs (treatment factors; previous fertilization (main plot), N or not 2012, and species mixture, were included in the model as fixed factors and block was random factor)
showed that RCG/goat’s rue intercrop had a higher autumn yield (9943 kg DW ha-1) and less weeds (6%) than the monoculture RCG, (8679 kg DW ha-1and 16% weeds). It showed no significant differences in yield or proportion of goat’s rue due to fertilization treatments either in the year of the extra experiment or the previous years. However, Dunnet’s one sided test showed that the B treatment had a lower yield (8679 kg DW ha-1) and that the C treatment had a higher proportion of goat’s rue (41%) than the fully fertilized control (9750 kg DW ha-1 and 28% goats rue). It is motivated to use a one sided test since it can be expected that N-fertilization increases yield and decreases legume proportion. However, the intercrop was lodging (only 10% standing up), compared to 74% in the monoculture RCG. Omission of N-fertilization a single year had no significant effects at all.
Grass/legume intercrops often are more productive than monocultures of the included species.in RCG/goat´s

rue this has been shown by [2]. One difficulty with intercrops is to achieve a predictable proportion of the different species. When reed canary grass is harvested for combustion is it most often done in spring. Then it is an advantage to have a low proportion of legumes because legumes are more easily decomposed during the winter [3]. In the widely used intercrop between grass and clover for forage it is possible to control the proportion of clovers by nitrogen fertilization. We show here that N-fertilization can control the amount of goat's rue in the intercrop to some extent, but not enough to prevent disadvantages such as lodging. The higher yield in the intercrop, probably due to N-fixation of the goat´s rue symbionts, is also not enough to compensate for extra costs of sowing and decomposition losses during winter.

Reed canary grass is previously shown to be dependent of N-fertilization. It is shown that a high N-fertilization leads to a higher allocation of both carbon and nitrogen to the rhizomes during winter [4, 5]. It has been assumed that this is beneficial for the biomass growth next spring. This study shows that the present N fertilization recommendations for RCG are probably too high since the lower N-fertilization level has only a small yield penalty. It is possible to omit mineral N fertilization for a single year and it is also possible to supply part of the N-requirement of the grass with organic sources like sewage sludge pellets.

Conclusions

In a spring harvest system with reed canary grass, where leached, nutrient poor biomass is removed from the field, it is possible to omit N-fertilization for a single year without yield penalties or effects on the botanical composition of reed canary grass/goats rue intercrop. There is a small negative effect of cutting of N-fertilization in half. Sewage sludge can be used to replace at least half of the N-fertilization without yield penalties.

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References

[1] Lindvall, E., Gustavsson, A.-M. Palmborg, C. 2012. Global Change Biology Bioenergy 4. p. 661-670.

[2] Jasinskas, A., Zaltauskas, A. Kryzeuiciene, A. 2008. Biomass & Bioenergy 32. p. 981-987.

[3] Lindvall, E., 2014, Thesis, Swedish University of Agricultural Sciences: Umeå, Sweden. p. 53.

[4] Xiong, S. and Kätterer, T. 2010. Acta Agriculturae Scandinavica. Section B, Plant Soil Science 60. p. 24-32.

[5] Xiong, S., Landström, S. Olsson, R. 2009. Acta Agricultura Scandinavica. Section B, Plant Soil Science, 59. p. 306-316

EFFECT OF DIGESTATE SOLID FRACTION ON HORTICULTURE SUCCESSION YIELD AND SOIL CARBON DIOXIDE EMISSION

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Objectives

The biomass anaerobic digestion for biogas production is one of the most widespread renewable energy form. However, together with biogas, anaerobic digestion produces a residual material (digestate) that considering its composition could be used in agriculture as fertilizer [1] if certain quality characteristics such as stability and hygiene are satisfied. Such organic matrix could then represent a good alternative to the use of mineral fertilizers determining both indirect reduction of CO_2 emission in atmosphere and improve of the soil physico-chemical properties, with environmental positive impact.

The aim of this study was to evaluate the environmental and production aspects of digestate solid fraction (DSF) use in a one-year horticultural succession.

Method

The trial was carried out at the Experimental Farm of Padua University at Legnaro, North-East Italy (45°20' N; 11°57' E) in open field conditions using DSF on green bean, savoy cabbage, cabbage and cauliflower. Three fertilization treatments were tested using DSF to substitute mineral N crop requirements: 1) 50% N through DSF and 50% N through mineral fertilizer (T50); 2) 100% N through DSF (T100); 3) 100% mineral fertilization (Tmin). The P and K content in the DSF were taken into consideration to calculate the amount of these elements to supply in the different treatments. Fertilization was supplied according to standard recommendations in the area: 40, 50, 100 kg ha^{-1} for green bean and 110, 70, 160 kg ha^{-1} for the other species respectively for N, P_2O_5 and K_2O. Both mineral and DSF was supplied from 1 to 4 days before sowing or transplanting and immediately incorporated by rotavator. The soil had a loamy texture. A randomized block experimental design with three replications was used with plots of 40 m^2. The green bean was sowed on 22 May 2014 and harvested on 14 July 2014, savoy cabbage was transplanted on 12 August 2014 and harvested on 15 January 2014. After, each plot was split into two subplots of 20 m^2 and both cabbage and cauliflower were together grown transplanting them on 3 April 2015. Cauliflower was harvested on 27 May 2015 and the cabbage on 3 June 2015. Crops were harvested at full crop marketable maturity. For each plot, five plants were cut into small pieces and dried in a ventilated oven at 65°C to calculate the dry matter content. In this last, the total Kjeldahl nitrogen (TKN) content was determined. During crops growing season the soil CO_2 emissions were measured two times per week in two points for each plot using the static non-stationary chamber technique. For savoy cabbage soil CO_2 emissions were not detected from half October till the first week of December. In each CO_2 measurement point, soil temperature and moisture (TDR 100 Soil Moisture Meter) in the first 7.5 cm were also detected.

Results

The crops yield was not significantly influenced by the fertilization treatments with an average (±SE) marketable yield of 9.0 ± 0.5, 9.9 ± 1.2 and 51.3 ± 6.4 Mg ha^{-1} for green bean, cauliflower and cabbage, respectively. The savoy cabbage marketable yield was significantly (ANOVA, $p<0.05$) higher in the Tmin treatment (25.9±1.0 Mg ha^{-1}) than T100 one (16.8 ± 2.7 Mg ha^{-1}); T50 was not significantly different between the previous two treatments (20.8 ± 2.3 Mg ha^{-1}). The lower production with DSF probably due to the low environmental temperatures that reduced soil microbial activity, with a consequent reduction of the nutrients availability by the digestate. With respect to the TKN biomass content, no significant differences were observed in relation to fertilization treatments for green bean, cauliflower and savoy cabbage with an average value of 2.89%. Cabbage showed a significant (ANOVA, $p<0.05$) lower TKN concentration in the biomass of T100 treatment (1.80%) than the other ones (2.26%). Among species the significant higher and lower

TKN concentration were showed by cauliflower (3.40%) and cabbage (2.10%), respectively. No significant difference was found between green bean and savoy cabbage with an average value of 2.61%. Fertilization treatment did not exert significant effect on N uptake whereas, as expected, significant (ANOVA, $p<0.05$) different N uptake was found among plant species with greater values for cabbage and savoy cabbage (average value of 70.5 ± 6.3 kg N ha^{-1}) than green bean and cauliflower (average value of 21.1 ± 1.4 kg N ha^{-1}). Considering the percentage N recovery with marketable biomass respect the N supplied it was not significant different among fertilization treatments with an average value of 58.3%, 45.9% and 42.7% for Tmin, T50 and T100, respectively.

The soil CO_2 emissions were not significantly different, for each crop, between fertilization treatments with median value always below 1 g m^{-2} h^{-1}. In the average of crops species the soil CO_2 emissions were positively correlated with soil temperature (Spearman rank 0.214, $p<0.001$) and moisture (Spearman rank 0.207, $p<0.001$). Considering the climate changes the environmental impact of productions and so of fertilization is of increasing interest. Therefore, the indirectly reduction of greenhouse gases emission in the atmosphere plays an important role. In our experiment, considering only the DSF and mineral fertilizers macronutrients (N, P_2O_5, K_2O), and using the $CO_{2(eq)}$ specific emission factors for mineral fertilizers production [2], the carbon emissions in the atmosphere were equivalent for: 1) green bean at 371.9, 50.9, -233.2 kg $CO_{2(eq)}$ ha^{-1} for Tmin, T50 and T100, respectively; 2) savoy cabbage at 724.9, -109.4, -803.4 kg $CO_{2(eq)}$ ha^{-1} for Tmin, T50 and T100, respectively; 3) cabbage and cauliflower at 724.9, -55.4, -694.9 kg $CO_{2(eq)}$ ha^{-1} for Tmin, T50 and T100, respectively.

Conclusions

Results showed that the use of DSF in a horticultural crop succession, alone or in combination with chemical fertilization: 1) did not show significantly different production than that obtained with only mineral fertilization in bean, cabbage and cauliflower; 2) showed a significantly lower production in winter crop, probably due to the low environmental temperatures that reduced soil microbial activity, with a consequent reduction of the nutrients availability by the DSF; 3) did not significantly influence the TKN concentration, N uptake and N recovery in the marketable biomass; 4) did not show different soil CO_2 emissions than those monitored with only chemical fertilization; 5) thus showing an indirect reduction of CO_2 emissions when used as substitute of chemical fertilization.

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References

[1] Nicoletto, C., Santagata, S., Zanin, G., Sambo, P. 2014. Scientia Horticulturae, 180, 207-213.

[2] Capponi, S., Fazio, S., Barbanti, L. 2012. Renewable energy, 37(1), 45-52.

IMPROVEMENT OF WINE TERROIR MANAGEMENT ACCORDING TO BIOGEOCHEMICAL CYCLE OF NITROGEN IN SOIL

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Objectives

Good yield wine production implies well-balanced BCN (biogeochemical cycle of nitrogen), in soil and plant [1]. Nitrogen is very important for grape quality and soil sustainability. The mineralization of organic nitrogen, depending on soil microbial activity, which is linked to soil cover crop management, is the main source of mineral nitrogen for the vine [2][3][4][5]. This study is focused on the microbial functional populations implicated in the BCN, in particular nitrifying bacteria.

Method

Experimental network has been set up since 2012, with 6 vine sites located France by the Atlantic coast (Loire valley: two integrated systems, Loamy, sandy and clayey soil / Bordeaux: organic and integrated systems, Sandy soil) and in North-East (Ribeauvillé-Alsace organic and integrated systems, Loam, sandy and clayey soil / Rouffach-Alsace, two integrated systems, Loam, sandy and clayey soil / Ingersheim-Alsace organic, Sandy loam soil / Chatenois-Alsace organic, Sandy loam soil). These vine sites represent a diversity of environmental factors (i.e. soil and climate) combined to terroir management. These 6 sites represent 11 sites-systems with different management (soil, pesticides' input and terroir management). Studied systems are either integrated or organic. All systems are innovative and deal with low or very low pesticides inputs.

The approach consists in measuring biological and chemical indicators to assess nitrogen dynamic in soil, i.e. nitrogen mineralization, microbial biomass and activity. Soil microbial communities (bacteria and fungi) are studied with quantitative PCR (Polymerase Chain Reaction) measures targeting 16S (bacteria) and 18S (fungi) DNA. The metabolic functional diversity of cultivable bacteria is determined using Biolog® Ecoplates systems with 31 carbon and nitrogen substrates. Potential nitrogen mineralization is evaluated in microcosm incubation with control condition (temperature and moisture used for soil incubation are those proposed by standard ISO 14238).

In 2014 and 2015, soils were sampled in triplicates at 3 dates: bud breack - veraison - leaf fall.
Statistical analyses (using Statgraphics) are performed to determine the relationship between biological indicator and nitrogen mineralisation regarding farmer's practices.

Results

In 2014 and 2015, for Alsacian sites (6 sites/systems), organic systems present higher values of functional richness than for integrated ones, this is particularly observed at bud break, even if it is not confirmed by significant statistical test. This effect is observed in the two studied years 2014 and 2015. Bacterial abundance measured in Ribeauvillé by qPCR show higher bacterial biomass in organic system than in integrated one, especially at bud break. Stimulation of bacterial activity (functional richness) is also observed for organic system. In Chatenois and Ingersheim, high functional diversity and high bacterial biomasses are measured for these two sites, at all dates of measure. This may be explained by organic farming since more than 10 years on these sites while others sites are organic for shorter periods (less than 10 years).

In 2014, higher functional diversity is measured for integrated system in Bordeaux at bud breack. This difference is not observed anymore after that date. Lower bacterial abundance is observed for integrated system

at veraison in Bordeaux both in 2014 (strong effect) and in 2015 (tendency). In Loire valley, there's no difference on functional diversity between organic and integrated systems.
No difference is observed on the soil organic nitrogen content in Atlantic coast sites according the terroir managements. However, significant differences are observed in the Alsace sites with higher soil organic nitrogen in integrated systems. Nitrogen mineralization kinetic is measured for 90 days. Results are used to model mineralization in all soils depending on time. For Alsace sites, the highest mineralization rate is observed for integrated system in Ribeauvillé and the lowest rates for Ribeauvillé-organic and Rouffach-integrated.

For the Atlantic coast, Loire valley sites have higher mineralization rates than Bordeaux ones in 2014, but this effect is not maintained in 2015. In addition, practice management affect rate of nitrogen mineralization in the Bordeaux sites-systems. However, this is observed only in 2015 when nitrogen mineralization is higher comparatively to 2014. These results indicate that practice managements affect net mineralization of nitrogen but this effect seems to be less pronounced than the effect of environmental factors.

To study how technical management of the sites-systems explain measured parameters (soil mineralization, soil microbial populations, physico-chemical parameters of soil), a Principal Component Analysis is performed. This analysis highlights a strong effect of environmental factors on measured parameters as figures are grouped by sites. However, type of systems also influenced our results: Alsace and Loire valley sites are grouped depending on type of systems. This is not observed for Bordeaux sites, but the type of soil (sandy) has a great influence especially on mineralization parameters. Furthermore, this site is also the youngest vine (3 years).

Conclusions

The sites-systems studied showed effect of farming practices (Integrated or Biological) on measures of bacterial abundance (qPCR), of bacterial functional diversity (Biolog® Ecoplates) and of nitrogen dynamic. This is observed even if an effect of environmental factors on microbial indicators is observed. These BCN indicators can be combined to differentiate between sites-systems according to practice managements. These indicators could help in managing nitrogen dynamics and nitrogenous nutrition of vine in innovative sites/systems with various practice management.

References

[1] Guilpart, N., Metay, A., and Gary, C. 2014. European Journal of Agronomy 54, 9-20.
[2] Barlow, K., Bond, W., Holzapfel, B., Smith, J., and Hutton, R. 2009. Australian Journal of Grape and Wine Research 15, 131-143.
[3] Ingels, C. A., Scow, K. M., Whisson, D. A., and Drenovsky, R. E. 2005. American Journal of Enology and Viticulture 56, 19-29.
[4] Raath, P. J., and Saayman, D. 1995. South African Journal of Enology and Viticulture 16, 7-13.
[5] Thiebeau, P., Herre, C., Doledec, A. F., Perraud, A., Panigai, L., Mary, B., and Nicolardot, B. 2005. Journal International Des Sciences De La Vigne Et Du Vin 39, 163-177.

MICROBIAL NITROGEN RECYCLING IN AGRICULTURAL SOIL - DOES FERTILISATION WEAKEN DISSIMILATORY NITRATE REDUCTION TO AMMONIUM?

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Objectives

A large excess of mineral nitrogen (N) in European agriculture is causing harmful consequences to the environment [1]. The mineral N compound nitrate can be reduced by two dissimilatory soil processes: (i) denitrification, the stepwise reduction to atmospheric dinitrogen, and (ii) dissimilatory nitrate reduction to ammonium (DNRA). While denitrification is a major source of the greenhouse gas nitrous oxide, DNRA retains mineral N in the ecosystem in the form of ammonium. The aim of this study is to investigate the competition of these two processes in order to better understand the fate of nitrate in agricultural soil.

Method

To compare the importance of denitrification and DNRA, we conducted a ^{15}N labelling experiment with two agricultural soils: an annual crop rotation with cereals and a grassland rotation system ('ley') with perennial forage crops and barley from a long-term trial field site near Uppsala (Sweden), both with different fertilisation levels. In laboratory incubations with fresh soil, subsamples of each treatment were enriched with ^{15}N labelled ammonium, nitrate or both moieties at about 25% of the native concentrations. For multiple time steps after labelling, we will analyse ^{15}N enrichment of mineral N species from soil extractions, and of nitrous oxide from headspace gas samples. The gross rates of denitrification and DNRA will be quantified using the *Ntrace* model [2]. Furthermore, we analysed soil properties and quantified the 16S gene of soil bacteria, the ITS gene of fungi, the NirS+NirK- and NosZI+NosZII genes of denitrifying bacteria, and the NrfA gene of DNRA performing bacteria using the qPCR in order to better understand what microorganisms are involved and what conditions favour either process.

Results

Preliminary results indicate that increased denitrification produced larger amounts of nitrous oxide in the crop soil, whereas more mineral N was conserved in the ley soil. In addition, analysis of the marker genes showed higher abundance of bacteria capable of denitrification than DNRA in the fertilised treatments indicating higher genetic potential for nitrous oxide emissions. These data agree with previous findings that N limited ecosystems, here represented by lower fertilisation levels and higher $C:NO_3^-$ ratios, conserve and re-cycle mineral nitrogen through DNRA [3, 4].

Conclusions

Our results suggest that different long-term agricultural management practices shift the importance of denitrification and DNRA due to altered soil conditions. However, it is still uncertain if and when DNRA can be an important N recycling mechanism in agricultural soil. For this, further work will be carried out for quantification of the gross N transformation rates and to evaluate the environmental factors that control both processes and the involved microbial communities.

References

[1] Sutton, M.A., Howard, C.M., Erisman, J.W., Billen, G., Bleeker, A., Grennfelt, P., van Grinsven, H. & Grizzetti, B. 2011. The European Nitrogen Assessment. Cambridge University Press.

[2] Müller, C., Laughlin, R.J., Spott, O. & Rütting, T. 2014. Soil Biology and Biochemistry 72, 44-54.

[3] Rütting, T., Boeckx, P., Müller, C. & Klemedtsson, L. 2011. Biogeosciences 8, 1779-1791.

[4] Fernandes, S.O., Bonin, P.C., Michotey, V.D., Garcia, N. & LokaBharathi, P.A. 2012. Scientific Reports 2, 419.

DENITRIFICATION OF GROUNDWATER INDUCED BY TWO CARBON SOURCES: VEGETAL COMPOST AND CRUSHED PALM TREE LEAVES

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Objectives

Artificial aquifer recharge with infiltration ponds is becoming a common method for enhancing groundwater supply and potentially improving water quality during infiltration [1]. Additionally, in infiltration ponds a reactive layer can be installed to create favourable conditions to induce biodegradation of target contaminant/s. Denitrification is an example of a process that could be achieved through artificial recharge with a reactive layer.

In the present study, the efficiency of two carbon sources as potential reactive layers was evaluated. The carbon sources were commercial vegetal compost, and palm tree leaves. The compost was studied because it is already used at the bottom of an infiltration pond in an artificial recharge system in Catalonia [2]. The palm tree leaves were tested in order to be used as reactive layer in an artificial recharge system planned in the Maghreb Region. We examined the efficacy of the two materials by means of flow-through experiments.

Method

Commercial compost was obtained from a composting plant located in Moià (Catalonia) and palm tree leaves were from Maghreb region. Two flow-through experiments were carried out using glass cylindrical columns (35 cm high, 9 cm inner diameter), one filled with commercial compost and the other filled with crushed palm tree leaves. In both cases, the studied material was homogeneously mixed with clean silica sand (Panreac®) to increase permeability. The experiments were set up and carried out in an anaerobic chamber with an Ar atmosphere to avoid the presence of O_2. The input water used was water with a composition very similar to the Llobregat River and it was spiked with nitrate at different concentration levels (see below). The flow rate in the column experiments was controlled by a peristaltic pump (Micropump Reglo Digital 4 channels ISMATEC). Eh, pH and conductivity were measured daily at the outflow water. Samples were collected for hydrochemical analysis (major and minor cations, anions, dissolved inorganic carbon (DIC), non-purgeable organic carbon (NPOC)) and isotopic analyses ($\delta^{15}N$ and $\delta^{18}O$ of dissolved nitrate, $\delta^{15}N$ of ammonium, $\delta^{34}S$ and $\delta^{18}O$ of dissolved sulphate, $\delta^{13}C$ of dissolved inorganic carbon).

Results

In both flow-through experiments complete nitrate removal was observed. In the commercial compost experiment complete nitrate removal was achieved after 10 days using an inflow nitrate content of 0.81 mM. An initial increase in nitrate concentration up to 4.84 mM was observed due to N leaching from the compost. In the palm tree experiment complete nitrate removal was achieved after 4 days using 1.61 mM NO_3^- as inflow concentration. In this case an initial release of 4.9 mM NH_4^+ was observed. Nitrite accumulation, produced if the denitrification reaction is not complete, was detected in both experiments with concentration up to 1.32 mM in the compost experiment and 0.06 nM in the palm tree experiment. In both experiments, nitrite concentration diminished to values close to 0.1mM after few days.

The isotopic enrichment factors for N (εN) and O (εO) in the flow-through experiments were calculated from the slope of the regression lines that fit the data of the natural logarithm of nitrate concentration vs. $\delta^{15}N$ and $\delta^{18}O\text{-}NO_3^-$, respectively. The values of εN and εO for vegetal compost and crushed palm tree were -13.3‰ and -11.0‰, and -11.1‰ and -10.7‰, respectively. The εN/εO ratios were found to be 1.2 for vegetal compost and 1.04 for palm tree-mediated denitrification, which are within the typical range for denitrification [3].

Conclusions

Flow-through experiments are a useful method to assess the role of different electron donors that can promote denitrification, to quantify the attenuation rates and to obtain isotope enrichment factors. The present work evaluated two different carbon sources for inducing denitrification during artificial recharge activities by means of flow-through experiments. The experiments demonstrate that (1) the commercial compost enhanced nitrate reduction although an initial release of nitrite was observed; (2) palm tree leaves were a good carbon source to induce denitrification although further studies should be performed in order to minimize nitrite and ammonium production.

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References

[1] Dillon, P. 2005. Future management of aquifer recharge. Hydrogeology Journal 13, 313-316.

[2] Valhondo, C., Carrera, J., Ayora, C., Tubau, I.,Martinez-Landa, L., Nödler, K., Licha, T. 2015. Characterizing redox conditions and monitoring attenuation of selected pharmaceuticals during artificial recharge through a reactive layer. Science of the Total Environment 512-513, 240-250.

[3] Torrentó, C., Cama, J., Urmeneta, J., Otero, N., Soler, A. 2010. Denitrification of groundwater with pyrite and *Thiobacillus denitrificans*. Chemical Geology 278, 80-91

NITROGEN MINERALIZATION FROM CLOVER LEAVES: EFFECT OF SOIL TYPE AND LOW TEMPERATURE

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Objectives

The period following the incorporation of N-rich leys into soil is crucial both for the N supply to the following crop and for the risk of N leaching. Soil-crop models used for exploring the possibility of improving the nitrogen recovery, generally assume that there is a stoichiometric relationship between carbon and nitrogen mineralization. Our aim was to study how temperature and soil type affect the net N mineralization relative to C mineralization of plant litter incorporated in soil. This knowledge is instrumental for improving the modelling of nitrogen dynamics after ploughing. Our hypotheses were:

1. Rapid N mineralization from N-rich plant material occurs even at 0 °C.

2. The ratio of net mineralized N to mineralized C from N-rich plant material is larger at lower than at higher temperature.

3. The ratio of net mineralized N to mineralized C from N-rich plant material is not affected by soil type

Method

A silty clay loam (27% clay, 3% sand) and a sandy loam (6% clay, 51% sand) from two fields with equivalent weather and cultivation history, were incubated at constant 0, 4, 8.5 and 15 °C for 80 days, alone or with incorporated dried red clover leaves (4.8% N. 4 g leaves dry matter kg^{-1} dry soil). The leaves were labelled with ^{13}C (2.29 atom percent). The soils had been sieved through a 2 mm mesh while moist and pre-incubated in the dark for 4 ½ months at about 15 °C under aerobic and moist conditions. The soils were further moistened to 75% of the pore volume at field bulk density and kept for three days at the final temperature before incorporation of the clover leaves.

The net N mineralization was studied in soil samples equivalent to 50 g dry soil placed in 200 ml jars with the lids left loose, to allow some aeration. At each sampling date, replicates were sampled destructively as the whole sample was extracted with KCl, and analysed for NH_4-N and NO_3-N content. The C mineralization was measured in gas tight 1 l chambers containing soil equivalent to 400 g dry soil. A NaOH solution in a plastic tube placed in the middle of the chamber was used to trap the CO_2. The atmosphere of the chamber was monitored and oxygen was added when needed. Sampling was performed after 24 hours, and on days 3, 8, 15, 30, 52 and 80. Within each temperature, three replicates were used for CO_2 analyses and four replicates for mineral N analyses.

The C mineralization rate k was estimated, assuming first order decay, as $k = -ln([C]/[C_0])/t$ for the period when the slope of the decay curve was close to a straight line ($R^2 \geq 0.98$), where C_0 is the initial C amount in the substrate, and C is the remaining substrate at sampling time t.

For N a similar analytical approach was not possible.

Results

Carbon and N mineralization occurred even at 0 °C. The rate of C mineralization increased with temperature, as expected. For the soil organic matter and for the initial decomposition of leaves the effect of temperature was well described by Arrhenius-like equations. Soil type affected the rate of soil organic C mineralization, which was twice as fast in the sandy loam as in the clay loam. Contrary to our expectation, soil type affected also the C mineralization of the incorporated leaves, which was faster in the sandy loam.

During the 80 days incubation period the total N mineralization from soil organic matter alone was negligible. We can rule any important loss by denitrification (methods and data not shown). Of the N added with clover leaves, only 13-22% was mineralized, and about half of this was mineralized already during the first few (3 to 8) days. Particularly the mineralization during the first three days was most rapid and it was not affected by temperature. Subsequently, this short but rapid mineralization period was followed by a phase of slow net N mineralization in the sandy loam, and net N immobilization in the silty clay. During this phase, the effect of temperature was weak and irregular in the sandy loam, while immobilization increased with temperature in the silty clay. Only from the sampling on day 52, the net N mineralization from clover leaves increased over all the temperature range of the experiment.

The ratio of inorganic N to mineralized C from clover leaves varied during the experiment: It was remarkably high in the first sampling, then decreased and reached a minimum on day 30. During these 30 days, there was a marked and well-delineated effect of temperature on the N/C ratio. Thus, the N mineralization relative to C mineralization was stronger at 4 °C, and especially at 0 °C, than at higher temperatures. Thereafter, at the last two sampling dates (day 52 and 80) the N/C ratio converged and remained approximately constant (about 0.053), unaffected by temperature and soil type. Thus, only during the last 30 days of incubation there was a clear correlation between net N and C mineralization from the leaves, while in the first 30 days of incubation the ratio of net mineralized N to mineralized C from clover leaves was large at lower temperature, as hypothesized. It was not clear from the data whether soil type modified the N/C ratio in the early period.

These results can be explained by a stronger inhibition of the microbial growth compared to gross mineralization of the plant residue as temperature decreases and approaches 0 °C, leaving a larger share of the gross mineralized N available in the soil solution.

Conclusions

The experiment confirmed that N mineralization of N-rich plant material occurs even at 0 °C, and that the ratio of net mineralized N to mineralized C is larger at lower than at higher temperature.

The results of this study cannot be properly predicted by decomposition models that do not account for the little correspondence between net N and C mineralization the first month after incorporation of N-rich plant residue. The modelling could probably be improved by modifying the response of the microbial growth to temperature. For prediction in a relatively cold environment in transition to warmer temperature, as e.g. after spring incorporation of a ley before sowing a new crop, an erroneous modulation of the temperature effect relative to a parameterization at 15 or even 20 °C is likely to result in an overestimation of N mineralization, particularly on clayey soils. For prediction of ley mineralization after late autumn ploughing, it is likely to underestimate the N mineralization during the first part of the winter. As nitrification was delayed at the lower temperatures, and ammonium is less prone to leaching than nitrate is, it is not sure whether this model inadequacy would result in an underestimation of the risk of leaching shortly after ploughing in late autumn.

More knowledge of how low temperature affects soil biology, and especially microbial growth, is needed for improving prediction of the net N mineralization of newly incorporated plant material.

Acknowledgement

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EFFICIENCY OF CONTROLLED DRAINAGE AND LAND DRAINAGE SYSTEM IN IMPROVING WATER SAVING AND REDUCING NON-POINT SOURCE POLLUTION IN A FIVE-YEAR TRIAL

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Objectives

Water management strategies are key issues in modern agriculture, especially in the context of increasing water scarcity and environmental concerns related to nonpoint-source pollution. Water outflows management has been adopted worldwide in order to improve water and nitrogen use efficiency, although its effectiveness is strongly dependent on the local pedo-climatic conditions. As a result, in this work we evaluated the performances of controlled drainage systems for continuous regulation of the water table during a 5-year monitoring period. The aim was to control excessive drainage and improve water quality in a shallow groundwater system in north-eastern Italy.

Method

The field trial is located at the experimental farm "L. Toniolo" of the University of Padova (Legnaro, north-eastern Italy). The experimental field was set up in 1996 and organised into 12 plots (0.3-0.5 ha each) covering about a 6-ha area. The layout is a split-plot design with three replicates, in which the two factors are: water table management (free drainage, FD vs. controlled drainage, CD), and land drainage system (pipe sub-surface drainage, P vs. open ditches, O). However, to limit lateral seepage all controlled drainage plots are located in the northern part of the field and isolated from free drainage by a PVC film buried up to a depth of 1.5 m in the soil. Downstream of each plot, a 1.2 m-deep delivery ditch collects surface and subsurface drainage water: the total outflow volume is then measured by a turbine flow meter. Each controlled drainage plot (CD) has a riser installed to avoid complete water outflow and control water table level. Each year, all plots were cultivated, tilled and fertilized the same way (with a mean of 208 kg N ha^{-1} y^{-1} and 76 kg P ha^{-1} y^{-1}).

Inflow and outflow water volumes for each plot were measured in order to determine the yearly water balance, organized by hydrological years October-September. Water table depth was weekly monitored while a meteorological station, located in the experimental site, allowed hourly rainfall data collection. Finally, outflow water collected during the monitoring period was analyzed in terms of N-NO$_3$ and total N. P-PO$_4$ and total P concentrations were determined too, in order to outline a more comprehensive framework of the environmental risk related to nutrient losses from different drainage systems (especially as regards eutrophication).

Results

Annual rainfall was higher during hydrological years 2009 and 2010 (1077 mm and 1037 mm respectively), while 2011 showed the lowest value (760 mm). Controlled drainage systems (CD) showed low drainage volumes, ranging from a minimum of 10 mm in 2011 to a maximum of 57 mm in 2010 (corresponding to 3% and 16% of the rain fallen during the monitoring period). By contrast, during the same years free drainage (FD) drained respectively 224 mm and 261 mm (59% and 73% of rainfall during the same timeframe), emphasizing a significant difference in terms of outflow water volumes. Moreover, subsurface pipe with free drainage (FD-P) had the highest outflow rates, since ranging from a minimum of 41% of total rainfall in 2009 to a maximum of 91% in 2010. This was due to the intensity and distribution of rainfall events, which started in early autumn and continued throughout winter and spring, when bare soil minimized evapotranspiration.

Overall, N-NO$_3$ concentrations showed the highest values in FD-P system, with a median of 20.7 mg l^{-1} and the 95th percentile at 53.4 mg l^{-1}, that significantly differed from open ditches systems (O). Total N followed a similar trend, with highest values for FD-P (median value of 24.0 mg l^{-1} and 95th percentile at 60.0 mg l^{-1}). By contrast, the highest $P\text{-}PO_4$ concentrations were found in CD-O, with a median of 0.19 mg l^{-1} and the 95th percentile at 0.73 mg l^{-1}, suggesting an opposite behaviour than for N dynamics.

Nutrients content in discharge water varied during the year: N concentrations sharply increased in autumn (November), reaching a peak in December-January (with 57.6 mg l^{-1} and 43.3 mg l^{-1} as median values for total N), then slowly decreased until May. By contrast, P concentrations were somewhat anticipated during the hydrological period, especially in open ditches systems (with a peak of 0.85 mg l^{-1} median value of total P, for FD-O in September), likely due to P movement with soil particles as a result of water runoff caused by intense rainfall events.

Totally, subsurface pipe with free drainage (FD-P) showed the highest losses per year both for nitrogen and phosphorus(a mean of 103,8 kg ha^{-1} of total N and 0.31 kg ha^{-1} of total phosphorus), suggesting a major impact on the environment. Indeed, FD-P was characterised by the highest outflow rates, and by the highest N concentrations too. Conversely controlled drainage, due to limited water discharge, gave the best performance in reducing nitrogen and phosphorus pollution.

Conclusions

Controlling water outflow volumes in the field proved to be the best strategy to reduce nutrients pollution and improve agro-systems quality. During the 5-years monitoring period, although characterised by different hydrological conditions, controlled drainage systems (CD) showed the best performance by reducing both nutrient concentrations and total losses. Indeed, avoiding a complete outflow improved soil moisture conditions as well as nutrients availability for the crop. In contrast, critical conditions were observed by combining subsurface pipe with free drainage (FD-P). Indeed FD-P was the less efficient management system both in terms of water conservation and nutrients leaching (N and P), leading to increased risk of surface water pollution and eutrophication. Water saving through appropriate water management systems (i.e., controlled drainage) is suggested as a winning strategy to improve agro-systems efficiency in shallow groundwater conditions.

GRAZING BEHAVIOUR, URINE COMPOSITION AND SOIL PROPERTIES ARE KEY DRIVERS OF NITROUS OXIDE EMISSIONSFROM LIVESTOCK URINE IN THE UPLANDS (UPLANDS-N2O)

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Objectives

Agriculture contributes ~7% of the UK's total Greenhouse gas (GHG) emissions[1]. Nitrous oxide emissions from UK agricultural soils have large uncertainty, particularly for grazed grassland. The current applied default methodology assumes emission factors (EFs) for grazing sheep of 1% of the excreted N deposited to land. Grazing is known to result in soil compaction, and heterogeneous distribution of nutrients due to excreta deposition especially in lowland intensive systems. Effects of grazing on upland extensive systems (no fertiliser addition, low stocking density) have been less studied. Additional factors such as the spatial distribution of palatable plant species may affect sheep movement and the quality of their excreta with potential impacts on soil nutrients and N_2O emissions. We aim to improve our understanding of the spatial and temporal interactions between grazing behaviour, forage selection, urine composition and edaphic conditions to improve the accuracy of N_2O emission estimates from extensive, grazed grassland systems.

Method

The field study will be carried out on a semi-improved enclosed hill land (no fertiliser or lime applications since 1985) at ca. 250 metres above sea level (year 1), and an unimproved area at higher elevation ("heft", year 2) at ca. 850 metres above sea level at the Bangor University Experimental Station. We will track sheep movement and monitor different behaviours (including grazing and urination) in three 12-week campaigns at each site, via the use of animal-attached high resolution GPS and accelerometer sensors. We will also measure spatial and temporal variability in soil properties such as moisture content, soil mineral N, bulk density, pH, total N and C, and plant species distribution and palatability at each site. We will collect urine from sheep feeding on representative diets and subsequently apply this urine to areas where animals have been excluded for a few weeks before hand. We will measure N_2O emissions from these urine patches for a full year as a requirement for IPCC emission factor determination, using a combination of static[2] and automated flux measurement chambers to determine the spatial and temporal variation in N_2O emissions.

In addition, soil and urine will be collected from each of the two sites and used to explore and rank the factors controlling N_2O fluxes in a controlled laboratory environment where NO, N_2O and N_2 will be simultaneously quantified [3]. We will adopt the Taguchi methodology [4] to statistically represent the combinations of different controlling factors (including urine N concentration, soil compaction, %WFPS, temperature). The relationships between N_2O fluxes and the N_2O:N_2 mole fraction with these controlling factors will be used to parameterise the integrative model described below.

The results from the field measurements will be used to develop a model of the spatial/temporal variability of individual animals and herd dynamics; combining model predictions with knowledge of diet composition (chemical and plant species) from different vegetation communities, urine-N composition, and the spatial & temporal patterns of soil physico-chemical properties and subsequent N_2O emissions.

Results

The project has only just started, so in the first few months we are developing and testing the field pens for urine collection. Six animals will be housed on slatted flooring, with collection trays beneath for urine collection. The volume of each urination event will be recorded and urine will be stored for metabolomic analysis and for later use in field experiments. The tracking and behaviour sensors are being optimised for fitting to sheep and will be tested before the field experiment starts. We are also developing protocols for urine collection, soil sampling for parameters such as mineral N and moisture; and the emissions of N_2O. The first intensive campaign will start in the spring 2016, which will provide the first dataset for model testing. The results from the first campaign will provide data to finalise the parameters to study in the laboratory experimentation.

Conclusions

We believe that a more spatially-explicit approach to estimating N_2O emissions, which takes account of animal behaviour, forage selection (and its effect on urine deposition), topography, soil type and soil conditions, will provide improved insights into the spatial and temporal variability of N_2O emissions and new estimates of emissions from extensive grazing systems for inventory purposes. The improved process-level understanding will also lead to the development of better-informed mitigation strategies for such systems.

References

[1] Brown (2012). UK Greenhouse Gas Inventory, 1990 to 2010: Annual Report for submission under the Framework Convention on Climate Change. AEAT/ENV/R/3264.[2] Chadwick, D.R., L. Cardenas, , Misselbrook, T.H., Smith, K.A., Rees, R.M., Watson, C.J., McGeough, K.L., Williams, J.R., Cloy, J.M., Thorman, R.E., Dhanoa, M.S., 2014. European Journal of Soil Science, 65(2): 295-307. [3] Loick, N., Dixon, L., Abalos, D., Vallejo, A., Matthews, G.P., McGeough, K.L., Well, R., Watson, C.J., Laughlin, R.J., Cardenas, L.M. Denitrification as a Source of Nitric Oxide Emissions from a UK Grassland Soil. SBB in press. [4] Garcia-Marco, S., Ravella, S.R., Chadwick, D., Vallejo, A., Gregory, A.S., Cardenas, L.M., 2014. Ranking factors affecting emissions of GHG from incubated agricultural soils. European Journal of Soil Science, 65: 573-583.

FERTILIZATION & ENVIRONMENT JOINT TECHNOLOGICAL NETWORK – CONCEPTS, PROJECTS AND TOOLS USED AROUND FERTILIZATION AND MANAGEMENT OF BIOGEOCHEMICAL CYCLES

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Objectives

Joint technological networks (RMT) are partnership-devices introduced by the French Ministry of Agriculture in 2007 to break down barriers, encourage networking of actors in research, training and development and foster innovation in the fields of agriculture and agro-food. The RMT Fertilization & Environment (F&E) aims to collect, develop and build synergies between existing technical and scientific expertise in the research, educational and agricultural development systems, in order to provide the stakeholders (farmers, agricultural extension agents, trainers, resource and territory managers, government) references, methods and tools for the sustainable management of biogeochemical cycles and soil fertility in the major cropping systems present on the French territory (Metropolitan and Overseas). The network was created in 2007.

Method

The joint technological network RMT Fertilization & Environment brings together 33 partners from research institutes, higher education and technical schools of agriculture and agricultural development bodies from France, Belgium and Switzerland around a work program. The members of the RMT F&E carry out as partners various research and development projects that focus on three thematic priorities: crop fertilization, organic waste products recycling, and control of biogeochemical cycles. While combining plant production and environmental protection, these priorities are part of the principles of agroecology at different spatial and temporal scales, i.e. sparing use and equitable distribution of resources, reduction of inputs, recycling of organic products, ecological intensification, developing and preserving the ecosystem services provided by agriculture and soil.

To carry out its program of activities and achieve the expected results, the coordination team of the RMT F & E organizes the work in four areas, defined by the type of production they generate:

1. Prospective and scientific monitoring, European and international strategy
2. Coordination and sharing around the acquisition of scientific and technical references and appropriation of new paradigms
3. Development and improvement of decision support tools for actors, particularly for fertilization
4. Transfer, dissemination, teaching and training; public policy support.

The activity of the RMT develops through joint meetings, workshops, R & D projects applied to competitive calls, participation in scientific and technical events at national and European levels in which the network members communicate their results.

Results

The results of RMT F & E are of various kinds, depending on the type of activity and the composition of the partnership that produced them:

- State of the art, studies and prospective analyzes, formulating new research questions
- Knowledge, references and common databases, including results from the joint projects
- Conceptual frameworks, methods, flow charts
- Decision support and diagnostic tools (specifications, algorithms, prototypes and marketable tools, computer and agronomic manuals)
- Evaluation of agricultural and environmental policy tools
- Educational tools (including tutorials) for teaching and development, training
- Scientific and technical publications (articles, posters, book chapters, internet pages)
- Scientific seminars, technical conferences.

Among notable productions RMT F & E, we can cite:

- Tools software: Régifert®, diagnostic software and prescription for the elements P, K, Mg, Zn, Mn, B, organic C and acid-base status of the soil; Syst'N®, tool for estimating N losses (NO3, NH3, N2O) diagnostics for the management of N at the scale of crops rotation; AzoFert®, software for fertilizer N recommendation for annual crops, with two variants under development, one suitable for the fertilization of fruit trees and vines (N-Perennes), the other suitable for educational purposes to promote learning of the N dynamics and the N balance method (N'EDU).

- A collective book «Fertilization and environment: What avenues for decision support?" (February 2014, co-published Quae ACTA), results of a prospective reflection on the changing context of fertilization in the coming 5-10 years, and future needs for references, tools and methods for managing the biogeochemical cycles and rational fertilization.

- Scientific and technical support to national public policies particularly with the Nitrates Directive

- Numerous projects on animal manures and organic wastes recycling in agriculture to improve the knowledge on the characterization of organic matters composition, potential mineralization, to improve substitution of mineral fertilizers by organic fertilizers, identification of agricultural practices and techniques that reduce losses of N by nitrate leaching, ammonia volatilization and nitrous oxide emission.

Conclusions

The RMT F & E promotes (i) the sharing of financial and human resources, knowledge, tools and references, avoiding dispersion and duplication, (ii) the development of scientific and technical consensus among its members and beyond, and (iii) the acquisition of a common vision of the major issues related to the management of biogeochemical cycles of main elements in agriculture.

For more information:

http://www.rmt-fertilisationetenvironnement.org

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MECHANISTIC INSIGHTS INTO THE EFFECTS OF NITROGEN FERTILIZER APPLICATION ON N_2O-EMISSION PATHWAYS IN ACIDIC SOIL OF A TEA PLANTATION

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Objectives

Long-term nitrogen (N) fertilization has been shown to stimulate N_2O emissions from acidic soil in tea plantations. However, the potential mechanism behind this stimulation remains unclear. We aimed to investigate the effects of 6 years of fertilizer application on N_2O emission pathways and the N_2O emission ratio from heterotrophic and autotrophic nitrification in tea plantation.

Method

We performed a ^{15}N-tracing experiment under 40% and 60% water-holding capacity (WHC) to investigate the effects of 6 years of fertilizer application on N_2O-emission pathways and emission ratios from heterotrophic and autotrophic nitrification in soil from tea plantations.

Results

6 years of fertilizer application stimulated both heterotrophic and autotrophic nitrification, particularly under conditions of higher soil moisture. Autotrophic nitrification was the predominant pathway for N_2O emission in tea soils, being responsible for 66.7–75.9% and 50.4–56.9% of N_2O emission in unfertilized and fertilized soils, respectively. Fertilizer application significantly increased the contribution of denitrification to N_2O emission (10.5–35.7%), independent of soil moisture conditions, which could be due to a fertilizer-induced reduction in soil pH. Fertilizer application and a subsequent reduction in pH resulted in a 3–4 and 8–9 fold increase in the ratio of N_2O emissions from heterotrophic nitrification and autotrophic nitrification, respectively.

Conclusions

The increase in N_2O emission following N fertilizer application was attributed to increased heterotrophic and autotrophic nitrification rates and an increased ratio of N_2O emission from heterotrophic and autotrophic nitrification. Our results suggest that pH was a critical factor regulating the ratio of N_2O emission from heterotrophic and autotrophic nitrification and thus controlling N_2O emission from the tea soils studied.

NITRIFICATION INHIBITORS: NITROGEN USE EFFICIENCY AND RESIDUAL EFFECT

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Objectives

The application of nitrification inhibitors (NI) is a strategy to increase the efficiency of nitrogen (N) in farming systems [1]. They could have a cumulative effect through N immobilization by microorganisms and ammonium fixation in the soil [2]. Therefore, NI could build up a pool of nutrients and increase the N supply capacity over time and reduce N losses from the cropping system.

During two seasons, a maize crop was established and fertilized with ammonium sulfate nitrate, with and without DMPP, with the objective of determining the effect of NI fertilizers on grain yield, N content and NUE, compared to conventional fertilizers. A non-fertilized sunflower crop was planted in the same plots in order to study the cumulative residual effect after the two previous years with different fertilizer applications. Laboratory determinations were performed in order to elucidate and locate the sources of residual N.

Method

The study was located in Aranjuez (Spain). The soil had a silty clay loam texture and pH~8 and the climate in the area is semiarid Mediterranean. The experiment design was factorial with two factors – fertilizer type and rate - and two levels. The fertilizers were ammonium sulphate nitrate (ASN); and ASN + the nitrification inhibitor DMPP 3, 4-dimethylpyrazole phosphate (ENTEC). The rates were 170 kg N ha^{-1}, the recommended rate in the region based in previous research, and a lower rate, 130 kg N ha^{-1}. A non-fertilized control was included. Each treatment had three replications randomly distributed.

The maize was sown during 2013 and 2014 in April and harvested in October. Sunflower was grown in the same plots in 2015 from April to September. The grain yield, grain quality and N content of the maize were assessed at harvest. The last season, anticipating the bird damage in sunflower before harvest, a sampling was performed at the end of the full flowering stage when N uptake had mostly occurred, and the crop biomass and N content were determined. Each season, the crop nutritional state was assessed with SPAD readings at different stages. At crop sowing and harvest the soil inorganic N content (N_{min}) was determined to 1 m depth.

Two component of the N use efficiency were calculated: the agronomic efficiency, that refers to the kg of crop yield increase obtained per kg of N applied and was calculated for 2013 and 2014 seasons. The second component was the recovery efficiency that refers to the kg of crop N uptake per kg of N applied, calculated in 2013, 2014 and for the whole experimental period (2013 to 2015).

In 2015, eleven months after the fertilizer application, an aerobic incubation was carried out to determine the N mineralization potential in samples from the 0-20 cm soil upper layer. The non-exchangeable ammonium ($NH_4{}^+{}_f$) was extracted and determined by the potassium hypobromite-dry soil combustion method in samples from the 0-20, 20-40 and 40-60 cm soil layers. As well, the ^{15}N was determined by ratio mass spectrophotometry.

Results

Grain yield and N content were affected by treatments but differences were significant the second year. Treatments fertilized with the recommended rate or the reduced with ENTEC had higher yield (10.8 Mg ha^{-1}) than the reduced rate with the conventional fertilizer (7.6 Mg ha^{-1}) and the control (5 Mg ha^{-1}). The crop N content was higher for ENTEC treatments (196 kg N ha^{-1}) than for the control (69 kg N ha^{-1}). SPAD readings were affected by treatments and sampling time and supported the yield results.

Differences in NUE were observed also by the second year of fertilizer application. The ENTEC with the lower rate achieved the greatest agronomy efficiency (49 kg grain produced per kg N applied), and no differences were found between fertilizer treatments with the recommended rate (33 kg grain kg N applied^{-1}). The recovery efficiency was greater for the ENTEC treatments compared to the ASN-130. The recovery efficiencies for these NI fertilizers were higher than those reported in the literature (up to 70% of N recovery) [3], suggesting a residual effect. No differences between treatments in the upper 0-40 cm layer were found in the soil N_{min} in 2014 samplings, indicating that the residual effect was not coming from the soil inorganic N content. In 2015, at the full flowering stage in the non-fertilized sunflower, ENTEC-170 had the greatest N content (100 kg N ha^{-1}). Treatments ENTEC-130 and ASN-170 formed a subgroup below and no differences were found between them (76 kg N ha^{-1}). Again, crop results were supported by SPAD results: at the heading stage, ENTEC treatments had greater readings. At harvest, in September 2015, no differences were found in the total N_{min} content in the profile between treatments, indicating that the sunflower was able to scavenge the N. For the whole period (2013 to 2015) similar results than the observed in 2014 were reported: the N recovery was higher for ENTEC treatments compared to ASN-130, and values were still higher than those observed in the literature. One year after fertilizer application, the aerobic incubation showed that the N mineralization rate was higher for ENTEC-170 (71 kg N ha^{-1}) than for ASN-170 and the control (51 kg N ha^{-1}), suggesting that at that time the residual effect due to the NI was still present. The average $NH_4^+{}_f$ (120 mg N kg^{-1}) was in the range reported in the literature for medium textured soils [4]. However, the content was low to detect differences between treatments. The $\varrho^{15}N$ in samples from the 40-60 cm soil layer was higher in ENTEC and ASN-170 than in the other treatments. The $NH_4^+{}_f$ found and the isotopic imprint suggested that fixation and defixation processes were occurring in the soil.

Conclusions

The fertilizers with nitrification inhibitors increased the efficiency of fertilizer N in a three year crop rotation, with respect to conventional ASN. In the following year after application, the ENTEC fertilizer rate was reduced 23% from the recommended rate in the region (from 170 to 130 kg N ha^{-1}) without decreasing grain yield or quality of maize. In addition, a non-fertilized sunflower planted after the maize was able to scavenge more N in treatments previously treated with ENTEC than with traditional fertilizers. After NI fertilizer application, N was conserved in non-ready soil available forms during at least 1 year and subsequently released to the following crop, thereby mitigating N losses. The aerobic incubation and the non-exchangeable ammonium extraction showed that this cumulative residual effect was produced by biotic and abiotic processes. In soils prone to retain NH_4^+, crop rotations using NI should be designed to profit from the residual effect of this fertilizer technology.

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References

[1] Quemada, M. et al. 2013. Agr. Ecosyst. Environ. 174, 1-10

[2] Ma, Q. et al. 2015. Soil Biol. Biochem. 89, 72-81

[3] Gabriel, J.L., Quemada, M. 2011. Eur. J. Agron. 34, 133-143

[4] Nieder, R. et al. 2011. Biol. Fert. Soils 47, 1-14

FEATURES IN VILLAGE-SCALE NITROGEN FLOW IN THE LOWER REACH OF YANGTZE RIVER, CHINA

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Objectives

Nitrogen limits primary productivity in the agro-ecosystems and results in eutrophication and haze. To overcome this limitation and maintain environmental security, densely populated agricultural regions in developing nations now use synthetic nitrogen fertilizers to boost yields. However, nitrogen saturation of aquatic and terrestrial ecosystems were observed here and there. Increased gradually reactive nitrogen emitted to the atmosphere. To assess the fate of reactive nitrogen cascade in the village scale of the lower reach of Yangtze River, material flow analysis method and the principle of conservation of mass was used in the rural area of Changshu City, Jiangsu Province, China.

Method

2.1. Description of study site

Changshu City (31°31′58.2″N、120°41′48.3″E) is located in the lower reach of Yangtze River, China. Most villages and farmlands are near to the rivers. In the past century, due to the excessive population growth and the increasing demands for cultivable lands, the water coverage had been greatly reduced. For the cropping system, the paddy rice-wheat was dominant. The cropping varieties incremented cropping intensity and were more dependent on chemical fertilizer. The number of farm animals had also increased. The excreta were sold for the farmers as manure in their cultivated lands.

2.2. Crop Production-Livestock Breeding System

The nitrogen flow in the Crop Production-Livestock Breeding System can be analyzed by the flow route as follows.

(1) Crop production subsystem

For the Crop production subsystem, nitrogen input items include nitrogen derived from chemical fertilizer, excreta, seed, straw returned to field, biological fixation, atmospheric deposition and irrigation water. While, total output items include nitrogen derived from crop yield, ammonia emission, emissions of nitrogen oxides, nitrous oxide and di-nitrogen from nitrification and denitrification processes, losses of runoff and leaching and soil accumulation.

2) Livestock breeding subsystem

For the Livestock breeding subsystem, nitrogen input items include nitrogen derived from fodder, kitchen waste, animal by-products and import fodder. While, total output items include nitrogen derived from meat, egg, milk, bone, by-products and excreta.

2.3. Data sources

Basic data (e.g. population, fertilizer use, crop yields, cultivated areas and animal numbers) were derived from governmental statistical yearbooks and bulletins (Changshu Statistical Bureau, 2000-2013). Crops category included wheat, paddy and vegetables. Farm animals were aggregated into seven animal categories (pig, dairy cattle, sheep, laying hen, broilers, duck and goose). Data about nitrogen content in crops and animal products, nitrogen excretion values and the partitioning of animal products into edible food were obtained from literatures (Chinese Statistical Bureau, 2000-2013). For nitrogen loss parameters (e.g. ammonia emission, emissions of nitrogen oxides, nitrous oxide and di-nitrogen from nitrification and denitrification processes and losses via leaching, runoff and discharge) were obtained from literatures (IPCC, 1997; Ti et al., 2011; Ma et al., 2012) and surveys.

Results

3.1 Nitrogen flux

During year 2000~2012, the nitrogen flux of Crop production subsystem in the rural areas of Changshu City decreased from 18640 to 14230 kg km^{-2}. Urbanization development was a great influence. Since 21st century, urbanization rate increased from 36% to 52.8% resulting in the improvement of agricultural intensification and changes of nitrogen flow pattern. For the Livestock breeding subsystem, the nitrogen input flux was within the range of 4250~5090 kg km^{-2}. The amount of animal fodder was insufficient. 52.9%~67.8% of fodder were imported from outside. With the expansion of livestock farming and enhanced intensification level, animal products-derived nitrogen increased from 350 to 490 kg km^{-2}. Meanwhile, a large number of manure from animals discharged freely, resulting in environmental pollution.

3.2 Nitrogen use efficiency

A low nitrogen flow efficiency of the Crop Production-Livestock Breeding System was found from 2000 to 2012. Results showed that the utilization efficiency of nitrogen (32.5%~37.5%) was higher than that of nitrogen recycle (18.9%~21.2%) in the Crop production subsystem. For the Livestock breeding subsystem, the utilization efficiency of nitrogen (8.1%~11.4%) was lower than that of nitrogen recycle (17.9%~18.3%). In the rural areas of Changshu City, fertilizer nitrogen applied to each crop (wheat 21000, rice 32700, vegetables 38700 kg km^{-2}, respectively) was far beyond the nitrogen demand of crop growth, restricting the utilization efficient of fertilizer nitrogen. As chemical fertilizer accounted for more than 70% of nitrogen input for the local farmland, its low utilization efficient caused low utilization efficient of nitrogen recycle.

3.3 Effects of nitrogen application on environmental loads

The study area is in the water network region of Taihu watershed. The rivers and ponds are near to the rural household and farmlands. Our results showed that 54.5% of total nitrogen losses from the Crop Production-Livestock Breeding System entered into the water body. These may contribute to the higher nitrogen load of Taihu Lake. It was reported that 34% of non-point pollution of Taihu Lake derived from cultivated lands. During year 2000~2012, the Crop production subsystem and Livestock breeding subsystem contributed 42.6%±3.0% and 32.9%±2.9%, respectively to the environmental nitrogen load. Taking year 2012 as an example, chemical fertilizer application was 310.8 kg hm^{-2}, 1.5 times than the national level. The significant correlation ($R^2= 0.96$, $p < 0.01$) between water nitrogen load and fertilizer application to the cultivated lands was obtained, suggesting that excessive nitrogen application restricted the nitrogen utilization efficient and enhanced water nitrogen load. With the increased population growth, urbanization and economic growth, large numbers of waste discharge-derived nitrogen from people and animals aggravated the environmental nitrogen load. For year 2012, excreta -derived nitrogen in the study area was 61.1 kg hm^{-2}, 3.2 times than the national level.

Conclusions

To confront the severe eutrophication of aquatic ecosystem and reduce non-point source pollution radically in the lower leaches of Yangtze River, China, the nitrogen flux, efficiency and environmental load in the village-scale were studied. Results showed that both amount of nitrogen input in crop production and livestock breeding were high. However, the nitrogen use efficiency was low in both subsystems. Most of the nitrogen inputs were lost to the environment, which was 280 t to atmosphere, 565 t to water body and 192 t stored in soil. As for nitrogen load of atmosphere and water body, crop production was the key factor. It was concluded that the demand for reasonable nitrogen management measures, such as balancing fertilization, increasing crop and animal production, and improving manure management was urgent.

Acknowledgements

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References

[1] IPCC, 1997. Intergovernmental Panel on Climate Change: Greenhouse Gas Inventory Reference Manual [M]. London: Cambridge University Press.
[2] Ti C.P., Xia Y.Q., Pan J.J., et al, 2011. Nitrogen budget and surface water nitrogen load in Changshu: a case study in the Taihu Lake region of China. Nutrient Cycling in Agroecosystems, 91(1): 55-66.
[3] Ma L., Velthof G.L., Wang F.H., et al, 2012. Nitrogen and phosphorus use efficiencies and losses in the food chain in China at regional scales in 1980 and 2005. Science of the Total Environment, 434: 51-61.

INTEGRAL ASSESSMENT OF FARM RESULTS BY BENCHMARKING

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Objectives

Agricultural policies, and so also minerals policies, need information about the performances in agriculture. In EU-member states participating farms provide this information to the Farm Accountancy Data Networks (FADN). In the Netherlands the FADN has been extended with the Dutch Minerals Policy Monitoring Programme (LMM) to collect even more detailed information on environmental issues such as nutrients and to link this information to quality of groundwater and surface water.

All in all about 1600 agricultural and horticultural holdings voluntarily participate in the FADN and/or LMM. To keep participation in the FADN/LMM attractive the farmers receive a report on their integrative performance (people, planet, profit) with both an internal and external comparison. For a good external comparison a sound benchmark is necessary [1]. Objective of this abstract is to create a sound benchmark for individual farms as well as for groups of farms explained by an example.

Method

A group of dairy farms in the Netherlands aims at improvement of their internal nutrient cycle (INC). They claim a lower environmental impact per kg of milk production for which reason nine of these farms were already more intensively researched including participation in both FADN and LMM. Data on economic and environmental performance as well as on structure and management were derived from FADN and LMM for the years 2008 and 2009: two years were chosen to stabilize yearly fluctuations. Not only data of the INC-farms were derived but also of 228 other dairy farms, available for both years.

Statistical matching [2] was applied to create the benchmark for the nine INC-farms. For each INC-farm, farms of the other 228 dairy farms were selected with the nearest neighbour method which resembled the INC-farm as closely as possible. Variables, which were used to decide whether a farm resembles an INC-farm (called imputation variables), have been determined by expert judgement. Based on the imputation variables the distance between an INC-farm and another farm is calculated. The farm with the smallest distance to the INC-farm is regarded as the farm that resembles the INC-farm most closely and gets the highest weight. In this case, where a group of farms is benchmarked, 3 or 4 most similar farms (with a total weight of 1) for each farm in the group would already satisfy to avoid underestimation. However for an individual farm the minimum is set at 10 to mitigate the influence of an individual observation and to ensure the privacy of the farms that are chosen for the benchmark.

To present the results of the benchmark especially bar charts and radar plots are suitable. When applying a bar chart the values for the benchmark group are set at zero and the values for the farm (or group of farms) to be benchmarked are shown as deviation from zero. A favourable deviation can be presented in green and an unfavourable deviation in red. A radar plot offers the possibility to give more weight to some indicators compared to other indicators.

Results

Experts considered soil type, groundwater level, milk production per farm, milk production per ha, nitrogen delivery capacity of the soil and distance in km as most appropriate imputation variables. After application of the statistical matching the averages of the INC-farms on the imputation variables were compared with the averages of the farms, chosen by the statistical matching, on the same variables. No significant differences were found and for all imputation variables the differences were smaller than 5% except for the groundwater level (8%): this indicates a very good matching.

Each INC-farm was connected with one most similar farm, a second best one and so on, up to 10. The average contribution of the most similar ones in the weight was 32% but even the numbers 10 contributed nearly 5% in the weight so their inclusion was useful.

A two sample T-test assuming unequal variance was conducted on the performance indicators to test for differences between the INC-farms and the farms in the benchmark. Concerning the economic performance the INC-farms performed significantly better on revenues for agri-environmental measures, fertilizer costs and crop protection costs but worse on costs for buildings and quota. All in all the farm income per 100 kg milk was significantly higher on the INC-farms. They also had a lower cost price compared to their benchmark but this difference was not significant. The environmental performance focused on nitrogen in kg per ha. The INC-farms had a lower surplus on the nitrogen surplus balance but the difference was not significant. Because of the method of manure application, used by the INC-farms, the emission of ammonia was significantly higher which caused a significantly lower nitrogen soil surplus. Besides the INC-farms used significantly less crop protection chemicals.

Several times the results of this study have been presented. The bar charts with green (favourable) and red (unfavourable) proved to be very clarifying. The radar plots were very useful for a first quick view to determine where to zoom in further. Partly due to this positive feedback the benchmarking as presented above has been introduced in the report for the participants in FADN and LMM to provide a better comparison compared to the former group comparison. In the former group comparison only the farm size was taken into account to detect comparable farms. Many participants in the FADN and LMM independently and continually mention that the benchmarking is the most useful part of the report they receive on their performance. So any improvement in the benchmarking is much appreciated. They highly value the described bar charts and radar plots because these figures deliver a fast and good integral overview concerning total farm performance.

Conclusions

To create a sound benchmark for a useful external comparison statistical matching turns out to be a good method. Application of this method to compare the results of dairy farms focussing on their internal nutrient cycle with the results of comparable farms showed excellent similarity between both groups on structure indicators such as size, soil type and intensity. Subsequently differences in farm performance between the groups were not caused by structure indicators.

This is not only important for (groups of) farmers themselves but also for policy makers. They can better zoom in on (improvement of) management because farm structure doesn't influence the external comparison anymore. Visualization in bar charts and radar plots is very helpful for a quick integrated overview, both in comparison of groups and comparison of an individual farm with a comparable group of farms.

References

[1] Dolman, M.A., Sonneveld, M.P.W, Mollenhorst, H., Boer, I.J.M. de. 2014. Journal of Cleaner Production 73, 245-252

[2] Vrolijk, H.C.J., Dol, W., Kuhlman, T. 2005. Integration of small area estimation and mapping techniques - Tool for Regional Studies. LEI, The Hague, Report 8.05.01

CALCULATING NITROGEN FOOTPRINTS ALONG THE CHAIN FROM AGRICULTURE TILL RESIDUE WHEREABOUTS ON THE EXAMPLE OF FOOD PROVIDED AT A CONFERENCE

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Objectives

The Nitrogen (N) chain with human food consumption as core starts in agriculture, since plants need to be fertilized and animals fed. A large part of the N gets lost until food reaches the consumer. Further losses occur with food wastages. The human N intake equalizes the releases from the body, whereas most is contained in excrements. Depending on the chosen disposal, treatment or reuse pathway, waste and excrement N may become an environmental problem, wasted or a valuable resource.

The N footprints along the food chain were calculated for the various stages: from agriculture to consumer (production, processing and transport of ingredients), and from the utilization by consumer (food preparation, cooking, and consumption) to the final whereabouts of food preparation residues, food left-overs, and excrements (generation, collection, transport, disposal, treatment, reuse). The evaluation was carried out for the food provided at the RAMIRAN2015 conference.

Method

RAMIRAN2015, a 3-days conference, with 229 participants caused an N-footprint due to food provided in 5 coffee breaks (fruit salads, mueslis, croissants, cakes, nuts, drinks), 2 lunch breaks (8 options for main dishes [1], 2 options for soup [1], salad, dessert, soft drink), 1 conference dinner (2 starter and main course choices, dessert buffet, drinks). The N footprints from agriculture to consumer for the food and drinks provided, and from the consumer to final whereabouts for residues were calculated as follows:

1) Data collection regarding type, amount and composition of food and drinks from:
    a. Conference organizer; providing companies and default recipes.
    b. Cafeteria; a detailed list of ingredients in each lunch meal and each soup was provided.
    c. Dinner restaurant; an approximate list of ingredients for starters and main courses was provided; default recipes for desserts.
2) Calculating the N footprints of food and drinks from agriculture to consumer [2]:
    a. Linking ingredients with USDA nutrient database; quantification of N in ingredients.
    b. Grouping ingredients to primary food groups of 'JRC tool' based on CAPRI factors; calculating ingredient footprints by using footprint factors.
    c. Calculating footprints of food and drinks based on provided portions.
3) Data collection for food preparation residues, food left-overs and toilet residues (literature, cafeteria, own measurements).
4) Data collection and chain design for pathways from kitchen resp. toilet over treatment up to product application resp. N losses into environment (literature, treatment companies).
5) Calculating N-footprint for steps from consumer to final whereabouts based on collected data for:

a. Toilet waste from conference location and restaurant to central wastewater treatment facility (WWTP Köhlbrandthöft) in Hamburg for N-Elimination.

b. Food preparation residues and food left-overs from lunch breaks to Parumer biogas plant with digestate application in agriculture.

c. Food left-overs from coffee breaks partial to anaerobic digestion and composting in Bützberg with compost application in agriculture and to N-Elimination in WWTP Köhlbrandthöft.

d. Food preparation residues and food leftovers from gala dinner to Stellinger-Moor biogas plant with partial digestate application in agriculture (65%) and with N-Elimination in WWTP Köhlbrandhöft (35%).

Results

The results are focused on reactive N (Nr) only. Releases of inactive N are not considered here.

(1) From agriculture to consumer

Lunches: The main dishes had following properties: quantity: 230-810 g, energy: 401-1676 kcal, N intake: 0.64-7.52 g [1]. Additionally 1 soup per participant and day was assumed. The Nr losses ranged between 1.8-13.5 g for main dishes, 0.4 resp. 2.3 g for soups (average Nr: 6.3 g per main dish, 1.5 g per soup, in total 3500 g Nr for 2 lunches).

Coffee breaks: 3 fruit salads (41.0 kg, 58.5 g Nr), 3 mueslis (40.2 kg; 675 g Nr), ham and cheese croissants (together 37.1 kg; 539 + 520 g Nr), 2 cake types (13.4 kg, 354 g Nr), nuts (3 kg, 3.6 g Nr) and drinks (coffee, tea, juices, water, in total 329 kg, 987 g Nr - mainly from orange juice) were provided (in total 3100 g for 5 breaks).

Gala Dinner: Vegan (38 portions) and mixed menu (152 portions) properties were as follows: salad and "Grilled tofu on barley risotto with glazed vegetables" - 0.30 + 2.6 g Nr; salad with salmon and "Breast of corn-fed chicken on mashed potato-beetroot with glazed vegetables and creamed morels" - 0.66 + 11.6 g Nr. Desserts were estimated with 654 g Nr in total (3.4 g per participant) and white wine with 301 g Nr (1.6 g Nr for 0.5 L wine per person), in total 2900 g for the dinner.

(2) From consumer to final whereabouts

Excreta: 4.9 kg N was diluted in blackwater (assumptions: N intake 5.7 kg by meals and drinks, 86 % of it segregated with excrement's. About 81 % of excrement N is removed via nitrification/ denitrification in the WWTP as N_2. The rest is mainly contained in the effluent and released into a river; minor fractions in sewage sludge go through anaerobic digestion, centrifugation, drying, and incineration. The non-nitrified/denitrified N was accounted for as Nr (900 g).

Food residues: 8.2 kg lunch preparation residues and food leftovers (cafeteria information); 18 kg coffee and some fruit residues in coffee breaks (own observations); 84 kg conference dinner residues (estimated from biobin pictures) were produced. Each residue took a different pathway (see methods). Following Nr releases were calculated: 30 g by lunch break residues, <10 g by coffee resp. by fruit residues from coffee breaks, 210 + 40 g by dinner residues (distinguished after digestate whereabouts: portions applied in agriculture + portions treated in WWTP; calculated with: 26 % food waste dry matter; 3.3 % N in DM; 1.3 coffee % DM, 2.5 % N in DM). Food waste residues in total did emit 300 g Nr.

Conclusions

More than 10 kg Nr were emitted - from agriculture to consumer almost 40 g per participant (18 g in 2 lunch breaks, 16.1 g in 5 coffee breaks, 15.5 g for gala dinner). In residue pathways, 2/3 of Nr was accounted to excrements and 1/3 to food residues. It makes 9.5 kg Nr up to the consumer and 1.2 kg Nr up to residue whereabouts. The core of the chain is protein intake (suggested for adult woman 7; man 9 gN/d). But eating has also cultural and social dimensions. Wishes of people have to be considered (questionnaire result - mixed food preferred by most). No specific ingredient should be banned, but all ingredients should be handled with care. At conferences food quantities, energy contents and footprints could be declared on menus with considerable effort to support food choice and raise awareness. If choosing a lunch dish with average quantity instead of high at RAMIRAN, Nr would have been 40 % lower per dish. Lists with Nr rich "hidden" (e.g. butter) and "luxury" ingredients (e.g. beef) could be supplemented. It could help to adjust cooking behaviors and meal selections. If at RAMIRAN coffee breaks fruits would have been served instead of mueslis, the N footprint of coffee breaks could have been reduced for about 20 %.

References

[1] Leip, A., et al. 2015. In: Körner, I. (ed.) Proceedings of the 16th RAMIRAN Conference, Hamburg, Germany, 26-30. www.ramiran2015.de

[2] Leip, A. et al. 2014. J. Agric. Sci. 152. 20.

EVALUATING SCENARIOS ON THE NITROGEN CASCADE IN RURAL LANDSCAPE MODELLING: *INTER-COMPARING ON THE EFFICIENCY OF SCENARIOS OF AGRICULTURAL PRACTICES OPTIMIZATIONS AND LANDSCAPING.*

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Objectives

In rural landscapes, the nitrogen cascade [1] -i.e., the way reactive nitrogen transforms and transfers into, out of and within the agro-ecosystem- depends on farm management and landscape structure. Most often, mitigation measures are conceived for the field or farm level and focus on reducing one type of N emission (i.e., NO3 leaching or NH3 emission). Designing mitigation strategies at the landscape level to improve overall N use and reduce all types of undesirable emissions is a major challenge [2]. As a part of the ESCAPADE project (ANR-12-AGRO-0003), agri-environmental scenarios are built in contrasted landscapes and their effects on N emissions to air and water are assessed using integrated models. The main objectives are (1) to evaluate the relative efficiency and complementarity of field-oriented and landscape-oriented measures to reduce N emissions (2) to discuss the risks of pollution transfer between N species and between water and air.

Method

Study sites are headwater catchments (around 4 km²) located in Brittany (Western France) and in Gascogne (South-West of France). They are contrasted in terms of agriculture type (respectively mix farming with high livestock density and cereal cropping), soil, climate (warmer and dryer in Gascogne) and landscape structures. Surveys were carried out to describe exhaustively agricultural practices. Measurements and monitoring of some major components of the nitrogen cascade such as discharge, NO3 concentration, NH3 and N2O emissions, are conducted on both sites. The approach is to simulate a set of scenarios aimed at mitigating the nitrogen cascade by: i) optimizing agricultural practices (fertilization adjustment, cover crops, organic manure management...) ii) landscape structure management according to two strategies: land sharing (i.e., diffuse arrangement of ecological structures (hedgerows, vegetated filter strips) in the landscape) and land sparing (large patches of natural vegetation or different production systems located in strategic locations). Two integrated and spatially distributed models are used complementarily. TNT2 is a spatially distributed agro-hydrological model focusing on nitrate transfer, hedgerows and riparian zone functioning [3, 4]. NitroScape is a model designed to quantify the contribution of both atmospheric and hydrological transfers to Nr fluxes, budgets and indirect Nr emissions [5].

Results

Four different scenarios are being simulated for each site. The scenarios will be designed with local stakeholders and assessed both in terms of overall N emission reduction, agriculture N use efficiency, N retention by landscape and allocation between NO3, N2O and NH3 emissions. The differences between the sites will be analyzed to discuss the relative effect of anthropogenic vs environmental context. This will be interpreted in terms of recommendations for designing context-specific mitigation strategies.

References

[1] Galloway, J. N. et al., 2003. BioScience 53, 341-356.
[2] Cellier, P. et al., 2011. In: Sutton, M. A. et al., (eds.) The European Nitrogen Assessment Sources, Effects and Policy Perspectives. Cambridge University Press, 229-248.
[3] Beaujouan, V. et al., 2002. Hydrological Processes 16, 493-507.
[4] Oehler, F. et al., 2009. Science of the Total Environment 407, 1726-1737.
[5] Drouet, J. L. et al., 2012. Biogeosciences 9, 1647-1660.

UTILIZATION AND DISTRIBUTION OF ^{15}N FROM FERTILIZERS TO COMPONENTS OF CEREAL - PEA MIXTURES

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Objectives

In the last ten years, in Poland, there has been a significant genetical progress in plant breeding, in particular, of field pea, resulted in higher yield of seeds, greater concentration of protein and favorable amino acid composition. Nevertheless, one of the fundamental problems of legumes growing is strong reaction on deficit of precipitation in the phases of critical demand for water. Intercropping of cereals and grain legumes is a practice intended to stabilize yields and make better use of plant growth resources. Fertilization of the mixtures in order to provide the cereal component with nitrogen is the essential, because higher doses of nitrogen under legumes are not economically justifiable as they depress atmospheric N fixation by legumes and prolong the vegetation period. Pot experiment was conducted to evaluate utilization of nitrogen ^{15}N from fertilizers applied to field pea mixtures with wheat, barley and oats and its distribution to plant organs.

Method

Two-factorial pot experiments were carried on in 2010 and 2011 at the greenhouse in Experimental Station in Puławy, belonging to the Institute of Soil Science and Plant Cultivation, Poland. The Mitscherlich's pots were filled with 6,0 kg sandy loam soil mixed with 1,0 kg sand, supplemented with optimal rates of macro – and micro – nutrients. The experiment was set up in a completely randomized block design with three replications. Nitrogen fertilizers in the form of $^{15}NH_4{}^{15}NO_3$, (10 at% excess) was applied in the rates: 0,3, 0,6, 0,9, and 1,2 g N per pot, accordingly to cereal percentage in the mixtures: 33% (2 cereal plant + 4 pea plants), 57% (4 cereal plants + 3 pea plants), 75% (6 cereal plants + 2 pea plants), and 88% (8 cereal plants + 1 pea plant). Total amount of fertilizers was subdivided into 0.3 g N/pot doses of which the first was applied before sowing and subsequent rates after every 10 days. At maturity, aboveground biomass was harvested, separated into grain, rachis and glumes or pods, and straw (shoots and leaves). Roots were separated from soil. Plant organs were dried at 60°C and the dry matter was evaluated. Total nitrogen concentration in the plant samples, as well as ^{15}N analysis were performed by the means of Elemental Analyzer – Isotope Ratio Mass Spectrometer (EA-IRMS) in Department of Applied Analytical and Physical Chemistry, Isotope Bioscience Laboratory, Gent University in Belgium. Both, seed yields of cereal-pea mixtures and protein yields were evaluated. Total nitrogen uptake by the mixtures and by the cereal- and pea-components were calculated. Distribution of nitrogen from fertilizers and its allocation to particular plant organs were determined. Nitrogen recovery fraction (^{15}NRF) was calculated for each component of the mixtures regardless on seedling rate.

Results

The mean yields of pea with wheat reached 60 g, with barley 43,2 g, and with oats 53,9 g per pot. Yields of wheat – pea and oats – pea mixtures raised together with the increase of the percentage of cereals in the pot, and with barley was affected by a larger share of pea plants. As a literature shows, various species of cereals differ in the degree of dominance in mixed crops with pea. The most competitive is oats and wheat, and the less competitive is barley. Thus in the stand with barley, the proportion of pea seeds in the mixture was about 30% greater than its seedling rate.

There was a slightly increase in protein yield as the pea proportion raised in the pot. Protein yield of pea mixture with wheat reached 8,7 g per pot, and with oats and barley -7,8 g on the average.

Total nitrogen uptake was calculated as the sum of N uptake by cereal and pea components of the mixtures. The mixtures took up from 1,52 to 1,61 g N/pot, and nitrogen rate did not affect significantly this parameter. The greatest quantity of N accumulated the mixture with wheat and the smallest one – with oats. On the contrary, ^{15}N uptake was strongly related to the quantity of fertilizers applied to the pot. In the pot of 0,3 g

N nitrogen uptake reached 0,28 g on the average, which is to 92% of ^{15}N applied in fertilizers, and in the pot 1,2 g N – 0,88 g which is to 73%.

Of the total pool of nitrogen, the percentage of ^{15}N derived from fertilizers (*%Ndff*) was significantly higher in cereals as compared with pea. Regardless of the N dose and cereal component, pea stored the greatest quantity of ^{15}N in straw (stalks with leaves – 29% and roots – 28%), and only 16% in seeds. On the contrary, cereals translocated nitrogen from fertilizers mainly to ears, to grain - 57%, and to glumes with rachis – 47% on the average. Roots accumulated relatively large amount of ^{15}N - 46% of the total N. The percentage of ^{15}N found in wheat biomass amounted to 55%, in barley - 61%, and in oats – 64% of the total N. Irrespective of mineral N availability, pea plants accumulated in grain and straw from 15% to 19% of ^{15}N. ^{15}N recovery fraction (^{15}NRF) calculated for the whole cereal – pea mixtures was very high and reached 90%-96% for the lowest N rate to 73%-75% for the highest one. Pea component utilized 45% of nitrogen from the rate of 0,3 g N/pot on the average, and from the rate of 1,2 g N/pot about 9%.

Conclusions

1. Yields of pea mixtures with wheat and oats was determined by the percentage of cereal in the mixture, and with barley – by pea percentage.

2. Regardless of N dose, pea accumulated N from fertilizers mainly in straw and roots, and cereals in ears

3. The pea component utilized more N from fertilizers from the lowest N rate and cereals at the highest rate.

TEMPORAL FATE OF ^{15}N FROM LEAF-LABELED WHITE AND RED CLOVER IN MIXTURE WITH GRASS

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Objectives

Efficient utilization of nutrients in agricultural systems is essential in order to achieve a sustainable production of food. Increasing the N supply through biological nitrogen (N) fixation, e.g. from an increased proportion of legumes like white and red clover in forage production will decrease the demands for mineral N fertilization. In order to evaluate the impact of legume-derived N input to cropping systems in terms of efficiency we need, however, an improved understanding of how legume-fixed N cycles in the plant-soil system. Therefore, we need adequate field methods to determine the fate of legume N. The aim of the present study was to investigate the temporal fate of ^{15}N-urea added to white and red clover via the leaf-feeding method and trace ^{15}N from the clovers in soil and companion grass.

Method

Experiments were conducted in mixtures of ryegrass (*Lolium Perenne* L.) and white (*Trifolium repens* L.) or red clover (*Trifolium pretense* L.) on a sandy soil at Krusenberg estate, Uppsala, Sweden. The mixtures were established in May 2011 with five replicates in a randomized block design. The experiments were carried out from May to October 2012. Leaf-labeling of red and white clover with ^{15}N-urea [1] was done twice, in spring and autumn, during the growing season in 2012, with subsequent samplings lasting for two months after the labeling events. The ^{15}N-urea was applied to six randomly selected red clover or white clover plants within each block during four days, either from May 8th to11th (spring), or from September 9th to 13th (autumn).

Sampling of soil and labeled plants was done at day 1, 4, 7, 14, 28 and 56 after termination of the labeling periods. Sampling was done by inserting a steel cylinder (ø 15 cm) around the labeled plant to a depth of 15 cm. The excavated cores were separated to recover intact plants including their roots and stolons (white clover) connected to the shoots. After gently washing, the roots, shoots and stolons were separated and the root system of the clovers plants was divided into nodules, primary and secondary roots. Roots from the grass were kept as one pool. The soil was sieved through a 2-mm sieve to remove roots in order to obtain an almost "root-free" soil.

All samples were ground to a fine powder in a ball mill and analyzed for ^{15}N and total N at UC Davis stable Isotope facility. The ^{15}N enrichment (atom% ^{15}N excess) was calculated as the difference in atom% ^{15}N between labeled plants or soil and unlabeled control samples taken prior to the start of the experiments.

The rhizodeposition (% N derived from rhizodeposition - NdfR) was estimated by the Janzen and Bruinsma equation [2] and N transfer from donating red or white clover to companion ryegrass was estimated on the basis of ^{15}N-yield of donor and receiver plant tissues using a modified version of the equation by Høgh-Jensen and Schjoerring [3].

Results

In this experiment we wanted to follow the temporal change in tracer presence in specific pools: plant shoot and root tissues, and in soil. Hence, we sampled only root tissues attached to the shoot of the labeled plant and we removed roots from the soil by sieving to obtain an almost "root-free soil". Thus, we did not aim at recording the full mass balance of the added tracers.

Red clover in mixture with ryegrass yielded significantly ($P<0.001$) more dry matter than the white clover/

grass mixture especially in respect to greater leaf and primary root biomass. The dry matter yields of both clovers were significantly ($P<0.001$) greater in spring than in autumn. Likewise ryegrass yielded significantly ($P<0.001$) more dry matter in spring than autumn, and there was no significant difference in dry matter yield of ryegrass growing in mixture with red or white clover.

All sampled plant tissues and soil were enriched in ^{15}N already at day 1 after the end of labeling for both clover species for both the spring and autumn labeling. Red and white clovers shoot enrichments showed decreasing trends with time, whereas grass shoots after day 1 had a stable enrichment over the following two months. The ^{15}N enrichment of the root tissues of both clover species and their companion grasses were surprisingly stable with time, especially after the spring labeling. We estimated N transfer both on a leaf-to-leaf basis and on a whole plant basis, and found that these two estimates were quite similar. The grass shoot ^{15}N enrichments were fairly stable and dry matter yield only increased slightly with time in both spring and autumn, therefore the changes in estimated N transfer reflects the changes in ^{15}N yield in red and white clover, respectively. The estimated N transfer for red clover was stable with time and corresponded to 2-5% of N in red clover in both spring and autumn. White clover on the other hand showed increasing N transfer with time, increasing from 5 to 20% of N in white clover in both spring and autumn. These findings indicated that N transfer was a two-step process, consisting of a fast initial period (a few days) dominated by root exudation of ^{15}N, and a subsequent slower period (weeks to months) with deposition of ^{15}N from plant tissue; in case of white clover especially ^{15}N from shoots.

The estimated rhizodeposition corresponded to 1-5% of soil N with the initial deposition of ^{15}N until day 1 after labeling constituting the majority of the ^{15}N recovered in the soil pool. This underlines that using the Janzen and Bruinsma equenation to estimate rhizodeposition can involve significant bias [4].

Conclusions

The study showed that red and white clover deposition and transfer of N occurs in two phases after leaf-labeling with ^{15}N-urea, where the first short-term phase is dominated by root exudation and the second longer-term phase of N deposition dominated by the turnover of plant shoot and root tissues; with shoot tissues being particularly important for white clover.

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References

[1] J. Rasmussen, et. al., 2013, Soil Biology & Biochemistry 57, 654-662.
[2] H. H. Janzen, Y. Bruinsma, 1989, Soil Biology & Biochemistry 21, 189-196.
[3] H. Høgh-Jensen, J. K. Schjoerring, 2000, Plant and Soil 227, 171-183.
[4] J. Rasmussen, 2011, Soil Biology & Biochemistry 43, 2213-2214.

RECYCLING OF BIOGAS DIGESTATE IN AGRONOMIC PLANT PRODUCTION - NITROGEN FERTILIZER VALUE AND POSSIBLE NITRATE LEACHING.

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Objectives

The main objectives of this study are to explore the N fertilizer value, and the possible negative N leaching aspects of bio gas digestates when utilized in agronomic plant production.

Method

A pot experiment was carried out in a greenhouse with wheat (*Triticum aestivum L.*) as a test crop. The pots had a soil volume of approximately 6.7 L. Three different soil types, i.e. sand, silt and loam, were used as growth media. Texture, carbon and nutrient content in the different soils were determined. The treatments consisted of a control without any fertilization, mineral fertilization, fresh manure, and four digestate treatments: one with digested manure, one based on whey co-digested with manure, one with whey and fish ensilage co-digested with manure, and two based on source-separated organic household waste. The amounts of manure and digestate were adjusted based on their inorganic N content, to correspond to the N applied as mineral N fertilizer, i.e. 400 mg mineral N/pot. Manure and digestates were analysed for the essential macronutrients by ICP spectroscopy. Although the organic fertilizers varied in element composition, the experiment was balanced only with respect to mineral N (sum of ammonium (NH_4^+) and nitrate (NO_3^-)).

In order to analyse the risk of N leaching, the pots with soil were leached with 1 L distilled water just after harvest, and the leachate was analysed for NH_4^+ and NO_3^- concentration by flow injection analysis.

In addition, a soil leaching experiment without plants, with the same soils and treatments as used in the pot experiment, was carried out in the laboratory. Plexiglass columns of 24 mm in diameter and 30 cm in length were filled with 15 cm of the three soils. Prior to leaching, the soil columns were saturated with distilled water and then regularly irrigated with distilled water at a flow rate of 1.3 ml h^{-1} corresponding to 500 mm of precipitation during a 7 days period. The leachates were collected at the base of the column every day during the seven days. The NO_3^- and NH_4^+ concentrations were analyzed as described above.

Each treatment was replicated 3 times for each soil in both experiments. Treatment and soil effects were tested statistically by analysis of variance and differences were considered significant at $p<0.05$.

Results

In the sand, there was a positive effect of digestate and manure application on biomass production compared to mineral N-fertilizer, and the digestate based on whey and fish ensilage gave the highest biomass production. The digestate based on whey and fish ensilage had the lowest NH_4^+ concentration, but the highest total N content among the organic fertilizers. Since the digestate with the lowest NH_4^+ concentration gave the highest biomass production, some of the organic N might have been mineralized during the growth period. Due to the low NH_4^+ concentration the largest amount of digestate and thereby the highest amounts of phosphorus, potassium and magnesium were applied in this treatment. All the treatments included sufficient concentrations of the essential plant nutrients, and no deficiency symptoms were seen in any of the treatments. However, the positive effect on biomass growth might have been an effect of the high input of other macronutrients than N. No positive effect of organic fertilizers on biomass production was recorded in the loam and the silt soils. Among the organic fertilizers treatments, the lowest biomass production was observed in the loam. In the control without nutrients and the mineral fertilizer treatment, the biomass growth in sand and loam was similar and lower than in silt, while a clear positive effect of organic fertilizers were seen in sand.

Leaching after harvest showed that mineral fertilizer treatments in sand and loam resulted in elevated concentrations of mineral N in leachate. In the mineral fertilizer treatment the biomass growth in sand and loam was lower than in silt. The mineral fertilizer was apparently not fully utilized by the plants in these soils. In the loam, the low biomass production was probably caused by compactness. Compactness may restrict root growth and thus the ability of plant roots to reach mineral N during vegetative development when plant N demand is at its highest. Organic fertilizers were expected to have a positive effect on compactness and oxygen availability, but positive effects on biomass growth in the loam was not seen in this study. In the sand, a large part of the NH_4^+ given as mineral fertilizer may have been transported towards the bottom of the pot before an effective root system was developed. The amount of NO_3^- leached from the sand receiving manure or digestate was lower than in sand not receiving any fertilizer. Thus, in addition to the positive effect on biomass growth, organic fertilizer application seemed to have an inhibitory effect on NO_3^- leaching in sand. Nitrate leaching was particularly low from sand treated with digestate based on whey and fish ensilage.

The soil column leaching experiment also showed that organic fertilizer application may reduce NO_3^- leaching in sand.

Conclusions

Digestates generally had an N fertilizing effect similar to manure and similar or better than mineral N fertilizer. In the sand, the organic fertilizers had a positive effect on biomass production, particularly the digestate based on whey and fish ensilage. In the loam and silt, digestate application had the same effect on biomass production as manure and mineral N fertilizer.

In the sand, organic fertilizers reduced the NO_3^- leaching. In the experiment with leaching from the pots after harvest, NO_3^- leaching in sand was not only lower than in the mineral fertilizer treatment, but also lower than in the zero application treatment, indicating an effect of organic matter on sand NO_3^- leaching. In the loam and silt the leaching of NO_3^- were independent of treatments.

DO CATCH CROPS IMPROVE NITROGEN USE EFFICIENCY OF SILAGE MAIZE?

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Objectives

Silage maize production in north-western Europe is concentrated on coarse-textured soils and constrained by imbalances between nitrogen (N) fertilisation, N mineralisation and N uptake, leading to reduced apparent N recovery in the harvested biomass and N losses via denitrification and leaching [1]. Resilient crop production aims at maximum resource use efficiency via crop rotations to enhance nutrient recycling. For continuous silage maize, winter catch crops (CC) may enhance N recycling, if timely sowing allows rapid dry matter (DM) and N accumulation. However, this often is limited by unfavourable climatic conditions after maize harvest and mainly depends on harvest date. The present study analyses DM yields, mineral N fertiliser uptake and N use efficiency of silage maize harvested on successive harvest dates as well as the effect of the N accumulation of a rye CC (Secale cereale L.) on N use efficiency of a succeeding silage maize.

Method

The present study is based on a field experiment conducted between April 2012 and October 2014 at the experimental farm ‘Ostenfeld’, in northern Germany on a silty-sandy soil. The experimental setup comprised a main crop maize (MM), followed by winter catch crops (CC) and a subsequent maize (SM), organised in a 4-factorial randomised block design with three replications. Treatments comprised two years (each cycle on new field), two maize harvest/CC sowing dates (10 September (hd1) early maize cv. Suleyka and 30 September (hd3) mid-early cv. Ronaldinio), maize phase (MM and SM) and two CC treatments (rye cv. Protector and bare fallow (BF)). N fertiliser was applied shortly after maize sowing as calcium-ammonium-nitrate (CAN) to MM and SM (180 and 140 kg N ha-1), taking soil mineral N into consideration but not to unfertilized control. The plots were harvested by plot harvester and the N yield was determined (NIRS).
Above- (AGN) and belowground (BGN) N uptake of rye was determined in spring by cutting plants to ground level and applying the auger technique (depth: 30 cm).
Mineral fertiliser uptake efficiency of rye was quantified by 15N isotope-technique applied to MM on microplots (1.5 m²) as CAN mixed with labelled ammonium-nitrate (15NH415NO3, 2 at% enrichment). Labelled fertiliser N uptake (Ndff) represents the quotient of the differences between 15N concentration in labelled and unlabelled plants and fertilizer and unlabelled plants. The 15N uptake efficiency (FNUE15) was calculated as quotient between Ndff and applied 15N fertiliser amount [2].
Nitrogen uptake efficiency (NuptE) of MM and SM was calculated as the quotient of N yield and N fertilisation according to [3] and apparent N recovery (ANR) as the quotient of the difference between N yield of fertilised and unfertilized control and applied N amount. Analyses of variance were conducted using ‘R’ software. For MM yield and NuptE, year, harvest date and fertilisation were assumed fixed, while for SM year, harvest date and CC were included. For N yield, Ndff and FNUE15 of rye, year and plant part were considered fixed. Block was generally assumed random. Multiple comparisons of means were conducted by linear contrasts.

Results

The DM yield of MM was affected significantly by the interaction of year × harvest date ($p \leq 0.01$) and by N fertilisation ($p \leq 0.01$). In both years, delayed harvest (hd3: 15.6 t DM ha-1) resulted in up to 25% higher yield. The N yield was affected by year ($p \leq 0.05$) as well as N fertilisation ($p \leq 0.001$), but not by harvest date, with a significantly lower N yield in 2012 compared to 2013 (147 vs. 182 kg N ha-1). As expected, N fertilisation increased DM and N yield by 42% and 60%, respectively [4, 5]. NuptE and ANR were unaffected by year and harvest date and averaged 1.5 kg N kg-1 N fertiliser and 92%, respectively. The N uptake of rye in spring was influenced by year ($p \leq 0.001$) and plant part ($p \leq 0.001$), resulting in significantly lower BGN compared to AGN (20 vs. 31 kg N ha-1), without any sowing date effect. Due to contrasting climatic conditions during winter, the N accumulation was lower in spring 2013 compared to 2014, 27 vs. 74 kg N ha-1, respectively. Ndff and FNUE15 of rye were both affected significantly by year ($p \leq 0.05$) and sowing date ($p \leq 0.05$), with Ndff and FNUE15 of AGN and BGN being significantly lower in 2013 than 2014 (0.7-1.2 vs. 3.8-4.7 kg N ha-1) and (0.5-0.8 vs. 2.5-3%), respectively, without any differences between sowing dates. These FNUE15 values are slightly lower compared to [6] reporting 4.1% for Italian ryegrass sown after winter wheat.

For both, DM (20.1 t DM ha-1) and N yield (211 kg N ha-1) of SM ANOVA did not show any influence of the tested factors. The NuptE of SM, however, revealed a significant interaction of year × CC ($p \leq 0.01$), with a significantly higher NuptE in 2014 compared to 2013 (2.5 vs. 1.7 kg N kg-1 N fertiliser) averaged over CC treatments and a lower NuptE for rye than BF in 2014 (2.3 vs. 2.7 kg N kg-1 N fertiliser). When considering the N accumulation of rye as N input to SM, the NuptE showed the same interaction of year × CC ($p \leq 0.001$), but with a significant difference between rye and BF in both years (average: 1.3 vs. 2.2 kg N kg-1 N supply). This was explained by a lower soil mineral N in spring for rye than BF and consequently a higher N supply (BF: 98, rye: 160 kg N ha-1). Consequently, the ANR, with or without additional N supply of rye, revealed an interaction of year × CC species ($p \leq 0.05$), with BF outperforming rye in 2014 (124 vs. 83%). If adding the N supply of rye the difference increased to 124 vs. 64%.

Conclusions

Delaying the harvest of MM resulted in the expected increase of DM and N yield, whereas no reduction of N accumulation of rye CC was observed. The uptake of residual fertiliser N by rye was low, indicating that the majority of N uptake originated from mineralisation. Thus, N mineralised during late autumn/winter is largely protected against losses, which is beneficial for the environment. NuptE of SM being lower for rye than BF emphasises the importance of a better estimate of CC N release to the succeeding maize with respect to total amount and timing to optimise the N fertiliser amount.

References

[1] Velthof, G.L. et al., 2014. Science of the Total Environment 468-469, 1225-1233.
[2] Nannen, D.U. et al., 2011. Nutrient Cycling in Agroecosystems 89, 269-280.
[3] Moll, R.H. et al., 1981. Journal Series NC Agric. Res. Service No. 6842.
[4] Masters, M.A. et al., 2016. Agriculture, Ecosystems and Environment 216, 51-60.
[5] Merbach, W. et al., 2013. Archives of Agronomy 59, 1069-1071.
[6] Martinez, J., Guiraud, G. 1990. Journal of Soil Science 41, 5-16.

N_2O FLUXES AND MINERAL N DYNAMICS FOLLOWING GRASSLAND RENEWAL TECHNIQUES AND GRASSLAND CONVERSION TO ARABLE LAND

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Objectives

Grassland renewal and grassland conversion to arable land are common agricultural practices on intensively used grassland sites in order to eliminate sward and soil disturbances and establish high-quality grass types. It is known that renovation can cause a flush of soil organic nitrogen mineralization due to soil disturbance during associated soil tillage [1;2] and decomposition of stubbles and roots from the old grass sward. Knowledge about enhanced nitrous oxide emissions (N_2O) and N leaching losses associated with renovation practices is scarce, although global climate change mitigation and water protection policies force countries to deal with this problem.

The aim of our study is to determine the impact of grassland renewal techniques and conversion of grassland to arable land on N_2O fluxes and mineral N dynamics at two sites with differing soil texture and to evaluate the effect on yield and N use efficiency.

Method

We set up a randomized field block trial near Oldenburg (Lower-Saxony, Germany), using two different soil types with varying C-contents and different drainage regimes (Histic Gleysol and Plaggic Anthrosol) with the following treatments: renovation through (i) reseeding, (ii) chemical killing and grass seeding, (iii) chemical killing, sward destruction by rotovating, ploughing and grass seeding. Reference treatments were (iv) conversion to arable land for maize cropping and (v) permanent grassland. N_2O fluxes were measured weekly using closed chambers. The relationship between N_2O fluxes and explanatory/controlling variables was investigated using generalized additive models (GAM). Potential N-losses via NO_3^- leaching were quantified by measuring weekly soil mineral N in the top soil (0 to 30 cm) and in depth profiles (0 to 90 cm) in spring and autumn. N removal by harvested biomass was quantified by determining its dry matter and analysing the N content. To identify processes of N_2O production and consumption, stable isotope analyses of emitted N_2O, soil water and soil NO_3^- were carried out on selected dates and supported by a ^{15}N tracing experiment to determine N losses via N_2.

Results

Following grassland renewal, N_2O fluxes from the Histic Gleysol (high organic matter content and mostly high moisture) increased to > 1 kg N ha^{-1} day^{-1}, whereas N_2O fluxes from the Plaggic Anthrosol (with sandy texture, exhibiting low organic matter content and mostly low moisture) were on a significantly lower level, ranging between 0 and 0.05 kg N ha^{-1} day^{-1}. In contrast to the site specific variation between the two soils, the mean annual N_2O emissions were not significantly different between the investigated grassland renewal techniques and continuous grassland. This is in contrast to other studies, who found large N_2O emissions following grassland renewal [1;2;3;4;5]. Moreover grassland conversion for maize cropping did not increase N_2O fluxes on the Histic Gleysol, but did result in large N losses via N_2 (52.46±31.47 kg N ha^{-1}) within the first 6 weeks. This means gaseous N losses via denitrification were highly relevant on this site. In contrast, N_2O fluxes from the Plaggic Anthrosol showed distinct N_2O emissions of 2.93±0.35 kg N ha^{-1} within the first maize cultivation period. Whereas gaseous losses from the Plaggic Anthrosol were relatively low, greater mineralization/nitrification, indicated a higher risk for leaching of excess mineral N following conversion/renewal. This was confirmed by potential N-leaching losses of 100 kg N ha^{-1} in the Chemical (ii) and Mechanical (iii) treatments over the first winter. Large leaching losses in the first year after grassland renewal have also been reported [1;6]. Moreover, the supposed yield effect could not be stated either, as dry matter yield and N plant content did not differ significantly between the different treatments.

Conclusions

Overall, the different grassland renewal techniques and grassland conversion for maize cropping had a lower impact on N_2O emissions at the two investigated sites, than previously expected, but site-specific effects have to be considered. Since high denitrification losses via N_2 were observed in the Histic Gleysol, this might have masked the presumed increase of mineralization due to grassland ploughing. Moreover, we could confirm the negative impact of grassland ploughing during fall for the N budget of grassland systems since potential N-losses via N-leaching substantially increased, especially in the Plaggic Anthrosol.

Acknowledgements

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References

[1] Velthof, G. et al., 2010. Nutrient Cycling in Agroecosystems 86(3): 401-412.

[2] Davies, M. et al., 2001. Biology and Fertility of Soils 33, 423-434.

[3] MacDonald, J. et al., 2011. Soil and Tillage Research 111, 123-132.

[4] Merbold, L. et al., 2014. Global Change Biology 20, 1913-1928.

[5] Mori, A. and Hojito, M., 2007. Soil Science and Plant Nutrition 53, 812-818.

[6] Seidel, K. et al., 2009. Journal of Plant Nutrition and Soil Science 172, 512-519.

EARLY SOWING ENHANCES GRAIN YIELDS AND N USE EFFICIENCY IN WINTER WHEAT

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Objectives

Increasing the Nitrogen Use Efficiency (NUE) in agricultural systems is essential to provide high yields while reducing pollution. Designing an N efficient cropping system requires adjustment of agronomic components such as: crop rotation, variety selection, sowing time, tillage, N fertilizer sources, and time of fertilizer application. A field experiment with winter wheat was conducted to evaluate if early sowing can enhance crop yields, reduce soil mineral N (SMN) during autumn and winter, and increase crop N uptake. The objectives were to: (i) test if sowing one month earlier than normal will increase NUE, and (ii) determine variety effect on winter wheat yield and NUE.

Method

The experiment was embedded in The Askov Long-Term Experiment on Animal Manure and Mineral Fertilizers with a history of 120 years of continuous application of either animal manure (AM) or mineral fertilizer (NPK). A split-split-plot design was used with three replicates. The main plot treatments were the long-term nutrient treatments: Unmanured, 1 AM, 1 ½ AM, 1 NPK, 1 ½ NPK; where 1 AM and 1 NPK in winter wheat are equivalent to 150 kg N ha^{-1} , 30 kg P ha^{-1} and 120 kg K ha^{-1} . In the autumn 2014, each main plot was divided into four sub-plots with two sowing times (early sowing: August 20, and normal sowing: September 18) and two winter wheat varieties Hereford (Sygenta, Switzerland) and Mariboss (Nordic seeds, Denmark).

Soil mineral nitrogen (N-NO_3^- and N-NH_4^+) was determined on four occasions: before early sowing (August 18), after normal sowing (September 17), before entering winter (November 20), and in early spring (March 18). The samples collected in the field were frozen (-18 ^{o}C). Upon analysis soil was left overnight at 4^{o}C and sieved (2 mm). A 15 g subsample was used to determine mineral N by extraction with 1 M KCl (1:2 w/w), shaking for 1 hour and filtering through a 0.7 µm glass fiber filter (Toyo Roshi Kaisha, Ltd, Japan). The filtrates were analyzed colorimetrically for N-NO_3^- and N-NH_4^+ using a Bran+Luebbe Autoanalyzer 3 (Seal Analytical, Nordestedt, Germany). The values were expressed as mg N kg^{-1} dry soil.

N uptake was determined in six cuts of plant samples that were taken every month from October 2014 until March 2015 (October 25, 2014; November 20, 2014; December 8, 2014; January 6, 2015; February 16, 2015; March 17, 2015). Every sample was taken from 0.9 m of row. Samples were dried, milled and analyzed for total N. The amount of ash was discounted from the dry matter content. The values were expressed as kg N ha^{-1}. On August 20, 2015 grain yield was determined using a combine harvester. Grain was dried for 80 ^{o}C minimum 18 hours. Grain yields are reported at 85% dry matter.

Results

NUE can be defined as the relation between unit of food or feed produced per unit of N fertilizer applied [1] hence, a higher biomass or grain yield with the same or lower N application rates represents a higher efficiency. We investigated the potential of early sowing to increase yields and N uptake while reducing SMN in the autumn-winter period. In general, it was a good season for wheat in terms of precipitation but there were low temperatures especially at the end of the season that delayed harvesting. Early sown wheat had 1.1 Mg ha^{-1} higher grain yield compared with normal sown wheat (9 vs 7.9 Mg ha^{-1}). Myrbeck et al (2012) also reported a yield increase in favor of early sown wheat in Southern Sweden in a study conducted from 2007 to 2010. [2].

The two varieties tested also showed significant differences. Hereford had higher yield than Mariboss ($p<0.001$). On average, Hereford provided 0.7 Mg ha^{-1} more grain than Mariboss (8.8 vs 8.1 Mg ha^{-1}). The difference between Hereford and Mariboss was related to long-term treatments since Hereford is more productive under 1 ½ NPK and 1 NPK compared to Mariboss. Rasmussen et al. (2015) found higher yield for Hereford compared with the modern varieties Cordiale, Genius and JB Asano. The authors attributed the higher yield of Hereford with a deep root system that can reach up to 1.7 m which was around 0.3 m deeper than other varieties. The authors found significantly less SMN under this variety compared to other varieties [3].

N uptake in the wheat during autumn and winter showed a significant difference between early sowing and normal sowing (20 vs 8 kg N ha^{-1}). There was a significant interaction for the sowing time and time of plant sampling. The greatest difference between early and normal sowing was found in December and January with around 16 kg N ha^{-1}. The N uptake depended as well on variety and time of cut. In general, Hereford had higher uptake than Mariboss (14 vs 11 kg N ha^{-1}) ($p<0.001$). The Agronomic efficiency (AE) as a measure of NUE was determined for grain yield. The results show that NPK had a higher AE compared with AM and Hereford had a higher AE compared to Mariboss.

SMN differed depending on the sowing time and the time of sampling. SMN showed the greatest difference at the September sampling with 2 mg N kg^{-1} of dry soil less for early than for normal sown wheat: representing around 6 kg N ha^{-1} (assuming a 1.5 g cm^{-3} bulk density). Hence, the greater N uptake and lower SMN in autumn could reduce the risk of N leaching under the early sown wheat.

Conclusions

This experiment showed higher grain yield of early than of normal sown winter wheat. Early sown wheat had higher N uptake during autumn and winter compared to normal sown wheat. The higher yield in early sowing can be explained in part by a higher N uptake during autumn and early spring and provided a significant decrease in SMN under normal sowing at the September sampling time. Hereford was a better variety for the year 2014/2015 with 0.7 Mg ha^{-1} more grain than Mariboss.

There were significant differences on N uptake due to sowing time. On average, early sowing had a significant higher uptake than normal sowing followed by a significant decrease in soil mineral N.

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References

[1] Dobermann, A. 2005. Agronomy & Horticulture Faculty Publications. Paper 316.

[2] Myrbeck, Å. Et al., 2012. Soil and Tillage Research 120: 25-31.

[3] Rasmussen, I.S. et al., 2015. European Journal of Agronomy 68: 38-49.

EFFECT OF APPLICATION AND NITRIFICATION INHIBITORS ON TRACE GAS FLUXES FROM A MAIZE FIELD AFTER CATTLE SLURRY AMENDMENT

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Objectives

Efficient use of organic N-fertilizers is a main global challenge. Strategies reducing gaseous N losses after application of organic fertilizers are still required.
Injection or incorporation of slurry efficiently reduces ammonia losses and thereby increases N efficiency in agricultural systems. On the other hand, slurry injection was shown to enhance N_2O emissions due to the creation of anaerobic conditions favoring denitrification in the injection slot [2].
The use of nitrification inhibitors (NI) is a technique which can improve N fertilizer use efficiency by retarding the oxidation of ammonium.
The main aim of our study was to test the applicability of two NIs to reduce N_2O emissions from a maize field by desynchronizing carbon availability in the injection slot and NO_3^- release from nitrification of the slurry ammonium. We further tested the effect of different application techniques on N_2O and CH_4 fluxes after slurry amendment.

Method

The study was conducted on the University Hohenheim research farm Heidfeldhof, 13 km south of Stuttgart (410 m asl). The mean annual precipitation in this region is 686 mm and the mean annual temperature 8.8°C. Soil type was a Haplic Luvisol derived from periglacial loess. The soil texture of the stone-free top soil consisted of 2% sand, 68% silt, and 30% clay [3].

We established a fully randomized block experiment with ten treatments and four replicates. Here we present results of the following treatments: (1) unfertilized control, (2) mineral N, (3) cattle slurry surface applied and incorporated immediately after application, (4) cattle slurry injected, (5) cattle slurry injected with NI 3,4-dimethylepyrazole phosphate (DMPP), and (6) cattle slurry injected with NI dicyandiamide (DCD).

N-fertilizers were applied in two doses. The first dose of 133 kg N ha^{-1} was applied on 10th May. Injection depth of the slurry was 10 cm. The second dose of 37 kg N ha^{-1} was applied on 12th June. The second dose of treatments 3-6 was surface applied with a trail shoe in order to avoid damages of the growing maize plants. NIs were only applied with the first N dose in treatments 5 and 6. Maize (variety *'Amadeo'*) was sown mid May 2015 (12.700 plant ha-1) and harvested at the end of August.

N_2O and CH_4 trace gas fluxes were measured between April and December 2015 at least once a week using a closed chamber method. Chambers design, gas sampling procedure, and determination of the gas concentrations in the samples was described in detail by [3]. Gas flux rates were calculated using an R-script (Roland Fuss, 2015, Thünen Institut Braunschweig).

Simultaneously to the gas sampling we measured the soil temperature and took soil samples and determined mineral N and soil moisture to parameterize the trace gas fluxes.

Results

The N_2O emissions during our investigation did not differ significantly between the unfertilized treatment, the slurry surface application with subsequent incorporation, and the mineral N treatment (2.53 to 3.58 kg N^2O-N ha^{-1}).

In contrast, slurry injection strongly increased the N_2O emissions during this period. N_2O emission from the slurry injection treatment without NI was 14.06 kg N_2O-N ha^{-1}. The addition of both NIs did not significantly reduce the N_2O emissions compared to the injection treatment without NI. With 14.58 kg N_2O-N ha^{-1}, the treatment with DCD showed the highest emission in this investigation within the whole experiment. Application of DMPP reduced the mean N_2O emission by 18%.

In the period between the two slurry applications, NIs significantly reduced the cumulative N_2O emission (DMPP: 25%; DCD: 19%). The magnitude of reduction was in agreement with the values reported by [4]. As compared to the DMPP treatment, the higher N_2O emission in the DCD treatment might have been a result of different chemical and physical NI characteristics. Similar results have been reported by [5]. when testing DCD and DMPP with mineral N-fertilizers, they found a faster mineralization of DCD and thus a lower N_2O reduction after N-fertilization.

After the second fertilization, which did not differ among the slurry treatments (all surface applied and all without NI), the N_2O fluxes from the NI treatments increased stronger than in the injection treatment without NI. This can be attributed to the higher NO_3^- contents in the treatments with NIs during this period, which was probably a result of the delay of nitrification.

A stepwise regression exhibited a strong positive correlation between N_2O flux rates and soil water content, NO_3^- availability and CO_2 emissions which clearly indicates (heterotrophic) denitrification as the main process for N_2O production.

Soil generally served as a net CH_4 sink. The CH_4 flux uptake in the control, surface applied and incorporated, and the mineral N treatment varied between -0,35 and -0,58 kg CH_4-C ha^{-1}. This indicates that the effect of volatilization of dissolved CH_4 produced during slurry storage was negligible.

In contrast, slurry injection stimulated CH_4 production due to the creation of anaerobic conditions as reported by [2]. Highest emission was measured in the injection treatment without NI (6,81 kg CH_4-C ha^{-1}). Application of NIs significantly reduced CH_4 emission (DMPP: 42 %; DCD: 47 %). The reason for this reduction remains unclear and will be focus of further research.

Conclusions

Organic fertilizers like slurry are important nutrient sources and the efficient and environmental friendly use of these nutrients must be a main aim in agricultural production.
There is no doubt, that ammonia volatilization can be avoided best when slurry is incorporated into soil. On the other hand it has been shown frequently, that slurry injection can increase N_2O emissions. In our study, nitrification inhibitors decreased the N_2O emission directly after slurry injection and tended to decrease the cumulative N_2O emission covering an 8 months measurement period.
Significantly lower N_2O emissions were measured, when slurry was applied on the soil surface and subsequently incorporated. However, this application technique needs a further individual operation and it holds the risk of increasing ammonia losses as long as the slurry is not incorporated. Since ammonia losses also contribute to climate change by fertilization of natural ecosystems, further investigations on slurry application have to include N_2O and NH_3 flux measurements.

References

[1] Flessa, H., Beese, F. 1999. Journal of Environmental Quality, 262-268.
[2] Flessa, H. et al., 1995. J. Geophys. Res., 23115 - 23124.
[3] Pfab, H. et al., 2011. J. Plant Nutr. Soil Sci., 545-553.
[4] Ruser, R., Schulz, R. 2015. J. Plant Nutr. Soil Sci., 171-188.
[5] Weiske, A. et al., 2001. Nutr. Cycl. Agroecosyst., 57-64.

N_2O EMISSIONS AFTER OILSEED RAPE RESIDUE INCORPORATION AS AFFECTED BY SOIL TILLAGE

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Objectives

Oilseed rape (*Brassica napus* L.) is a prominent oilseed crop in the northern part of Europe. Production of oilseed rape has increased in Germany during the last decades due to its economic and ecological importance towards biodiesel production. Winter oilseed rape is known for its elevated nitrogen demand during early growth stages and a low nitrogen use efficiency resulting in high N surpluses and possible gaseous or leaching losses [1]. Furthermore the crop residues of oilseed rape are suspected to cause high N_2O emissions in the following crop. In this experiment, the fate of ^{15}N labelled rape residue was studied during autumn under field conditions. The main objective of this study was to quantify the effect of post-harvest rape crop residues incorporation at two tillage depths on N_2O emissions and on the direct contribution of the residue bound N to the N_2O fluxes.

Method

Preparation of ^{15}N labelled crop residues

Winter oilseed rape (var. Visby) was planted at BBCH 3 into planting pots. ^{15}N labelled potassium nitrate (60 atom % ^{15}N) was used as N-fertilizer. Similar to the field experiment, the fertilizer amount used for labelling was 180 kg N ha^{-1}. The final average ^{15}N abundance of the crop residue (CR) was 14.42 atom%.

Field experiment

This study was conducted on a Luvisol at the research station Ihinger Hof, South Germany as part of a block experiment (Split-Plot-Design, n = 4). Before the application of the crop residues, rapeseed was grown and harvested on 23. July 2014. The ^{15}N labeled crop residues were applied end of July and incorporated at the end of September. The total crop residue application rate per mini plot was 455 g (C:N 49,7; total N-amount 121,5 kg N ha^{-1}). In the period between application and incorporation, the residues were covered with a plastic net. On 13. October, winter wheat (var. Julius) was sown.

Four treatments were investigated: (1) Shallow tillage with CR (15 cm), (2) shallow tillage without CR, (3) conventional tillage with CR (30 cm), and (4) conventional tillage without CR. Mini plots (0.3 m²) were established in the regular experimental plots. The mini plots were cleared stubble free and roots of the rape were removed in all treatments in the first 30 cm. Labelled crop residues were mulched on the surface of the +CR treatments, control plots without any crop residues were established too. According to the regular tillage praxis, tillage in the mini plots was simulated.

Trace gas measurement started one week after field preparation. Trace gas fluxes of N_2O, ^{15}N-N_2O, and CO_2 were measured at least once a week with additional event driven samplings. Closed chambers used for flux measurements and a similar GC-configuration used for the determination of the trace gas concentrations in the gas samples as described in detail earlier [2]. ^{15}N abundance in N_2O was analyzed using a GC-IRMS.

Results

Following harvest of the rape crop and several weeks without rainfall, N_2O fluxes increased after heavy rainfall events. N_2O emission in the period between application and incorporation of the crop residues was 960 and 878 g N_2O-N ha^{-1} 61 $days^{-1}$ for the +CR and the –CR plots, respectively. This difference was statistically significant for the first three weeks after application ($p < 0.05$).

Such a rise in the N_2O fluxes after rewetting of dry soil has often been reported [3]. Stimulated N_2O emissions after crop residue application has also been frequently observed [4]. The residues provide easily available labile carbon as a nutrient substrate which in turn can increase the microbial activity in the soil. Rapid oxygen consumption by microbes during turnover of easily available C can result in a strong decrease of the redox potential [5] and thus favoring conditions for denitrification [6].

After this initial pulse, N_2O fluxes from the +CR treatment declined below the fluxes measured on the –CR plots. We attributed this phenomenon to the broad C-to-N-ratio of the crop residues (52) and to the resulting immobilization of nitrate [7] acting as a source for N_2O production in soil.

Immobilization may also be the reason for the low portion of crop residue bound N to the total N_2O emission between application and incorporation (6.5 %).

After tillage, N_2O fluxes declined strongly. The cumulative N_2O emission between tillage and the end of our measurements varied between 132 and 271 g N_2O-N ha^{-1} 62 day^{-1}. This decline was attributed to aeration of the soil due to tillage and to the exceptional low rainfall in this period.

In the period after tillage, N_2O emissions from the shallow treatments were higher than the emissions from the conventional tillage treatment with a deeper incorporation. This could be a result of increased C-turnover in the topsoil of then shallow treatment due to the higher concentration of easily available C.

The direct share of crop residue bound N to N_2O emissions was again low. It accounted for only 2.0 % in the conventional tillage treatment and for 1.8 % in the shallow tillage treatment.

Conclusions

Increase in greenhouse gas fluxes are often observed after crop residue application during incubation or field trials. However in our field study, postharvest N_2O emission from winter rape crop residues was low and not significant higher than treatments without crop residues. Due to the high C-to-N ratio present in the crop residues, there was an immobilization of mineral N. Therefore the N losses through postharvest crop residue application play just a minor role in the total reactive N losses during rapeseed cultivation. Consequently, the N-fertilizer not taken up by the plants or N released in the field by humus is of greater importance. Although for short period, significantly higher N_2O emissions from shallow tillage as compared with conventional tillage were observed. These additional N_2O emissions should be considered while accounting for greenhouse gas emissions.

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References

[1] Rathke et al., 2006. Agriculture, Ecosystems & Environment, 117, 80–108.
[2] Flessa et al., 1995. Journal of Geophysical Research, 100, 23115–23124.
[3] Ruser et al., 2005. Soil Biol. Biochem., 38, 263-274.
[4] Baggs et al., 2003. Plant and Soil, 254, 361–370.
[5] Flessa and Beese, 1995. Soil Science Society of America Journal, 59, 1044–1051.
[6] Miller et al., 2008. Soil Biol. Biochem., 40, 2553-2562.
[7] Chen et al., 2013. Global Change Biology, 19, 2956–2964.

LAND USE RELATED INTERVENTIONS ON THE NITROGEN CYCLE - A CASE STUDY OF THE UPPER ENNS VALLEY, A LONG-TERM SOCIO-ECONOMIC AND ECOSYSTEM RESEARCH REGION IN AUSTRIA

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Objectives

In this paper we investigate i) the flows of reactive N under present conditions and ii) potential alternative opportunities aimed to improve nitrogen use efficiency. Natural conditions, such as climate and soil, are typically characterized by high spatial variability and uncertainties in their future fate. Many techniques to estimate environmental consequences are proposed, but too often, cross-links and trade-offs are ignored.

In this paper, we apply a biophysical soil model in order to i) assess future scenarios under different conditions of land use and ii) to provide stocks and biosphere-atmosphere-hydrosphere fluxes of N to an external decision-making module performed by an autonomous agent approach.

We select a landscape level for a well-investigated study region, which is part of an Austrian Long-Term Socio-economic and Ecosystem Research (LTSER) region. Interventions aimed at optimizing nitrogen use efficiency and closing nutrient cycles are tested, and land use related consequences are identified.

Method

The study region, the Upper Enns Valley, covers about 23 000 ha grassland and alpine pastures and about 8 000 ha arable land. Forest (about 76 000 ha) has not been dealt with in this study. The most recent version of the DeNitrification-DeComposition (DNDC) model, LandscapeDNDC, Version 0.36.4 [1] a process model for simulation of biosphere-atmosphere-hydrosphere exchange processes is used to estimate land-use related N emissions in the selected study region. For a comprehensive regional emission inventory, Homogeneous Spatial Mapping Units (HSMUs) are identified ranging between 1 and 1400 ha. Spatial explicit data is processed with ArcGIS 10.2. In the following, datasets used to build the HSMUs are described.

Area-specific accounts of crops and animal husbandry have been obtained from a data base generated by a European integrated administration and control system (IACS). The system has been established to provide background information on agricultural subsidies. In Austria, this system is known under the acronym INVECOS. Spatial land-use categorization splits grassland areas into i) alpine forage areas, ii) permanent and common pastures, iii) hay meadows cut once or twice a year and iv) hay meadows with three- or more cuts. For arable land, typical regional crop rotations are considered for the simulation.

Soil data was retrieved from the digital soil map of Austria (http://www.bodenkarte.at/) developed by the Austrian Federal Research Centre for Forests (BFW). The most crucial soil parameters to N emissions and plant growth i) texture, ii) soil pH and iii) humus content, were intersected to differentiate between relevant variations in soil type.

Information on temperature and precipitation is available on a daily base, on a 10 x 10 km grid. The regionalized and bias-corrected climate scenario datasets have been developed within a national project (reclip:century - see http://www.klimawandelanpassung.at/ms/klimawandelanpassung/de/kwa_news/kwa_forschung/kwa_reclip/). Slope and aspect are also considered relevant topics to further separate distinct HSMUs, for which we used a freely available digital surface model of Austria (http://www.oe3d.at/).

Results

Model results allow to assess the flows of nitrate and nitrous oxide emissions as well as the flows of ammonia, nitrogen oxide and molecular dinitrogen. Thus a full nitrogen balance of the respective agricultural good under selected conditions can be calculated. Nitrogen-use efficiency in terms of emissions per produced unit of agricultural good is established and management strategies with at least the lowest environmental costs compared to agricultural productivity are identified.

The scenario analysis of the arable region show emission factors and yield-based emission factors depending on i) different crop rotations, ii) the rate of slurry application, iii) the integration of legumes, such as soy beans, into the crop rotation, and iv) the use of slow-release fertilisers.

The grassland scenario analysis shows differences of emission release concerning i) changes in animal stocking rates, ii) inorganic N fertiliser addition, iii) slurry application rates, iv) changing areas of extensive and intensive grasslands, and v) the conversion of grassland into forest.

About 91 % of the reported arable land and about 62 % of reported grassland is represented by the model results. Soil information is the limiting factor, where for 97 % of arable land and for 74 % of grassland adequate soil information is available. Soil types representing less than 1 % of the considered agricultural area are neglected. For grassland, 1459 ha of the area is excluded. This concerns areas where grassland management is not specified, as well as areas, where biomass is not grazed or harvested for animal husbandry or nutritional purposes (e.g. christmas tree plantations, or land which is no longer used for production purposes, but maintained in good agricultural and environmental conditions).

Since multiple processes and drivers are involved, especially N2O emissions are highly variable and often associated with “hotspots” (high emissions from small areas) and “hot moments” (high emissions for brief periods) and often discussed as a non-linear response function. The range of emission factors, as well as hotspots and hot moments of N emissions in the examined study region will be presented and discussed in terms of prevention and mitigation options.

Conclusions

The current study demonstrates that local natural conditions determine whether a management change may have stronger effects to yields than to emissions, or whether the opposite reaction occurs. This is still very relevant as emissions per produced unit (as emission footprints) deserve consideration. However, management activities highly depend on human decision. In a further step, motivations and willingness of farmers for management change is explored by the ALISEN (Analysing LInkages of SocioEcological Nitrogen flows) project, aiming to couple an agent-based modeling to the presented stock and flow modeling approach - able to assess impacts of changing management on the N cycle quantitatively.

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References

[1] Haas, E. et al., 2012. Landscape Ecology, 28, 615-636.

SOIL NITROUS OXIDE (N_2O) EMISSIONS IN SPRINKLER CORN (*ZEA MAYS* L.): INFLUENCE OF IRRIGATION TIME AND FREQUENCY.

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Objectives

Agricultural soils are the primary anthropogenic source of N_2O [1]. Likewise, N_2O has 265 times the global warming potential of CO_2 [2]and it is mainly produced via microbial transformations of inorganic N through nitrification and denitrification processes. The understanding of the relationships between soil N_2O emissions and soil management practices, (e.g., tillage, irrigation and fertilization) are necessary to develop best agricultural practices for reducing N_2O emissions. Several studies have assessed the effects of tillage and fertilization on N_2O emission [3], but just few of them have been conducted to evaluate the influence of irrigation management. The objective of this study was to assess the impact of irrigation management on soil N_2O emissions. In particular, the effect of irrigation frequency (i.e., high frequency *vs*. low frequency) and the time of irrigation (i.e., daytime *vs*. nighttime) on soil N_2O emissions were compared during the growing season of a continuous corn crop.

Method

The field experiment was conducted at the experimental farm of the Estación Experimental de Aula Dei in Zaragoza (NE Spain). The experimental layout was a randomized factorial design with three replicates per treatment. The plot size was 18 m x 18 m.

Two factors were compared: (i) irrigation frequency with two levels: high frequency (H), consisting of daily irrigation, and low frequency (L), with irrigation twice a week; and (ii) irrigation time with two levels: daytime (D) with irrigation starting after 10:00 GTM; and nighttime (N) with irrigation starting after 22:00 GTM. The combination of the two factors resulted in the following four treatments: DH (Daytime, High frequency), DL (Daytime, Low frequency), NH (Nighttime, High frequency), NL (Nighttime, Low frequency). All received the same tillage operations, (i.e., subsoiling and disking) and two fertilizer applications: 800 kg ha^{-1} NPK (8-15-15) on 9 April 2015 and 100 kg ha^{-1} N-32% solution on 15 June 2015. Irrigation was applied with sprinklers according to the crop water requirement. Each irrigation event lasted for a minimum of 1 hour (5 mm) and a total of 604 mm of irrigation water was applied at all plots during the growing season.

From April to September 2015, N_2O emissions were measured weekly till August, and every three weeks from late August to harvest (9 October 2015). The sampling frequency was increased following the N fertilizer applications. Gas samples were collected by placing PVC chambers of 32.4 L over permanent collars and collecting gas samples from the chamber headspace through a rubber septum at regular intervals of 0, 20 and 40 min after deployment. Concentration of N_2O in the gas samples was determined using a gas chromatograph (Agilent Technologies 7890B GC System). For each N_2O sampling date, moisture content (water-filled pore space, WFPS) at 5 cm depth was also measured. Harvest was done mechanically for each plot using a combine (New Holland CX8040) and taking by hand a subsample to determine the total biomass and yield components.

Results

Seasonal N_2O emissions kept steady and low before N fertilizer applications. However, 24 hours after N-32% solution application, N_2O emissions increased from average values near 0 to values about 200 g N_2O-N ha^{-1} day^{-1}, thereafter N_2O emissions decreased quickly during the rest of the sampling period. The highest peak of N_2O emission occurred on 16 June 2015, the day after N application with the irrigation water. This peak event represented approximately 25% - 30% of the total N_2O emissions measured throughout the entire growing season.

In seven sampling dates, nighttime irrigation resulted in higher N_2O emissions compared to daytime irrigation. Furthermore, the seasonal cumulative N_2O emission was also significantly greater in nighttime irrigation (3.42 kg N_2O-N ha^{-1}) compared to daytime irrigation (1.97 kg N_2O-N ha^{-1}). However, the frequency of irrigation did not affect soil N_2O emissions in any sampling date. At the same time, the seasonal cumulative N_2O emission was similar between low frequency irrigation (2.40 kg N_2O-N ha^{-1}) and high frequency irrigation (2.98 kg N_2O-N ha^{-1}). In only two sampling dates (28 July 2015 and 8 September 2015) there was an interaction between the two factors with greater soil N_2O emissions in the nighttime-high frequency treatment compared to the other three treatments.

Differences in soil N_2O emissions observed could be related with the different soil water content among treatments [4, 5]. Thus, the WFPS (0-5 cm soil depth) in the nighttime irrigation plots was significantly higher than in the daytime irrigation plots.

Corn grain yield was affected by the interaction of the irrigation time and frequency. The daytime-high frequency showed significantly lower grain yield compared to the other three treatments.

Yield-scaled emissions (expressed as N_2O-N emitted per tonne of grain yield) were in the range of 146 to 270 g N_2O-N Mg^{-1} grain, similar to the values reported in similar experiments [6, 7]. Yield-scaled emissions were significantly affected by the time of irrigation with greater values in the nighttime treatment (226 g N_2O-N Mg^{-1} grain) compared to the daytime treatment (150 g N_2O-N Mg^{-1} grain). The frequency of irrigation did not affect yield-scaled emissions.

Conclusions

During the growing season, soil N_2O emissions were affected by sprinkler irrigation management. Nighttime irrigation resulted in greater N_2O emission than daytime irrigation due to differences in soil water content between treatments. Although irrigation frequency did not affect N_2O emissions, it affected grain yield. Yield scaled emissions of N_2O were greater in nighttime compared to daytime irrigation, even though the highest corn yield obtained in nighttime irrigation. This research suggested the relevance of irrigation management to control soil N_2O emissions.

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References

[1] Bouwman, A., et al. 2001. Food and Agriculture Organization of the United Nations, Rome, Italy

[2] Deng, Q., et al. 2015. Plos One 10, 14.

[3] Linquist, B., et al. 2012. Global Change Biology 18, 194-209.

[4] Abalos, D., et al. 2014. Science of the Total Environment 490, 880-888.

[5] Aguilera, E., et al. 2013. Agriculture Ecosystems & Environment 164, 32-52.

[6] Halvorson, A.D., et al. 2010. Journal of Environmental Quality 39, 1554-1562.

[7] Venterea, R.T., et al. 2011. Journal of Environmental Quality 40, 1521-1531

QUANTIFICATION OF N-RHIZODEPOSITION OF PEAS UNDER FIELD CONDITIONS

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Objectives

Quantification of the C- and N-rhizodeposition under field conditions is difficult as labelling plants with stable or radioactive isotopes and separating labelled and unlabelled roots is difficult and often creates unnatural conditions. As a consequence experiments are often done under controlled conditions. To estimate a realistic amount of C- and N-rhizodeposition, experiments have to be conducted under field conditions without influencing the root system or the water and nutrient dynamics. The objective of the presented study was to quantify the C- and N-rhizodeposition of peas over time, its spatial distribution and its transfer into different soil compartments under field conditions. Special emphasis was put on estimating the microbial biomass C and N derived from rhizodeposition.

Method

In April 2013, peas (*Pisum sativum* L. "Santana") were manually sown into 40 microplots (0.5 m x 0.38 m) in the field. Per microplot, 12 pea plants were cultivated with a distance of 12.5 cm between the seedlings and between the rows, to reach an optimal seed density (64 plants m^2). In 20 microplots, all plants were labelled at 3 leaves unfolded, 41 days after sowing (DAS), with 0.5 ml labelling solution of 2% ^{13}C-glucose (99 atom%) and 0.5% ^{15}N urea (95 atom%) using the cotton wick method [3]. Every two days, the solution uptake was documented. If plants had taken up the solution completely, 0.5 ml solution was refilled by pipette. In case of a contamination of the labelling system (in some cases fungi formation could be observed), a new labelling system was installed. Frequent application of labelling solution aims at mimicking continuous labelling, which is necessary to achieve label homogeneity, a prerequisite for quantification of rhizodeposition. To investigate the development of rhizodeposition over time, plants were harvested at four dates depending on plant development (beginning flowering, end of flowering; green ripe and dry ripe). At each harvest date, plants of 5 labelled and 5 non labelled microplots were separated into shoots, grain and roots. For analyzing the ^{13}C/^{12}C and ^{14}N/^{15}N isotope ratio, soil samples were taken in 0-30, 30-60 and 60-90 cm depth, evenly distributed in each microplot. In order to calculate the complete root biomass of one pea plant, a second soil sampling always took place in three defined sectors of the microplots (directly on one plant; between two plants in the row; between two rows). The microbial biomass N (N_{mic}) was calculated according to [1]. Total N derived from rhizodeposition (NdfR) and NdfR in microbial biomass and in mineral N were calculated with an isotope mass balance approach [2].

Results

It was found that the same amount of N is released by rhizodeposition throughout plant development, as no significant differences could be observed between the four harvest dates (between 20 and 35 mg NdfR plant-1). The amounts of NdfR in the microbial biomass and in the inorganic N pool show a similar pattern. Between 15 and 33% of NdfR were recovered in the microbial biomass and between 8 and 22% in the inorganic N pool of the soil. The results show that pea plants release the largest amount of N by rhizodeposition until the beginning of flowering. After that, possible plant uptake of NdfR might be masked by the additional release of NdfR from root turnover. At the end of flowering, 68 days after sowing, there was significantly more NdfR in the topsoil (30-60) compared to the subsoil (60-90 cm). At dry ripe, 103 days after sowing, the amount of NdfR was significantly lower in 30-60 cm depth, compared to 0-30 and 60-90 cm depth. As already mentioned, for the calculation of rhizodeposition a continuous labelling is important. Our approach of multiple pulse labelling plants using the cotton wick method resulted in homogeneous enrichment of all plant parts and rhizodeposits with ^{15}N showing the reliability of the methodological approach. When comparing this field study to a former pot experiment with the same harvest dates, the same labelling method and the same soil, differences in the below ground N –to- above ground N ratio (BGN/AGN) are noticeable.

At the beginning of flowering and at dry ripe the plants in the pot experiment have a significantly lower BGN/AGN-ratio. In the pot experiment, the amount of NdfR in mg g-1 plant dry matter was always significantly higher compared to the field study. These differences between pot and field imply possible problems by transferring results (like the amount of NdfR as a percentage of root-N) from greenhouse studies to field conditions. Of course, in many cases, a pot experiment under controlled conditions is easier to perform than a field experiment. In case of N- rhizodeposition, a different BGN-AGN-ratio, because of the restricted root growth in pots or plant growing under optimal abiotic conditions, can influence the amount of NdfR (exudation and root turnover).

Conclusions

Rhizodeposition of peas is an important pool of available N for soil microorganisms and thus influencing inorganic N status as indicated by our results. However, about half of the N released from roots is not found in these pools, indicating that rhizodeposits consist of substantial particular amounts, such as root residues or root fragments, which take longer to be mineralized. Moreover, our study clearly shows that estimation of NdfR under field conditions is possible, even though laborious and expensive. However, to estimate a realistic amount of N-rhizodeposition, experiments have to be conducted under field conditions, as BGN/AGN and NdfR/BGN ratios differ between field and pot conditions.

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References

[1] Brookes, P. C. et al., 1985. Soil biology and biochemistry 17, 837- 842

[2] Hupe, A. et a., 2016. Biochemistry 96, 137-144

[3] Russell, C.A., Fillery, I.R.P. 1996. Crop and Pasture Science 47, 1047–1059

REMOTELY SENSING-BASED ANNUAL NITROGEN BALANCE FORECAST AT FIELD SCALE FOR WINTER WHEAT, POTATO AND MAIZE CROPS IN BELGIUM

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Objectives

The establishment of a field-specific provisional annual nitrogen balance for N fertilization advice, at the beginning of the growing season is based on information of different farmers' fields [1]. Required information such as crop rotation, annual farming practices and field delineation is often inaccurate or missing. An objective assessment of most of the required information by remote sensing (RS) could be a solution to face this uncertainty which hampers the nitrogen fertilization advice quality and relevancy.

The objective of this study, which is part of a global research project called "BELCAM" (http://maps.elie.ucl.ac.be/belcam/) started in 2015, is to evaluate the potential of satellite imagery to assess inputs for the nitrogen balance method at the field scale, i.e. mapping of crop type sequence along the year and parcel zoning capturing local heterogeneity. This abstract summarizes the results of the first year of the project.

Method

The N-balance sheet methods applied in Belgium are on the one hand the "Livre Blanc Method" (Ulg, Gembloux ABT) for winter wheat and on the other hand for potato and maize the Azobil/Azofert method developed by INRA (Laon, France) and adapted to the Belgian conditions, in Wallonia [2].

During the first year of the project (2015), the remotely-sensed information at parcel level was the current main crop identification and the limits of the different parcels, the type of the winter soil cover (species identification) and a qualitative assessment of their biomass production. For each variable, "field" data were collected to calibrate/validate the algorithms/methods used to derive the variable.

The new generation of high resolution optical satellites (e.g. Sentinel-2) allows to collect information over large area on a regular basis and to monitor crops at intra-field scale which opens the door to a modulation of fertilizer applications per homogeneous area (identified by remote sensing) within heterogeneous fields.

As Sentinel 2a satellite images were not available before August 2015, DMC/Deimos and RapidEye high resolution satellite images were acquired in 2015 over Belgium. UAV (eBee) images (RGB, RedEdge and Multispec4C cameras) were acquired for some specific fields. Orthophotographs and digital terrain models were generated for two winter wheat and three potato fields in the Gembloux area at several moments during the growing season. The RGB images were used to evaluate field heterogeneity.

Results

A crop type map was generated over Belgium for the 2015 summer season based on a DMC/Deimos images time series acquired between mid-March and mid-July, in order to obtain "early crop type estimates". The IACS dataset derived from farmers' declarations, available for Flanders and provided by the Flemish government was used as training data set. An overall accuracy of 73% was obtained. Winter crops were classified accurately while summer crops (maize, potato, sugar beet) were often mixed. Possible improvements include per-field post-classification and the use of images in August-September. These improvements should result in an increase of accuracy of at least 10%. Additional improvements of the classification accuracies are expected by the use of the red-edge bands of Sentinel-2

A map was also generated for 2015 autumn cover crops based on RapidEye images acquired in November

2015. A supervised Maximum Likelihood classification was performed. A field survey was organized to collect ground truth information: 220 parcels were surveyed and 15 different crop / land cover types were identified, the dominant classes being winter cereals, mustard and bare soils. The overall accuracy of the obtained autumn cover map was about 77%. Overall, winter cereals were well classified, the presence of mustard was slightly overestimated.

Parcel zoning aims to capture local heterogeneity within a parcel**.** This heterogeneity may for instance be induced by differences in mineral composition of the soil, soil moisture, organic matter content or soil texture. Local differences in plant growth may be indicative for differences in soil characteristics. Remote sensing derived vegetation indices were used to reveal soil heterogeneity from RapidEye fAPAR images acquired at different moments during the season (13 May, 30 June, 17 July, 31 August, 11 September and 1 November 2015). Tests were performed using blue, green, red, red edge and NIR reflectances separately and using derived vegetation indices. For two winter wheat specific fields, hundreds of soil and biomass measurements were collected. Once processed, these data will be used as reference for determining the optimal settings of the segmentation algorithm. The results were evaluated with field observation, for selected winter wheat, maize and potato fields. For a few fields UAV images and/or yield measurements were available for comparison. First results will be presented during the workshop.

Conclusions

The results of the first year of the project are promising for the development of a remote sensing-based annual nitrogen balance forecast at field scale. The potential to obtain early identification of the previous crop through remote sensing within a field have been demonstrated; the identification of autumn cover crops is also encouraging. Zonation of a heterogeneous field seems realistic but needs further analysis.

Acknowledgements

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References

[1] Goffart, J.P. & Olivier, M. 2004. In Haverkort A.J., MacKerron DKL (eds). Decision support systems in potato production: Bringing models to practice, Wageningen, The Netherlands, pp. 68-83.

[2] Abras M. et al., 2013. Biotechnol. Agron. Soc. Environ., 2013, 17(S1), 215-220.

POTENTIAL FOR MITIGATING ATMOSPHERIC AMMONIA IN CANADA

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Objectives

Ammonia is the only atmospheric pollutant emitted mainly by agriculture. Atmospheric ammonia impacts the environment and human health. Both ambient and deposited ammonia can damage plants, degrade biodiversity in pristine environments, degrade marine waters and acidify soils. Ammonia reacts quickly with acid gases producing fine particulates ($PM_{2.5}$) that damage human health and can remain airborne and transported for long distances, impacting ecosystems far from the emission sources.

Ammonia volatilization is the largest loss pathway for reactive N from Canadian farms and is also a significant loss of an essential plant nutrient. Many technologies can limit the loss of ammonia from farms, however, the impact of these mitigation methods must be assessed at the level of the whole systems. Emission inventories help to assess the impact of mitigation methods and can help inform policy. The goal of this paper is to assess the potential for mitigating atmospheric ammonia in Canada.

Method

This paper is based mainly on a number of previously published studies conducted in Canada. Detailed farm surveys quantified farm practices that relate to ammonia emissions across agricultural sectors and eco-regions in 2005 [1, 2] and 2011 [3]. Ammonia emissions in Canada were computed with emission inventory models based on the farm practices data from the surveys, emission factors adapted to Canadian farms and conditions, and official farm statistics such as animal numbers and fertilizer consumption. Costs and efficacy of abatement measures were based on the UNECE Guidance Document [4], and data on food consumption, food waste and food exports were obtained from official Statistics Canada reports [5]. Deposition of ammonia to the Canadian landscape as well as atmospheric transport into and out of the country was calculated for the year 2002 using AURAMS (A Unified Regional Air-quality Modelling System) model [6-8].

Results

Canada emitted 408 kt of ammonia N from agricultural sources in 2005, which was about 85% of emission from all sources. Of the agricultural sources, 55% was related to food consumed domestically and the remainder 45% to agricultural exports which included large amounts of grains, beef and pigs [5]. On the basis of consumable protein produced, beef production in Canada was associated with most ammonia loss (1.3 kg NH_3-N kg^{-1}), followed by pigs (0.43 kg NH_3-N kg^{-1}), milk, poultry meat and eggs (0.21 - 0.15 kg NH_3-N kg^{-1}). Plant based foods emitted much less than animals based foods with vegetables> cereals>pulses. Therefore, replacing animal protein with pulses in the Canadian diet will significantly reduce ammonia emissions. Since cattle and pigs are value-added products, reducing these exports in favour of more grain exports would harm the agricultural economy.

Largest sectoral emissions were beef (170 ktNH_3-N), crop fertilizers (100 ktNH_3-N), and pigs (70 ktNH_3-N), so targeting these sectors can yield greater impact than targeting dairy (48 ktNH_3-N) or poultry (21 ktNH_3-N). Generally, housing (153 ktNH_3-N) and landspreading (110 ktNH_3-N) of manure were the greatest loss pathways and so offer the greatest potential for mitigation.

It is worth noting that Canadian producers widely employ several practices for economic or social reasons that coincidentally mitigate ammonia. Examples are pasturing of breeding cows, multiple feeding phases for pigs and poultry, injection of mineral N fertilizer, and in some regions, low emission spreading of pig and to a lesser extent cattle slurry. Winter grazing has greatly expanded in recent years to save money, but the impact on emissions was not incorporated into the above estimates . Successful adoption of these practices without regulations or incentives in unsupported sectors (beef, pigs and grain) is instructive.

We considered the potential of low-cost methods for mitigating national emissions in Canada. The overall mitigation was determined in the context of the manure chain and farming sectors. Methods included reducing protein in feed to UNECE target levels, hastening incorporation of solid manure to <4 hours, reducing splash plate application of slurries in favour of low-emission surface-banding and injection methods, increasing winter grazing of beef cattle, covering pig slurry storages and some inexpensive housing changes. Considering only the measures with fairly firm costs (low emission slurry application and slurry storage covers), it was possible to reduce national emissions by 16 ktNH_3-N at a cost of $13m or 0.80 per kg of abated N (net fertilizer value). When considering all the putative low cost methods, it was possible to reduce emissions by 79 ktNH_3-N or 26% of livestock emissions (19% of all agricultural emissions). The will to implement mitigation policies depends on understanding the benefits to the overall community.

Conclusions

The impact of mitigation must be considered holistically. Currently there is an atmospheric import of about 500 kt of ammonia [6], mostly to southern Ontario, so mitigating ammonia emissions in that region would have little impact. In contrast there is excellent evidence for the Lower Fraser Valley (LFV) of British Columbia were local agricultural emissions greatly influence ambient ammonia concentrations; this was demonstrated by seasonal changes and during a period when much of the regional poultry flock was culled. It is also necessary to understand the harm reduction associated with abatement. For example, in the LFV there is an abundance of ammonia so abatement of 30% will have little effect on $PM_{2.5}$, unlike regions like southwester Ontario and Southeastern Quebec where ammonia is the limiting reactant in $PM_{2.5}$ formation. Note that this relationship changes strongly with season. The study in the LFV suggested that focussing mitigation on periods with poor air quality would be easier to accomplish and more effective than year-round mitigation. More collaborative research is needed among agricultural, environmenta, and health scientists to lessen harm from ammonia in Canada.

References

[1] Sheppard, S.C. and S. Bittman. 2013. Agric. Ecosys. Environ. 171: 90-102.

[2] Sheppard, S.C. and S. Bittman. 2013. Anim. Feed Sci. Technol. 166-167: 688-698.

[3] Sheppard, S.C. et al. 2015. Can. J. Anim. Sci. 95: 305-321.

[4] Bittman, S., et al. 2015. Atmos. Environ. 113: 108-117

[5] Sheppard, S.C. and S. Bittman 2014. Atmos. Environ. 103: 43-52.

[6] Clair T. et al. 2014, Global Biogeochem. Cycles, 28:1-15.

USING BAYESIAN HIERARCHICHAL MODELS TO BETTER UNDERSTAND AGRICULTURAL NITRATE CONTRIBUTION TO RIVER WATER

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Objectives

Understanding agricultural nitrate contribution to river water is critical to water quality assessment and management. Export coefficient models, which assign a calibrated export coefficient (the rate of pollutant loading per unit of land area) for each modeled land use, are attractive tools for predicting nitrogen exports because they can flexibly incorporate processes and have minimal data requirements. However, export coefficient models typically do not account for the extensive spatial and temporal variability in land characteristics, weather, and management practices. This study seeks to better quantify agricultural nitrate contribution to river water by addressing structural and parameter uncertainty of an export coefficient model.

Method

Confidence in model predictions depends on uncertainties in model structure and parameters. Compared to the base export coefficient model, we investigated three strategies that apply Bayesian hierarchical methods in export coefficient modeling to accommodate spatiotemporal variability in nitrogen sources and sinks and to quantify uncertainty in coefficients and predictions. The first approach assumes that errors arise mainly from unspecified sources or sinks, and it uses additive structural and non-structural error terms in space and time to address uncertainty. The second approach assumes that errors come mainly from using static export coefficients and instead estimates coefficients that vary independently in time and space. The third approach extends the second one by assuming that the temporal and spatial structures of the parameter series are similar, and then using dynamic parameter estimation techniques to accommodate the autocorrelation of parameters. We comparted the three strategies in a case study of nitrate export from nine watersheds in the Coastal Plain physiographic province of the Chesapeake Bay drainage.

Results

All three strategies adapted a published export coefficient model that quantifies nitrate contribution of crop land and nitrate removal. The base model is effective choice for modeling the effects of cropland and riparian buffers on nitrate concentrations. However, the model does not capture spatial variation in model parameters among watersheds or temporal variation among weeks of observation. We expect important spatial and temporal variations because nitrate concentration is strongly affected by spatial heterogeneity of soil types, terrestrial storages, and land use and by the timing of precipitation, evapotranspiration, and agricultural activities. Compared to the base model, model 1 achieved higher model accuracy by adding spatial and temporal variability terms to accommodate structural error. It was not the best method in this study, probably because structural error is not the main cause of uncertainty in the base model. The strong performance of model 2 suggests that parameter uncertainty is the most important source of uncertainty of the base model. Model 2 performed well by representing spatial and temporal variations in parameters as the main source of uncertainty, as in other models of non-point source pollution. However, according to recent inferences, the modeling efficiency of this model would get slow with model runs by assuming complete independence of each parameter distribution. The third approach had the best fit and most reasonable complexity of the three strategies. The Gaussian first-order random walk model well represents correlations among the error terms of spatial parameters, and its application is conceptually similar to hierarchical dynamic linear model (DLM) and the Kalman filter. The DLM model with a discount factor explicitly recognizes temporal correlation within the time series of parameters. Gaussian first-order random walk models and data driven priors have been used previously to characterize ecological process. Our study is the first study to combine the random walk and DLM to simultaneously characterize spatial and temporal parameter variability in a water quality model. We compared our model 3 results with published results from original model in the Coastal Plain province. We found similar strong effects cropland and riparian buffers on stream nitrate concentrations. Our study improved understanding beyond the previous study by quantifying spatial and temporal variations in nitrate sources and sinks. Consistent with theory and previous measurements, the variations of cropland nitrate exports were positively related to stream flow and watershed average slope, while instream nitrate retention was positively correlated with nitrate concentration.

Conclusions

We better quantified agricultural nitrate contribution to river water by addressing parameter uncertainty of an export coefficient model. We confirmed previous findings that cropland is the largest land use source of exported nitrate, and that nitrate removal by riparian buffers can greatly reduce watershed nitrate export. However, we also demonstrated that nitrate sources and sinks vary strongly in space and time, and we verified that Bayesian approaches can deal effectively with that variation. The methods developed here can be readily applied in other watersheds where pollutants have impacts that vary spatially and temporally.

SENSITIVITY ANALYSIS OF NITIRSOIL MODEL OUTPUTS: SOIL MINERAL NITROGEN, NITROGEN LEACHING LOSSES AND NITROGEN CROP UPTAKE

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Objectives

The NITIRSOIL is a one-dimensional transient-state model with monthly time step for predicting main nitrogen transformations and transport in soils cultivated with irrigated crops [1]. A global sensitivity analysis (SA) was carried out to know how the uncertainty in each input factor of the NITIRSOIL model propagates to each of its main outputs, namely end season soil mineral nitrogen (Nmin), cumulative nitrogen leaching losses (Nleach), and cumulative nitrogen crop uptake (Nupt). The SA was done for the cropping of globe artichoke (*Cynara cardunculus* var. *scolymus*) under Mediterranean climate in the Valencian Community (E Spain). Following the SA, the coefficients of the nitrogen dilution curve (C_1, C_2) were calibrated for this crop with data from three plots and two cropping seasons each. Finally, the NITIRSOIL model was validated for globe artichoke by comparison of predictions and measurements of Nmin, Nleach and Nupt using data from a different plot and two seasons.

Method

TThe probability density functions (normal, log-normal or uniform), distribution parameters (mean and standard deviation), and variation ranges (maximum and minimum) of 48 input factors to the NITIRSOIL model were assessed. Depending on the class (crop, soil, weather, irrigation, or management) and type (parameter or variable) of the input factors, the assessment of their variability characteristics was based either on published data, e.g. for soil coefficients, or on available information from the Valencian Community, e.g. for soil, weather, irrigation and management factors. These variability characteristics were used to generate 10,000 independent random samples of the set of 48 input factors by means of the SIMLAB 2.2 software [2]. Note that covariances among input factors were considered null for the development of this SA. Next, the NITIRSOIL model was run on each one of these 10,000 samples and the corresponding Nmin, Nleach and Nupt outputs were recorded. The multiple linear regression models (MLRM) for explaining the variation in each output due to the 48 input factors was assessed by means of the R software [2]. The standardized regression coefficient of each input factor (β_i) was squared and divided by the summation of all 48 in each MLRM ($\Sigma\beta_i^2$) in order to obtain the sensitivity measures of the SA, i.e., the percent of variance in each output explained by each input.

For calibration and validation four commercial plots located in different places in the Valencia surroundings were cropped to globe artichoke, during two years in a row each. In each plot four different levels of nitrogen mineral fertilization by means of NH_4NO_3 were tested. The experimental plots were characterised for soil properties, and then monitored during the cropping seasons for irrigation management, weather conditions (rainfall, evapotranspiration, temperature), crop development and nitrogen contents in stems and fruits, nitrogen content in soil at various depths, and nitrate in irrigation and rainfall waters. On basis crop development and nitrogen contents, the parameters C_1 and C_2 of the nitrogen dilution curve were calibrated in three plots, and the NITIRSOIL model validated for the prediction of Nmin, Nleach and Nupt in the remaining plot.

Results

The MLRM could explain 76, 69 and 55% of output variance for, respectively, Nmin, Nleach and Nupt. Accordingly, the model could be considered linear enough for Nmin and Nleach and thus, the SA could be based on the squared standardized regression coefficients (β_i^2). With over 50% of explained variance, the most influential input factors on both Nmin and Nleach are the nitrate content of the irrigation water (NO_3irrig) and then, the nitrogen fraction in the soil organic matter of fast turnover rate (N_no_pool). Specifically for Nmin, the input factors in order of explained variance are: NO_3irrig (39%), N_no_pool (23%), the soil organic matter in the arable layer (SOMsup) (13%), the fractional nitrogen uptake (fNU) (7%), the annual fertilizer amount (6%), the soil organic matter mineralization coefficients (Komm) (5%), the nitrogen dilution curve coefficients (C_1 and C_2) (2%), the desnitrification coefficient (1%), and other factors (3%). For Nleach the same input factors arise, however, for Nleach the important input factors related to the soil water dynamics such as annual rainfall, irrigation and evapotranspiration (ET0ann) and the nitrogen leaching coefficient (Kleach) logically intersperse throughout the list giving rise to the following percentages of explained variance from more to less: NO_3irrig (38%), N_no_pool (15%), annual rainfall (10%), SOMup (8%), fNU (8%), annual irrigation (8%), Komm (3%), ET0ann (2%), Kleach (1%), the bulk density in the arable layer (BDsup) (1%) and the rest of input factors (5%). For Nupt the MLRM could not explain a high enough amount of variance, what reveals the existence of higher order effects, i.e. important interactions between crop and management factors. In any case, fNU (68%) and C1 and C2 (14%) were the most influential factors, followed by NO_3irrig (4%), harvest index (4%), dry matter index (3%), SOMsup (3%), N_no_pool (2%), annual fertilizer amount (1%), Komm (1%) and others (1%). The coefficients of the nitrogen dilution curve (C_1, C_2) were thus revealed as very important for Nupt, important for Nmin and barely important for Nleach. Their calibration gave values of $C_1 = 3.7 \pm 0.9$ and $C_2 = 0.41 \pm 0.14$ at 95% confidence. Following the validation, Nmin, Nleach and Nupt were predicted with RMSE of respectively, 29, 33 and 235 kg/ha and index of agreement of 0.89, 0.67 and 0.99. Thus, Nmin and Nupt were reasonably well predicted while Nleach was remarkably overestimated. This can be a result of the use of a default value for the nitrogen leaching coefficient, which must be correctly estimated according to its importance as revealed by the SA.

Conclusions

NITIRSOIL is a simple one-dimensional monthly transient-state model for simulating nitrogen transformations and transport through the following processes: mineralization, nitrification, denitrification, volatilization, nitrogen uptake and nitrate leaching. Since SAs are essential in model communication to inform users about the importance input factors have on outputs and thus, about model suitabiltity to specific simulation goals, SAs are required by different authorities like the US EPA, and the European Commission for model use acceptability. Through the SA of NITIRSOIL we identified on which model parameters calibration efforts must be focussed and similarly, on which model variables analytical determinations should more accurately be done. The relevant NITIRSOIL model parameters are those related to the fractional nitrogen uptake throughout the cropping season, the nitrogen dilution curve, the soil organic matter mineralization coefficients, and the nitrogen leaching factor. Amongst the variables, we found mainly the nitrate content in the irrigation water. However, even more important than stressing the need to correctly determine NO3irrig, is to stress the importance the nitrogen content in the organic matter fraction of fast turnover rate has. Accordingly, N_no_pool should be carefully determined for modelling in NITIRSOIL, thus avoiding the use of default values. Similarly the soil organic matter mineralization coefficients, and nitrogen leaching factor must be correctly calibrated.

References

[1] de Paz, J.M. et al., 2012. In: Richards, K.G. et al. (eds) Proceedings of the 17th Nitrogen Worskhop. Wexford, Ireland. p. 443-444.

[2] Saltelli, A. et al., 2004. Sensitivity Analysis in Practice. Willey: London.

EFFECT OF DIFFERENT N-MANAGEMENT MEASURES TO REDUCE N SURPLUSES ON N_2O EMISSIONS FROM VEGETABLE PRODUCTION

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Objectives

Vegetable production is partly associated with elevated N-fertilization and thus results in high N surpluses since vegetables such as cauliflower and broccoli are harvested in the vegetative growth stage. Different N-management measures like i.e. the reduction of N-fertilization (either as a general reduction or with the help of optical sensors to determine plant demand), nitrification inhibitors, cultivation of catch crops, or the removal of crop residues before winter have been proposed to reduce these N surpluses.

Some of these measures were tested on their applicability to reduce nitrate leaching [1] and [2], whereas the effect on the release of the climate relevant trace gas N_2O from horticultural systems is only rarely investigated. Main aim of our investigation was therefore to test some of these N-management measures for their potential to reduce N_2O emissions under field conditions.

Method

The study was conducted on block experiment with four replicates on the University Hohenheim research farm Heidfeldhof, near Stuttgart, south Germany. Soil type was a silty Haplic Luvisol derived from periglacial loess. A closer description of soil characteristics was published earlier [3].

In the first experimental year, crisphead lettuce and broccoli were grown, in the second year cauliflower followed by broccoli. Ammonium sulfate nitrate was used throughout the whole experiment as N-fertilizer.

We tested the following treatments:

1. Unfertilized control
2. High N: N-fertilization according to demand without consideration of mineral N and with a safety margin. This approach is common in horticultural practice
3. KNS: Reduction of common N-fertilization rates in horticulture according to the KNS system (German target value system developed for N-fertilization consultation). Except for treatment 1), 2), and 4) the N-fertilizer amount proposed by the KNS system was used for all other treatments reported here
4. SPAD: Reduction of N-fertilization while monitoring chlorophyll contents after a first basal N application with the option for further top dressings in case of plant brightening
5. NI: Use of a nitrification inhibitor (NI: 3,4-dimethylpyrazole phosphate)
6. Integration of green rye as a winter catch crop
7. Immobilization of soil nitrate before winter through straw addition
8. Crop residue removal

Trace gas fluxes were measured at least weekly over the entire two year experimental phase using the closed chamber method. Chamber type, GC-configuration and calculation of the gas flux rates were described elsewhere [4].
Simple N-balances were calculated for each treatment as N-input (N-fertilization + straw-N in treatment 7) - N-removal (N in marketable yield + N removed with the residues in treatment 8).

Results

N_2O flux rates showed a high temporal variation with high N_2O fluxes after N-fertilization and rainfall or irrigation, after soil tillage and after harvest of the last crop over winter. In both years highest flux rates were measured outside the cropping season. We found strong correlations between the N_2O fluxes, CO_2 fluxes, soil moisture and nitrate contents of the topsoil indicating that denitrification was the major N_2O source.

N_2O emissions over the entire experiment varied between 12.8 and 81.5 kg N_2O-N ha^{-1} 2 yr^{-1} in the unfertilized control and the High-N treatment. Reduction of N-fertilizer amounts (High-N) to the amount recommended by the KNS system significantly reduced N_2O emissions by 37% (51.3 kg N_2O-N ha^{-1} 2 yr^{-1}) without any decrease in marketable yield or visible quality characteristics of the vegetables. A similar N_2O reduction for the KNS system at the same study site was found in an earlier study and was explained with the lower nitrate contents in the top soil [3].

As compared to the KNS treatment, N-fertilization in the SPAD treatment was reduced by 36% and the N_2O emission by 51% but yield of some vegetable crops was reduced.

The use of a NI did not reduce the emissions when compared to the treatment KNS without a NI. The statistically not significant lower emission during the cropping season in the NI treatment was nullified by the high N_2O emissions during the winter seasons. The reason for the inefficient NI remains unclear. In an earlier study, N_2O reduction of approximately 45% was found during the cultivation of vegetables at the same site and the same NI [3].

Implementation of green rye as a winter cover crop resulted in lower nitrate contents of the top soil and thus reduced the N_2O emission by 41% as compared to the KNS treatment with black fallow over winter.

Straw application reduced the mean N_2O emission from the KNS treatment (34%). However, this reduction was not statistically significant. This measure significantly reduced nitrate contents over winter but, as observed in other studies, the major problem of this measure was the assessment of the release of the immobilized N.

Although removal of the crop residues required a higher N-fertilizer amount than the KNS treatment (690 vs. 625 kg N ha^{-1} 2 yr^{-1}), the N-balance for this measure was negative and successful in N_2O reduction. With 74% lower emissions, crop residue removal was the most effective among the N-management measures tested. The N_2O emission was statistically not different from the emission of the unfertilized control.

We found a strong positive correlation between the N-balance and the N_2O emission during the two experimental years. It accounted for 90% of the variability of the N_2O emissions.

Conclusions

Our data clearly indicate that N-management measures have a high potential for the reduction of N_2O emissions from vegetable fields. A high N_2O mitigation can be achieved by reduction of N-fertilizer amounts according to the KNS system without any decrease in vegetable yield.

The highest N_2O reduction was realized when crop residues were removed, i.e. for composting. On the other hand, this measure removes organic C for humus reproduction. Therefore long-term studies which focus on the effect of crop residue removal on changes of the C_{org} stocks in vegetable production systems seem worthwhile.

Based on the strong correlation between N-balance and N_2O emissions, the most important conclusion of our results is that every measure which reduces N surpluses also (not always statistically significant) reduces N_2O emissions from vegetable production.

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Referensers

[1] De Ruijter, F.J. et al., 2010. Nutr. Cycl. Agroecosyst. 86, 241-253
[2] Wiesler, F. et al., 2008. Agrarspectrum 41, 95-108
[3] Pfab, H. et al., 2012. Agric. Ecosyst. Environ. 150, 91-101
[4] Flessa, H. et al., 1995. J. Geophys. Res. 100, 23115 - 23124

SOIL N AVAILABILITY PATTERN ON HORTICULTURAL LAND

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Objectives

Soil organic N, which forms the main part of the soil N stock, is made available to plants as a result of decomposition of soil organic matter (SOM) by soil microbiota. This N release process is referred to as N mineralization. On the other hand, soil mineral N (Nmin) is consumed by soil microbiota and converted in organic forms, i.e., N immobilization. When N losses are not considered, Nmin availability is the net result of N mineralization, N immobilization and crop N uptake. We hypothesized that the balance between mineralization and immobilization is different in a bare or limited rooted soil compared to an intensively rooted soil. Our objectives were (i) a better understanding of these N availability inducing processes and (ii) based on this new knowledge, making suggestions for optimization of Nmin based fertilization advice systems for field vegetable cropping systems.

Method

N availability due to mineralization-immobilization was studied in field vegetable cropping systems. It concerned two multi-year soil management trials, one under conventional (SMTco) and the other under organic cultivation (SMTorg), and a field survey (FS; 2009) on conventionally cultivated horticultural land, with leek (*Allium porrum*) as test crop. In SMTco, the crops were broccoli (*Brassica oleracea,* var. *Italica Group*) (2009) and leek (2011), and management factors were tillage practice and compost application [2]. In SMTorg, test crops were leek (2012) and celeriac (*Apium graveolens,* var. *rapaceum*) (2013), and management factors were tillage practice (2012&2013), grass-clover termination strategy (2012), cut-and-carry fertilization (ensilaged grass-clover) and compost application (2013).

In order to assess net N mineralization from SOM, balances of plant available N were calculated. A balance result was obtained by subtracting N supply from N recovery items and represents the “apparent” net N mineralization (ANM) from SOM, inclusive of the organic fraction of recently applied organic material [1]. ANM is the net result of soil N mineralization and immobilization, but “apparent” as it may also include N losses occurring during the growing season. The amount of recovered N is the sum of aboveground crop N uptake and residual Nmin in either the 0-60 cm (SMTorg) or 0-90 cm soil profile (FS & SMTco). The N supply is the sum of the mineral N input and the initial Nmin in the soil profile. Soil of three subsequent soil layers was sampled for determination of Nmin in the soil profile, initially just before fertilization and tillage (s1), intermediately under a young crop (s2) and finally at crop harvest (s3). ANM was calculated for different time spans in the cultivation period. Besides an overall balance for the s1-s3 period, partial balances were calculated for the s1-s2 and s2-s3 periods. Both base and top mineral dressing were registered. Intermediate and final crop N uptake were known by determination of dry matter yield and crop N content. In FS and in case of the broccoli crop in SMTco, intermediate N uptake was estimated based on crop N uptake curves.

Results

In FS, $ANM_{s1\text{-}s3}$ varied from a few tens to a few hundred kg N ha^{-1}. Remarkably, $ANM_{s2\text{-}s3}$ was mostly negative indicating apparent net N immobilization in the second half of the growing season. Planting date significantly affected mineralization-immobilization processes. All but two early planted fields showed $ANM_{s1\text{-}s2}$ values larger than 100 kg N ha^{-1} followed by large negative $ANM_{s2\text{-}s3}$ values. This phenomenon was observed to a lesser extent in late planted fields. Given a growing season with no excess precipitation, N leaching losses were likely to be non-significant.

For both broccoli and leek in SMTco, the decrease in soil profile mineral N in the s1-s3 period was larger than the crop N uptake in that period. This resulted in negative $ANM_{s2\text{-}s3}$ values, on average -66.7 and -20.9

kg N ha^{-1} in respectively the broccoli and leek growing season. Part of the applied or available Nmin was either lost, immobilized, or both. Only in the leek growing season, we may assume some leaching losses between s2 and s3 as this period spanned the colder months of September and October. Therefore, N mineralization and immobilization apparently were in balance in the s2-s3 time span. In contrast, leaching losses were less probable under broccoli in the s2-s3 time span, because that period comprised the warmer months of June and July. The daily ANM_{s1-s2} for broccoli in 2009 was half of the daily ANM_{s1-s2} for leek in 2011. In the leek growing season, ANM_{s1-s3} was significantly higher under conventional tillage (CT: 112.4 kg N ha^{-1}) compared to reduced tillage (RT: 96.4 kg N ha^{-1}). Neither ANM_{s1-s2} nor ANM_{s2-s3} were affected by any of the soil management factors. By contrast, partial balance results in the SMTorg trial were clearly affected by soil management factors in both the leek and celeriac growing season. ANM_{s1-s2} and ANM_{s1-s3} under the leek crop in 2012 were significantly lower in case of removal of a full-grown cut of the preceding grass-clover cover crop compared to both other termination strategies, i.e. early termination after one time mulching and late termination after three times mulching. ANM_{s2-s3} was negative by on average -12.5 kg N ha^{-1}. In the celeriac growing season (2013), ANM_{s1-s2} was significantly higher under CT compared to RT and significantly higher for the highest dose of cut-and-carry fertilizer compared to the intermediate and zero dose. And, in analogy with FS, a higher ANM_{s1-s2} corresponded with a lower ANM_{s2-s3} (more negative; on average -64.4 kg N ha^{-1}).

Partial balances showed that N mineralization prevailed over N immobilization in the first half of the growing season, whereas in the second half of the growing season - under a well-established crop - N immobilization prevailed over N mineralization.

Conclusions

The balance results of both the field survey and the multi-year field trials suggest that N availability in field vegetable cropping systems follows a cyclic rather than a linear pattern. In the course of the growing season, apparently, a transition occurs from a bare soil stage where N release from SOM prevails to a ‘plant-soil system’ where immobilization prevails. We may assume that under a well-established crop, with a root system that extensively occupies the soil volume, soil microbial life is strongly activated by root exudates.

This understanding of the N availability pattern might contribute to the amelioration of Nmin based fertilizer recommendation systems, in which soil testing for plant N availability assessment should be based on soil sampling both before and after full establishment of the crop, rather than by a single soil sampling during the youth stage of the crop. Both mineral N measurements and N mineralization tests might suit for soil sampled before crop establishment or during the youth stage of the crop. However, we presume that another type of soil test should be developed for estimation of potentially plant available N under a well-established crop.

[1] Feller, C., Fink, M. 2002. Acta Hortic. 571, 195-201.

[2] Willekens, K. et al., 2014. Sci. Hortic.-Amsterdam 178, 79-86.

N YIELD-SCALED EMISSIONS AND GREENHOUSE GAS INTENSITY FROM FORAGE MAIZE IN RELATION TO ADDITION OF 3,4 DIMETHYLPYRAZOLE PHOSPHATE TO CATTLE SLURRY AND MINERAL FERTILIZERS

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Objectives

Maize, which is one of the main crops in Galicia, covers around 68, 909 ha of land in the region. Nitrogen (N) based fertilizers are applied to enhance crop yields and can significantly affect greenhouse gas (GHG) emissions. In a previous study carried out in Galicia, where the climate is characterized by high rainfall (>1000 mm) and mild temperatures, high emissions of nitrous oxide (N_2O) were observed in relation to the fertilizers typically applied to maize crops by local farmers [1]. The present research focuses on developing new fertilization strategies to produce lower GHG emissions and higher crop yields. Use of nitrification inhibitors such as 3,4 dimethylpyrazole phosphate (DMPP) is a promising strategy [2].

The aim of this study was investigate how the addition of DMPP to cattle slurry and mineral fertilizer affects GHG emissions and crop yields under the Galician climate.

Method

The study was carried out during spring and summer (in 2013 and 2014) at the CIAM Research Centre (NW Spain), on a silt loam soil classified as Humic Cambisol. The soil was characterized as follows: pH 5.9; organic matter (OM) content of 49.6 g kg^{-1} (on a dry matter [DM] basis); total N content, 1.8 g kg^{-1} DM and C/N ratio 10.6. Fertilizers were applied twice: at the end of May (before sowing) and mid July, as top dressing. Maize (cv LG 33.85) was sown at a density of 98000 plants per ha. The trial was conducted as a completely randomized block design with four replicates and eight treatments. In three treatments, a single dose (200 kg of total N ha^{-1}) of different N fertilizers was applied before sowing: in T1, cattle slurry (CS) was injected into the soil; in T2, CS was applied with DMPP; and in T3, Entec (ammonium sulphate nitrate established with DMPP) was added. In four treatments, the N fertilizer was split in two doses (100 kg of total N ha^{-1} each): in T4, only calcium ammonium nitrate (CAN) was added; in T5, CS was combined with CAN; in T6, CS and Entec were combined; and in T7, CS was applied with DMPP and combined with Entec. A control treatment without N was included (T8). To monitor GHG, two closed chambers (diameter 25cm, height 36cm, depth in the soil 3cm) were installed in each plot. Samples collected 40 minutes after closure of the chambers were analyzed by gas chromatography (Agilent 7890A). Soil samples were analyzed to determine Water Filled Pore Space (WFPS), and meteorological station data were used to determine the influence of weather on N_2O fluxes.

Maize was harvested on 1 October and sub-samples were collected to determine DM yield and N uptake. For comparison of gaseous emissions, the following were calculated for each treatment expressed as percentages: i) N yield-scaled emissions, calculated by dividing the net N_2O cumulative emission by the total N uptake for the maize; and ii) greenhouse gas intensity (GHI), calculated as the global warming potential (GWP) divided by the yield.

Results

Cumulative N_2O emissions during the maize growing season ranged from 0.78 (control) to 4.04 (CS) in 2013 and from 0.54 (control) to 2.08 (CS) kg N_2O-N ha^{-1} in 2014. Total rainfall during the crop season in 2013 was 36% lower than in 2014. The WFPS values were markedly different at the beginning of each growing season: approximately 55% in 2013 and 70% in 2014. This was decisive in increasing cumulative N_2O emissions in 2013 because the high WFPS values in 2014 promoted conversion of most of the N_2O to N_2 via denitrification. Comparison of total cumulative N_2O emissions did not reveal any differences between mineral fertilization treatments (T3 and T4) or combinations with CS (T5, T6 and T7). Significantly higher cumulative emissions were only found for the single dose CS (without DMPP) (T1) relative to the mineral treatments (T3 and T4).

The highest emission fluxes occurred after the first application of fertilizer in both years, coinciding with the highest WFPS values (around 60-70%). In plots to which the fertilizer was applied as CS in a single dose (T1 and T2), the combination of DMPP and CS caused a decrease in the emission of N_2O: to 45% in 2013 and 54% in 2014. When only half of the N was applied as CS (T5, T6 and T7), the inhibitory effect of DMPP was 47% in 2013 and 65% in 2014. High WFPS values suggested that N_2O emissions may have been due to nitrification and denitrification.

During the period between the second application of fertilizer and harvesting, a global decrease in N_2O emissions occurred with all the treatments, and cumulative emissions were not significantly different from those associated with the control treatment. In treatments T4, T5, T6 and T7, application of CAN or Entec was not followed by distinct emission peaks. The low fluxes may be attributable to the WFPS values (close to 30%) in both years during this period. These values indicated nitrification as the major process underlying the emissions.

Crop yield was highest in treatments with including CS in a single dose, with or without DMPP. No significant differences between treatments were observed in factors such as N yield scaled emissions or GHI in the first year. In the second year, N yield scaled emissions were significantly higher in plots fertilized with CS (T1), and for T5 and T6 were higher but not significantly, relative to treatments with mineral N (T3 and T4). However, this difference disappeared when CS was applied with DMPP (T2 and T7).

Conclusions

We observed large differences in N_2O losses between the two maize cropping seasons. These were probably mainly due to the differences in WFPS values after the first fertilizer application. The highest cumulative N_2O emissions for the crop growing season were observed after application of cattle slurry in May. Use of the inhibitor not decrease yield obtained after CS application and caused a decrease in the cumulative N_2O and N yield scaled emissions to values similar to those obtained after application of mineral fertilizer or CS plus mineral N. The application of a single dose of mineral fertilizer as Entec yielded the same results as application of CAN in two doses (May and July), thus reducing the field effort required.

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References

[1] Louro, A. et al., 2015. Geoderma Regional 5, 54-63.

[2] Huérfano, X. et al., 2015. Europ. J. Agronomy 64, 47-57

NITROGEN-FERTILIZATION EFFECT ON N_2O EMISSION FROM A TYPICAL RUBBER PLANTATION

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Objectives

Transformation of primary tropical rainforests to rubber (*Hevea brasiliensis*) plantations has been widely occurring in the tropics. This landuse change could result in lots of environmental impacts, which should be paid more attention to. In Xishuangbanna, Southwest China, rubber plantations cover an area of about 4.7 × 10^5 ha (24.6% of the local landscape), which represents about half the tropical rainforest. However, little attention has been paid on the GHG emissions from the rubber plantation. Hitherto, the report on the fertilizer effect on the N_2O emission dynamics, mechanism and the global warming potentially (GWP) were lacked. Thus, effects of fertilization on nitrous oxide (N_2O) emission and the contribution to GWP are not clear. To meet this requirement, we carried out 2-year field measurements of N_2O fluxes from fertilized and unfertilized fields of a typical rubber plantation in Xishuangbanna, southwest China.

Method

Site description

The study manure rubber plantation (21° 55′30″N, 101° 15′59″E; elevation 580 m),transplanted from tropical rainforest, was planted in 1993 in Xishuangbanna, Yunnan Province, Southwest China. The annual average temperature is 21.7 °C, the mean annual precipitation is 1557 mm.

Experimental design

Taking into account the slope gradient, slope direction, and buffer zone, there were terraces (NN), fertilizer trenches (NNt), narrow slopes, and wide slope (NN+) treatment in the NF plots, and terraces (UN), dry season fertilizer trenches (UNts), rainy season fertilizer trenches (UNta) narrow slopes, and wide slope (UN+) treatments in the F plots. In line with local farming practices, 1 kg of mineral fertilizer (supplied by the Hubei Sanning Chemical Co. Ltd, China) containing 15% N, 15% P, and 15% K (comprising $(NH_2)_2CO$, $NH_4H_2PO_4$, and KCl) was applied to each rubber tree per year; this amounted to an application rate of 75 kg N ha^{-1} yr^{-1}.

Measurements

We measured the N_2O fluxes simultaneously in all the F and NF treatments for two years from April 1, 2012 to March 30, 2014 using a static opaque chamber technique.

Soil volumetric water content (0-12 cm) was determined with time-domain reflectometry (TDR100, Campbell Scientific, USA). Soil temperature (0-10 cm) and the air temperature were recorded with a needle thermometer. Rainfall was recorded half-hourly by an automatic recorder attached to the top of the eddy flux tower.

Throughout the soil N_2O flux observation period, soil samples were collected for analysis of NH_4^+-N and NO_3^--N, microbial biomass N (MBN), microbial biomass C (MBC), dissolved organic carbon (DOC), and total dissolved nitrogen (TDN). Mineral N was the sum of NH_4^+-N and NO_3^--N, and DON was the difference between TDN and mineral N.

Results

Fertilizer made a noticeable contribution to N_2O emissions in the rubber plantation. The average N_2O emissions from UNts (0.55 ± 0.092 mg N m^{-2} h^{-1}) and UNta (0.58 ± 0.11 mg N m^{-2} h^{-1}) were 39 and 41 times greater, respectively, than the lowest N_2O emissions from NNt (0.014 ± 0.0016 mg N m^{-2} h^{-1}). This shows that the fertilizer trenches were N_2O emission hot spots in the rubber plantation.The area-weighted N_2O flux from the fertilized rubber plantation showed a bimodal pattern. The area-weighted N_2O flux from the F area (0.046 ± 0.032 mg N m^{-2} h^{-1}) was significantly higher than that from the NF area (0.029 ± 0.026 mg N m^{-2} h^{-1}) in the rubber plantation.

The rubber plantation fertilization EF (1.96%) was within the range of global agricultural systems (1.25 ± 1.0%), but higher than the default factor (1.0%) reported by the IPCC.

In this study, with the exception of the UNta treatment, the N_2O flux correlated with soil temperature and soil moisture. Seasonal variations in the N_2O fluxes from UNta did not correlate well with soil temperature shows that the timing of the fertilizer application influences the relationship between soil temperature and N_2O flux.

The regression relationship between the area-weighted mean N_2O flux and soil water and moisture in the NF and F plots also indicates that soil temperature and moisture predominantly explain the variation in N_2O. Furthermore, fertilizer applications reduced the sensitivity of N_2O emissions to temperature and moisture variations because of variations in the N input to the substrate.

In this study, variations in the N and C fractions had very little influence on temporal variations in N_2O fluxes in any of the treatments.

The significant correlation between the area-weighted mean N_2O fluxes and NH_4^+-N, and the high percentage of spatial variation in the N_2O fluxes that was explained by NH_4^+-N suggests that the N_2O emission processes were controlled mainly by nitrification in the rubber plantation.

N_2O from the fertilized rubber plantation contributes 1227.6 kg C ha^{-1} yr^{-1} to the 100-year GWP, which accounts for 6.0% of the rubber plantation net ecosystem exchange (NEE) (9.04 t C ha^{-1} yr^{-1}).

Using the land use ratio, we calculated that for the GWP, the rubber plantation N_2O will offset 17.1% of the NEE of the primary tropical rainforest in Xishuangbanna, Southwest China. This indicates that as the area of the rubber plantation increases, the local tropical rainforest carbon sink will decrease because of the contribution of fertilizer in the rubber plantation, and there will be positive greenhouse effect feedbacks to the local climate, with particular influences on precipitation and temperature

Conclusions

By comparison study in fertilizer and no-fertilizer rubber plantation, our study showed that chemical fertilizer increase rubber plantation N_2O flux and change the seasonal dynamics of N_2O . The changing of tropical rainforests to fertilized rubber plantations may intensify climate warming by enhancing the regional N_2O emission.

This study only investigated one stage of the life cycle of a mature rubber plantation, so we have insufficient knowledge about the greenhouse gas emissions over the whole life of a rubber plantation. Future studies should investigate the whole life cycle of the rubber plantation to obtain more accurate information about the N_2O feedback from fertilized rubber plantations to the local GWP, and the accumulated greenhouse gas feedback to local climate change.

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POTENTIAL INHIBITOR EFFECT OF HIPPURIC ACID ON NITROUS OXIDE EMISSIONS FROM GRASSLAND ON A HEAVY CLAY SOIL

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Objectives

Of the total agricultural land under permanent grassland in Britain, approximately 50% occurs on soils with a shallow impermeable substrate. This type of heavy soil frequently occurs in western Britain where high levels of rainfall can lead to seasonal water logging where drainage has not been installed [1] greatly reducing the soil aerobic microbial activity and favoring the occurrence of anaerobic processes. Our research aimed to quantify the nitrous oxide (N_2O) emissions from cattle urine patches in a permanent grassland under heavy clay soil in the southwest of the UK, and to study the effectiveness of the hippuric acid (HA) content in artificial urine on reducing N_2O emissions under high water filled pore space (WFPS) soil conditions (> 85%).

Method

A field experiment was carried out during autumn 2015 on a permanent grassland comprised mainly with ryegrass (Lolium hybridicum) and white clover (Trifolium repens L.) at Rothamsted Research, North Wyke, Devon, UK (50:46:10N, 3:54:05W) on a clayey typical non-calcareous pelosol soil [2]. A randomized complete block experimental design with four treatments replicated three times was used. Each replicate plot included a gas sampling area with five static chambers installed (i.e., 60 chambers in total), and a soil sampling area of 1 m^2. Chambers comprised white polyvinyl chloride (PVC) open ended boxes with a volume of 0.032 m^3. The lid was fitted with a sampling port and a three-way valve for gas sampling. Treatments were applied on September 30th 2015 and consisted of a control (C) and artificial urine [3] with three different hippuric acid contents: 37 mM (HA1), 55.8 mM (HA2), and 90 mM (HA3). Urine was applied with a measuring cylinder at a rate of 5 L/m^2 (532 kg N ha^{-1}) inside each chamber using a watering can over the soil sampling area. N_2O was measured one day before treatment application and on 22 occasions after the application date during a total period of 79 days. Gas samples were taken between 11:00 and 14:00, four times a week for the first two weeks, twice weekly for the next five weeks and weekly thereafter. Atmospheric samples were collected each sampling day to provide background values. Chamber lids were placed on the chambers sequentially across the paddocks and after 40 min a gas sample was collected from each closed chamber via the sampling port using a plastic 50 mL syringe [4]. Samples were then placed in pre-evacuated 22 mL headspace vials using a hypodermic needle. Vial N_2O concentration was determined by gas chromatography. The N_2O flux data showed a skewed distribution so a log transformation as ln(flux+1) was applied. A one way analysis of variance (ANOVA) was performed on the transformed data and a pairwise comparison of treatments means was done for each sampling date. Soil samples were taken weekly from the soil sampling area to determine WFPS.

Results

The WFPS averaged 97.9% among all treatment replicate plots, with a range of 85-112.5 %, which assured a natural and high soil water saturation level during the entire experimental period.

N_2O daily fluxes showed no significant differences between control and HA treatments during the first 20 days of the experiment with values lower than 20 g of N_2O-N ha^{-1} d^{-1}. During the entire sampling period, fluxes from HA treatments did not show significant differences among them, but did differ from control ($p<0.01$) five times during the 30-days “emissive period” of the experiment (sampling days 20 to 50) when high emission peaks were measured. The highest peak appeared 22 days after treatment application (> 40 g of N_2O-N ha^{-1} d^{-1}). During the last period of the experiment (sampling days 57 to 79), fluxes remained low and with no differences between HA treatments and control.

Over the study period, cumulative emissions from HA1, HA2 and HA3 were 696, 790 and 627 g N_2O-N ha $^{-1}$, respectively, and were significantly higher than the emissions from the control ($p<0.05$), a total of 4.09 g N_2O-N ha $^{-1}$. Based on previous studies [5, 6] carried out on a silt loam soil and on a loam soil, we have ratified the 'no effect' of HA on the N_2O emissions on our heavy clay soil. Whereas the mitigation effect of HA has been proved in incubation experiments [7, 8] no effect has been demonstrated in situ.

Clough et al. [5] study under low WFPS (18-51%) and Krol et al. [6] under higher WFPS (60-80%), both carried out in the autumn, agree with our results which was carried out under much higher soil moisture levels. The current study addresses the knowledge gap of N_2O mitigation potential under favourable environmental conditions for N_2O loss i.e. >85% WFPS in a high clay soil and confirms that it is not a viable route for mitigating emissions at the end of the grazing season.

Conclusions

N_2O emissions from artificial urine in grasslands on heavy clayey soils under high water content conditions (WFPS >85%) were not affected by the addition of hippuric acid. Whereas the mitigation effect of HA has been proved in incubation experiments [7, 8, 9] we have ratified the no effect in situ.

References

[1] Granger, S.J. et al., 2010. Rapid Communications in Mass Spectrometry 5, 475-482.

[2] Avery, B.W., 1980. Soil Survey Technical Monograph No. 14, Harpenden, UK.

[3] Doak, B.W., 1952. Journal of Agricultural Science 42, 162-171.

[4] Chadwick, D.R. et al., 2014. European Journal of Soil Science, 65(2): 295-307.

[5] Clough, T.J., et al., 2009. Soil Biology and Biochemistry 41, 2222-2229.

[6] Krol, D.J. et al., 2015. Science of the Total Environment 551, 362-368.

[7] Bertram, J.E. et al., 2009. Global Change Biology 15, 2067-2077.

[8] Van Groenigen, J.W. et al., 2006. Soil Biology and Biochemistry 38, 2499-2502.

[9] Kool, D.M. et al., 2006. Soil Biology and Biochemistry 38, 1021-1027.

NITRATE LEACHING UNDER WINTER OILSEED RAPE AS AFFECTED BY SOWING DATE AND EARLY INCORPORATION OF SLURRY

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Objectives

In previous studies, nitrate leaching has not increased when winter oilseed rape, sown at normal to late sowing dates (18-25 August) directly after ploughing, is fertilised with 30 -60 kg nitrogen per hectare at sowing. The nitrogen uptake in late autumn was obviously enough so that fertiliser or soil mineral nitrogen would not cause increased leaching. However, there is an increased risk for higher leaching after early cultivation and fertilisation followed by late sowing, since the nitrogen uptake may be too late and too small. In order to investigate how nitrate leaching is affected by early and late sowing after 1) early ploughing and slurry application and 2) early ploughing and mineral nitrogen fertiliser applied at sowing, two field experiments were performed 2012/2013 and 2013/2014 on a sandy soil at Götala farm, near Skara in Västergötland, Sweden.

Method

The experiments were of randomized block design, with four blocks and five treatments. The previous crop was a two year old grass-clover ley in the first experiment and a barley crop following a grass-clover ley in the second experiment. The soil was ploughed 30 July, after dairy slurry application. Dairy slurry (60 and 100 kg total nitrogen per hectare, in the first and second experiment respectively) was applied on 30 July in both the treatment with early sowing (1 August) and the treatment with later sowing (20 August). Treatments with mineral nitrogen fertilisers were also ploughed on 30 July and 60 kg nitrogen (50 % nitrate, 50 % ammonium) per hectar was applied at each sowing date. In spring, 100 kg nitrogen per hectar (mineral fertiliser) was applied to the winter oilseed rape. Soil water samples were taken regularly from suction cups at 80 cm soil depth for nitrate analysis. For calculation of nitrate leaching the measured drainage runoff was used from a nearby leaching experiment with a tile draining system on a similar soil. The yearly drainage, 1 July-30 June 2012/2013, was 190 mm (normal) and mainly in the period September-January. The total drainage runoff 2013/2014 was low, 120 mm and occurred mainly in the period December-February.

Results

In both experimental years the nitrogen uptake in late autumn was similar regardless of sowing date and if slurry or mineral nitrogen fertiliser had been applied. The reason was a long and warm autumn in 2012 that enabled the later sown crop to catch up with the early sown. Similarly, a dry period between the early and late sowing date in 2013 enabled the later sown crop to catch up with the early sown in that year. There were no differences in yield between early and late sowing. Due to dry periods in June 2013 and July 2014, water was limiting yield and may have contributed to reduce differences in yield potential between sowing dates. In early sown oilseed rape other factors such as plant death due to frost in the first experiment and a lot of weed in the second experiment, may have limited the yield levels. The effect on yield from slurry or mineral nitrogen fertiliser at sowing of oilseed rape was similar, 360-740 kg/ha in yield increase.

The yearly nitrate leaching under early sown and fertilised oilseed rape was just as small as for unfertilised both years, regardless if slurry (60 or100 kg total nitrogen per hectare) was ploughed in just before sowing or mineral fertiliser (60 kg nitrogen per hectare) was applied at sowing after ploughing. Nitrate concentration in soil was generally higher after the late sowing date than the early. This caused the yearly nitrate leaching to be 52 % higher after late sowing than early both years (significant higher in one year), regardless if slurry (30 July) or mineral fertiliser (at sowing) was applied. The reason was most likely that ploughing date was the same for both sowing dates (30 July) and that soil nitrogen, mineralised in soil after ploughing, moved down the soil profile and was out of reach for the crop sown 20 August and therefore caused higher leaching than the earlier sowing.

Conclusions

An equal effect on nitrogen uptake in late autumn and yield can be obtained for application of mineral nitrogen fertiliser (60 kg total-N/ha) or slurry (60 or 100 kg total-N/ha) at early sowing after ploughing.

Nitrate leaching can be expected to increase when sowing of oilseed rape is delayed after ploughing, regardless if fertilised with mineral nitrogen fertiliser at sowing or slurry three weeks earlier.

Sowing of oilseed rape directly after ploughing and fertilisation (slurry or mineral fertiliser), instead of three weeks later, can be an efficient way of reducing the risk for nitrate leaching during autumn and winter, especially at sites where leaching can be high e.g. on light textured soils and soils with high nitrogen mineralisation.

DEVELOPING ‘N-CIRCLE’: A PRIORITISED AGENDA TOWARDS ‘CLOSED-LOOP’ AGRICULTURAL NITROGEN CYCLING FOR CHINA AND EUROPE

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Objectives

China’s agriculture is increasing its productivity rapidly, but low efficiency of nitrogen (N) use through over-fertilization increasingly threatens its sustainability [3]. Agriculture in Europe, by contrast, has had static production for twenty years but has a strong knowledge-base and infrastructure for pollution control. A new Virtual Joint Centre (VJC) between the UK and China, ‘N-Circle’, has been established to enhance the sustainability of N use in China, whilst also testing how agricultural productivity might be released from N use constraints in Europe. This paper describes the VJC’s ‘N-Circle’ philosophy and approach (Materials & Methods), its component aims and activities (Results) and its feasible outcomes (Conclusions).

Method

The N-Circle VJC is led by the University of Aberdeen with four research partners from the UK and nine from China; over the three years from 2016 it is funded by almost €4 million from the BBSRC and Newton Fund, and over €5 million from sources in China. Whilst easy changes may be possible initially, systematic changes will take more time and require broader engagement. Thus the VJC is set up to become stakeholder-driven, branded and self-perpetuating beyond the life of the project.

The vision is of closed-loop N cycling, achieved not only by individual innovations, but by promoting high-level appreciation of N cycling such that macro-synergies are exploited. Examples are co-designing (i) application methods for fertilisers (and manures) with their chemical formulation, (ii) fertiliser management with crop breeding, (iii) crop breeding with food processing and feed formulation, and (iv) livestock feeding with manure composition and management [7].

Thus the VJC comprises bilateral multidisciplinary teams (described below) with expertise along an innovation pipeline feeding into a multi-organisation change agenda, identified by an ‘N Circle’ quality mark. The research teams are undertaking an integrated programme of laboratory analyses, field experiments, modelling and outreach. Target agro-ecosystems include the highly populated crop production region of the North China Plain experiencing critical water and air pollution due to overuse of N (>400 kg ha^1 yr^1) [5], as well as the North Eastern, North Western and South Western regions where N overuse can also be serious (100-250 kg N ha^1 yr^1).

As the VJC’s programme gains momentum, new N cycling strategies, incorporating the new innovative approaches, will be compared with ‘Business as Usual’ strategies using the VJC’s modelling framework, and optimal strategies will be resolved and promulgated with local policy-makers and other stakeholders to achieve the most effective attainable impacts within each region. New strategies can draw upon features of local agricultural knowledge, beliefs and practices and will build-in new systematic information to attain sustainability.

Results

N-Circle’s (NC) bilateral teams are working at strategic scales on virtual system integration (NC1), system impacts (NC7), and implementation (NC8), and also at finer scale on innovations within each system-sector (NC2-6). Team activities are:

NC1: Developing options for near-closed-loop N cycling.

The process-model ECOSSE [1] will integrate sector-specific outcomes (NC2-6), analyse whole-system sensitivities and uncertainties, and summarise relationships for incorporation in decision tools based on the Cool Farm Tool [4].

NC7: Demonstrating feasible impacts through up-scaled studies.

Findings from plot, field and farm scale (NC2-6) will be expanded to catchment scale using spatially distributed data, so that policy options can be explored and optimised.

NC8: Providing out-reach and dissemination to farmers, extension services, and policy-makers.

Relationships, organisations, networks and branding will be established, with governance that ensures the VJC will persist beyond the project, becoming stakeholder-driven, principled, branded and permanent.

Concurrently, sector-level innovation teams will explore technical targets expected to provide largest or most synergistic impacts on N inputs and N emissions, described here in order of dependence (NC6 to NC2):

NC6: Reducing end-user N demand and N excretion

A socioeconomic analysis and animal experiments will explore how the content and types of N in foods and livestock feeds might be optimised, to maximise N-retention and minimise N-excretion, and how successful approaches (such as feeding high-energy, low-protein grains) might be implemented in China.

NC5: Defining mechanisms to reduce crop N demand, and crop-stock transfers, by

(c) Using artificial microRNA transgenes to genetically tailor seed proteins more closely to requirements in foods and feeds, hence minimising N export in grain and crop demand for N.

(b) Testing whether N-efficient canopy phenotypes excel in Carbon (C) uptake, assimilation or partitioning, using C^{13} and N^{15} isotopes, and an endophytic diazotroph inoculant [2].

(a) Developing a canopy N model that enables real time, weather-related optimisation of crop N supply for C assimilation, and supports extant canopy sensing technologies.

NC4: Devising rotations and agronomic practices that maximise leguminous N capture

Exploring how amounts of N fixed (and transferred to adjacent non-legumes) relate to photosynthate availability (affected by light capture and competing sinks), and defining optimal legume-based rotations accordingly.

NC3: Providing options to reduce reenhouse gas (GHG) emissions arising from N applications

Testing how nitrite relates to other soil mineral N species. Then modelling mineral N dynamics, nitrous oxide (N_2O) emissions and crop uptake so to identify practical strategies that minimise N_2O without diminishing economic crop responses to added N.

NC2: Defining practices to enhance recovery of applied N

Testing short-term soil mineral N responses to C & N applications as fertiliser or manure so to devise techniques that temporarily perturb N immobilisation, hence enhance crop N recovery.

Conclusions

The ultimate outcomes of the ‘N-Circle’ VJC will be (i) greater understanding of the mechanisms underpin-ning agricultural management for sustainable N cycling, (ii) a rigorous evaluation of the potential for sustainable N cycling to deliver future sustainable intensification of Chinese and European agriculture and (iii) an agenda to achieve this. Exciting technological synergies are feasible if the power of multiple innovations in molecular, chemical, micro-biological, agronomic and engineering technologies can be integrated and upscaled into economically viable systems at field, farm and regional scales.

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References

[1] Bell, MJ., etal. 2012. Nutr. Cycl. AgroEcosys. 92, 161

[2] Cocking, E.C. *et al.* 2006. *In Vitro Cell. Dev. Biol. Plant* 42, 74-82.

[3] Duan, Y., *etal*. 2014. *Field Crops Res*. 157, 47-56.

[4] Hillier J et al. 2011. Environ. Model Software 26, 1070-1078

[5] Norse, D. & Ju, X. 2015. *Agric. Ecosys. Env*. 209, 5-14

[6] Smith, P. 2013. *Global Food Sec.* 2, 18-23

[7] Sylvester-Bradley, R., & Withers, P. 2012. Proc. Fert. Soc. 700.

CHARACTERISTICS OF NITROGEN BALANCE IN OPEN-AIR AND GREENHOUSE VEGETABLE CROPPING SYSTEMS OF CHINA

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Objectives

Vegetable production in China has increased significantlyover the past three decades. In general, vegetable fields are often characterized by intensive cropping rotations (multiple harvests within a year) and high nitrogen (N) application rates. Hence, given the increased cultivation of vegetables and its environmental impacts, the objectives of the present study were to(i) identify and assess the N balances in the vegetable cropping systems of China, (ii) determine the primary N loss pathways as affected by N fertilizer rates and NUE, and (iii) discuss the potential pollutants in open-air and greenhouse vegetable cropping systems.

Method

According to the Organisation for Economic Cooperation and Development (OECD)methodology[1], inorganic fertilizers, livestock manure, biological N fixation, and atmospheric deposition are considered as inputs. Outputs included crop harvest, NH3 volatilization, N leaching and runoff, soil accumulation, and gaseous loss from nitrification and denitrification. The N use efficiency was calculated as total N(N in inorganic fertilizer plus N in manure) uptake by vegetables from treatments with applied N fertilizer.

Data on the total area of vegetable cultivation in China in 2010 was obtained from the National Bureau of Statistic of China [2]. We collected N flux data (for example, application rates of chemical fertilizer, crop production, and NH3 volatilization) of open-air and greenhouse vegetable cropping systems from field measurements taken during the vegetable growing season that are published in peer-reviewed Chinese and English journals. For example, a total of 42 and 65 experimental datasets for chemical N fertilizer input in greenhouse and open-air cropping systems, respectively, from 17 publications, were considered in this study.

Results

Evaluation results showed that N balances in the vegetable cropping systems of China were characterized by high fertilizer N input, large N losses, and N storage in the soil. Total N input in open-air and greenhouse vegetable cropping systems was 5.44 and 2.60 Tg, respectively, in 2010, with chemical N fertilizer dominating this total input. More than 60 % of total N input was lost into the environment through gaseous loss from nitrification and denitrification, leaching, runoff, and NH3 volatilization. Greenhouse vegetable cropping systems can produce more fresh vegetables than open-air systems but require higher N inputs, accumulate more N in the soil, and pose a greater impact on the environment. The NUE of greenhouse vegetable cropping systems was less than 20 %, much lower than that of open-air systems. The latter was similar to the NUEs of the main cereal crops in China but was still substantially lower than the world average NUE. Large inputs of N to vegetable cropping systems with lower crop N uptake will lead to environmental problems such as groundwater pollution and soil acidification.

Conclusions

In our study, estimation of N balances in both open-air and greenhouse vegetable cropping systems in China was established. Results showed that the total N input in open-air and greenhouse vegetable cropping systems in 2010 was 5.44 and 2.60 Tg, respectively. Chemical fertilizer N input in the two cropping systems was 201 kgN ha^{-1} per season (open-air) and 478 kg N ha^{-1} per season (greenhouse). The N use efficiency (NUE) was 25.9±13.3 and 19.7±9.4 % for open-air and greenhouse vegetable cropping systems, respectively, significantly lower than that of maize, wheat, and rice. Approximately 30.6 % of total N input was accumulated in soils and 0.8 % was lost by ammonia volatilization in greenhouse vegetable system, while N accumulation and ammonia volatilization accounted for 19.1 and 11.1 %, respectively, of total N input in open-air vegetable systems.

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References

[1] Organisation for Economic Co-operation and Development, 2008. Environmental performance of agriculture in OECD countries since 1990. Organisation for Economic Cooperation and Development, Paris

[2] National Bureau of Statistic of China. 2011. China statistical yearbook 2011, China Statistic Press, Beijing

DISSIMILATORY NITRATE REDUCTION PROCESSES AND THEIR CONTRIBUTION TO NITROGEN LOSS IN CHINESE PADDY SOILS

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Objectives

In paddy fields, nitrogen (N) is generally the central element limiting rice production and the waterlogged conditions during the main stage of rice growth provides unique environment for dissimilatory nitrate reduction processes including denitrification, anaerobic ammonium oxidation (anammox) and dissimilatory nitrate reduction to ammonium (DNRA). In this study, soil core incubations and slurry experiments with ^{15}N tracer technique were performed to quantify the rates of denitrification, anammox, and DNRA processes in 11 typical Chinese paddy soils aiming at: 1) evaluating the relative contribution of denitrification, anammox, and DNRA to total nitrate removal and 2) elucidating the key influencing factors regulating the dissimilatory nitrate reduction processes in the paddy soils.

Method

In the present study, 11 representative soil samples were collected across China covering 11 parent materials. The physico-chemical and biological properties including pH, total C and total N, soil organic carbon (SOC), soil nitrate and ammonium, soil sulfate, particle distributions, abundances of denitrification functional genes (*narG*, *nirS*, *nosZ*), and abundances of anammox functional genes (*hzsB*) were sequentially analyzed. Net N2 fluxes in these soils were determined by soil-core incubation combined with N2/Ar technique as described by Li et al. [1]. Potential rates of denitrification and anammox in the soils were measured via slurry experiments in combination with ^{15}N tracer technique [2]. Potential DNRA rates were determined by the combination of the ammonium oxidation technique and membrane inlet mass spectrometry (MIMS) analysis [3]. All the experiments were performed in triplicates.

Results

The net N_2 fluxes measured by soil-core incubation in combination with N_2/Ar technique ranged from 9.07 to 29.86 nmol N g^{-1} h^{-1}, while the rates of denitrification measured by ^{15}N tracing technique ranged from 2.37 to 8.31 nmol N g^{-1} h^{-1}, implying denitrification rates based on ^{15}N tracer significantly underestimated the nitrogen removal rates compared with soil-core incubation. The potential rates of anammox and DNRA measured by ^{15}N tracing technique ranged from 0.15 to 0.77 nmol N g^{-1} h^{-1} and 0.03 to 0.54 nmol N g^{-1} h^{-1}, respectively. Denitrification, anammox and DNRA play different role in controlling the fate of nitrate in the paddy soils, both denitrification and anammox results in permanently nitrate removal from paddy soils, whereas DNRA converts nitrate into ammonium, which is biologically available and less mobile than nitrate and thus contributing to N conservation in paddy soils. Among the nitrate reduction processes in the paddy soils, denitrification is predominant contributing 76.8-92.1% to total nitrate reduction, as compared to 1.4-9.2% for Anammox and 0.5-17.6% for DNRA. Net N_2 fluxes, denitrification and anammox rates were significantly correlated with soil organic carbon (SOC) content, soil nitrate concentration, and the abundance of *nosZ* genes, whereas DNRA rates showed significantly correlation with C/N ratios, DOC/NO_3- and sulfate concentration. The positive correlations between net N_2 fluxes and denitrification rates with the contents of SOC and nitrate were in good agreement with previous studies [4], which were probably related to the supply of C sources and substrates for denitrifying bacteria. The closely relationship between DNRA and DOC/NO_3- indicating that DNRA is prone to occur in environment with higher labile C sources to nitrate, in consistent with previous studies [5, 6].

Conclusions

Denitrification was shown to be the predominant pathway for nitrate removal in the paddy soils, averagely contributing 85% of the total nitrate reduction. In contrast, anammox and DNRA played minor roles in the nitrate removal, on average accounting for 5.3% and 9.1% of the total nitrate reduction. The net N_2 fluxes, denitrification and anammox rates in the tested soils were significantly correlated with SOC, nitrate and *nosZ* abundances. DNRA was closely related to C/N ratios, DOC/NO_3- and sulfate concentration. This study provides the first results of the dissimilatory nitrate reduction processes and the associated contribution to nitrate removal in the paddy soils strengthening the understanding of nitrate dynamics in paddy field.

References

[1] Li et al., 2013. J. Soils Sediments 13, 783-792.

[2] Risgaard-Petersen et al. (2003). Limnol. Oceanogr-Meth. 1, 63-73.

[3] Yin et al. (2014) Environ. Sci. Technol. 48, 9555-9562.

[4] Yang et al. (2015) Appl. Environ. Microbiol. 81, 938-947.

[5] Lu et al. (2015) J. Soils Sediments 15, 1169-1177.

[6] Rutting et al. (2011) Biogeosciences 8, 1779-1791.

MORE BENEFIT FROM COVER CROPS BY HARVESTING

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Objectives

The area of cover crops (CCs) increased greatly in Finland in 2015. Last growing season CCs were grown on about 250 000 ha, mainly because of subsidies in agri-environmental program had been raised, currently 100 € ha^{-1}. However, growing CCs could be intensified on most of the fields and thus to reach better effect in reducing nitrogen (N) leaching or fixing N from atmosphere. This would diminish eutrophication in waters and, in case of legume CCs, need for N fertilizers. Further, good growth of CCs is also related to positive effect on soil fertility. A field study was started in 2015, aiming at intensified use of CCs, by means of harvesting the crop in autumn. Feasibility of the biomass for forage or biofuel production will be examined.

Method

Keeping the nutrients in the fields, instead of waters –project ('Nutrient resource') aims at intensifying nutrient recycling in agriculture and decreasing nutrient load to waters. The study introduced here strives for the goal by intensifying cropping systems with help of harvesting CCs in autumn.

Two separate fertilization systems were included in the trial: 'an arable farm' was fertilized solely with synthetically produced fertilizer, and 'a livestock farm' was fertilized with the manure and synthetic fertilizer. The amount of N given in mineral fertilizer was 70 kg ha^{-1} for the 'arable farm' and 45 kg ha^{-1} for the 'livestock farm'. The latter got additionally 40 kg ha^{-1} soluble N in manure.

In both systems Italian ryegrass (*Lolium multiflorum* Lam.) with two seeding rates (7 and 20 kg ha^{-1}), a mixture of perennial grasses {English ryegrass (*Lolium perenne* L., 6 kg ha^{-1}), timothy (*Phleum pratense* L., 2 kg ha^{-1}), meadow fescue (*Festuca pratensis* Huds., 4 kg ha^{-1}) and tall fescue (*Festuca arundinacea* Schreb., 4 kg ha^{-1})}, red clover (*Trifolium pratense* L., 6 kg ha^{-1}) and a mixture of red clover (6 kg ha^{-1}) and Italian ryegrass (7 kg ha^{-1}) were undersown in spring barley (*Hordeum vulgare* L.). In addition, oilseed radish (*Raphanus sativus* L., 20 kg ha^{-1}) was sown after barley harvest in two treatments, either after barley with red clover or without undersowing. Moreover, white clover (*Trifolium repens* L.) was undersown into the 'arable farm'. Barley was harvested for grain, but in one treatment at the 'livestock farm' it was harvested earlier as whole crop silage. The undersown crop was red clover and Italian ryegrass mixture.

Grain yield of barley and harvested biomass of CCs were measured. In addition, CC yields were analysed for feeding values. Plant samples were taken in order to study competition between main crop and undersown crop. Small silage samples for biofuel studies in laboratory were taken, too. Total N was examined both in barley grains and CC biomass.

Results

Rainy spring delayed sowing of the trial until late May. Barley was harvested one month later than usual because of slow accumulation of temperature sum until warm period in August. This caused rather short time for CCs to grow after the barley was harvested on 27th August. Oilseed radish was sown too late, in early September, to grow enough. Both barley and CCs grew well through the season. However, clovers obviously suffered somewhat of herbicide treatment.

The yields of CCs consisting of grasses were higher in the 'livestock farm', obviously because of higher soluble N and possibly because of N release from manure in late summer. Also barley benefited of higher N application.

Grain yield of pure barley was 5400 kg ha^{-1} in the 'arable farm' and 5750 kg ha^{-1} in the 'livestock farm'. Grain yield was affected by competition of the undersown CC, and mostly adhered to opposite order with CC yield. Italian ryegrass decreased the grain yield by 800 – 900 kg ha^{-1} at seeding rate 20 kg ha^{-1}, and by 350 – 550 kg ha^{-1} at seeding rate 7 kg ha^{-1}. In the 'livestock farm' grain yield was 270 kg ha^{-1} lower when red clover was undersown compared to no undersowing, but in the 'arable farm' it was 100 kg ha^{-1} higher with red clover. White clover did not show any effect on barley grain yield.

Highest CC dry matter yield in the 'livestock farm', about 2000 kg ha^{-1}, was reached when seeding rate of 20 kg ha^{-1} for Italian ryegrass was used. The yield was 300 kg ha^{-1} lower with lower seeding rate. Perennial grasses yielded about 1250 kg ha^{-1}. Yields for all grass species were 400 – 600 kg ha^{-1} lower in 'arable farm' compared to 'livestock farm'. Clover yields were low, 500 – 700 kg ha^{-1}, despite of farming system. CC yields included straw from barley stubble, the share of which was the higher the lower was the total yield. Barley was cut three weeks earlier in the whole crop silage treatment. However, the biomass of CC remained low. Distinctly the CC did not compensate lost biomass in earlier cut with extra growth after it. The season was dry right after the whole crop silage harvest which might have resulted to the performance of the CC in that treatment.

The N content of the harvested CC biomass was greatly affected by the straw from barley stubble. When barley was harvested for whole crop silage, the N content of CC was nearly 3%, otherwise 1.5% or less. Obviously straw material in otherwise green CC biomass decreases usability for forage. The highest biomethane potential (400 dm^3 kg^{-1} DM) was obtained with a mixture of perennial grasses.

Conclusions

New means to use CCs are desired, when improving their positive effects on N management and soil fertility. According to first results of Nutrient resource -project, biomass production of undersown CCs could be adequate for profitable harvest in late autumn. However, when the target is high biomass yield in autumn by high yielding undersown CC species, grain yield of the main crop inevitably decreases. Therefore after main crop harvest established cruciferous CC is a feasible method but only when the main crop is harvested not later than in early August. Results from quality analysis of the CC biomass have to be studied carefully before conclusions of the usability for feeding and biofuel use. However, according to first results, CCs seem to have a high biomethane potential and provide an excellent raw material for biogas production. When having data from the projects second year (2016), a holistic analysis is carried out to evaluate the value of the system for the Finnish agriculture.

ORGANIC VERSUS CONVENTIONAL- CAN δ^{15}N BE USED AS AN INDICATING PARAMETER IN GARLIC, SWEET PEPPER AND CARROT?

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Objectives

Since organic farming has expanded and organic products attain higher prices, mislabelling and adulteration have become the most serious problems in many areas of food industry. The application of synthetic nitrogen fertilizers with δ^{15}N values close to 0‰ shall result in the δ^{15}N of plants grown under conventional production systems being lower than of those grown under organic conditions. The aim of our work was to investigate whether the N isotopic composition (δ^{15}N) of produce can reveal the use of synthetic nitrogen fertilizer in organic production using different N fertilizer types and combinations of them in order to leave a specific δ^{15}N fingerprint in garlic (*Allium sativum* L.), sweet pepper (*Capsicum annuum* L.) and carrot (*Daucus carota* subsp. *Sativus* L.). The influence of different fertilizing regimes (using synthetic and organic fertilizers with different δ^{15}N) on the N isotopic composition of vegetables was evaluated in two pot and one field experiment.

Method

Experimental design

A pot experiment with garlic and sweet pepper was performed in a greenhouse, while carrot was grown in the field. Six treatments were applied in a completely randomised design with four replications for garlic, three replications for sweet pepper and five replications for carrot, as follows: an unfertilised control (C), two single organic fertilizations with different organic fertilizers (Org 1, Org 2), a single synthetic fertilization (S) and combinations of organic and synthetic fertilizations (Org 1 + S, Org 2 + S). Within every treatment there were three biological replications for garlic, two for sweet pepper and three for carrot. The same organic fertilizers with different δ^{15}N (Org 1 with δ^{15}N = 9.85‰ and Org 2 with δ^{15}N = 3.9‰, respectively) were applied in all three experiments. As single synthetic fertilizer (S) synthetic fertilizer with δ^{15}N = 0.4‰ was used.

Analysis

At each sampling event, three plants were destructively sampled for each treatment. Samples were dried in an oven at 60°C until constant weight. The analysis was carried out using a Europa Scientific (U.K.) Europa 20-20 continuous flow isotope ratio mass spectrometer with ANCA S-L unit in order to determine nitrogen isotope ratio and N content. About 5 mg of homogenised samples for δ^{15}N and N content analysis were weighed, compressed in a tin capsule and introduced into autosampler. Samples were analysed in duplicates and the average was adopted. If the difference between two values for δ^{15}N exceeded 0.2‰, the analysis was repeated. The accuracy of the δ^{15}N isotopic analysis was checked with the certified reference materials and in-house standards. Additionally, δ^{15}N and N content of soil used in pot experiments were tested. Basic statistics included analysis of variance by ANOVA with Duncan's test for comparisons of means.

Results

No statistically significant difference was found between δ^{15}N values and N content of soil, fertilized with organic or synthetic fertilizers or combination of them in pot experiments with garlic and sweet pepper.

In garlic, statistically significant differences were found in mean δ^{15}N values between Org 1 (with mean δ^{15}N

= 6.15 ± 0.4) and all the other treatments (C with $\delta^{15}N = 3.3 \pm 0.3$; Org 2 with $\delta^{15}N = 4.4 \pm 0.3$; S with $\delta^{15}N = 3.0 \pm 0.3$; Org 1 + S with $\delta^{15}N = 4.7 \pm 0.5$; Org 2 + S with $\delta^{15}N = 3.4 \pm 0.6$), reflecting the higher $\delta^{15}N$ value of organic fertiliser Org 1. Statistically significant difference in mean $\delta^{15}N$ values between garlic fertilized with synthetic fertilizer and both organic fertilizers was observed. Combined treatment Org 1 + S was resulted in significantly different $\delta^{15}N$ value than conventional treatment (S), in contrast to Org 2 + S, where the difference was not significant. In comparison with control, significant differences were observed in Org 1, Org 2 and Org 1 + S regimes, meanwhile no apparent differences were determined in S and Org 2 + S regimes. Similar to $\delta^{15}N$ values, the highest N content was determined in garlic treated with Org 1 (2.4 ± 0.2 g/ 100 g) and Org 1 + S (2.3 ± 0.0 g/ 100 g), showing statistically significant difference in comparison with other treatments, including treatment with synthetic fertilizer and control.

In sweet pepper and carrots, no statistically significant differences were found nor in $\delta^{15}N$ values, neither in N content irrespective of the fertilization regime.

Conclusions

Considering the obtained results, $\delta^{15}N$ of sweet pepper and carrot alone could not be used even as a rough marker to discriminate between organic and conventional production, while $\delta^{15}N$ in garlic showed a statistically significant difference, reflecting the higher $\delta^{15}N$ values of organic production compared to that of conventional production. However, the addition of synthetic fertilizer to basal organic fertilization could not be detected by this method. Results obtained suggest that the method was found insufficiently sensitive to detect low or moderate rates of synthetic N fertiliser which could be illegally applied to organically grown garlic, sweet pepper and carrot and it seems not possible to detect and identify the combined use of organic and synthetic fertilisers. Consequently, $\delta^{15}N$ could not be used as indicator of organic way of production by itself, but only as a supporting, additional indicator in combination with other parameters.

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PLANT AND MICROBIAL BIOMASS, NITROUS OXIDE AND CARBON DIOXIDE EMISSIONS IN INTENSIVELY MANAGED PERMANENT GRASSLAND UNDER CONTROLLED CONDITIONS AS AFFECTED BY NITROGEN LEVEL

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Objectives

Nitrogen fertilization of grassland aims at maximizing yield and feed quality. However, fertilization also has to reduce negative side effects, such as gaseous and liquid N losses. It is therefore necessary to predict the biomass, its N uptake and the N mineralization. Consequently, a plant growth model for grassland needs to be combined with an N mineralization model. Our study contributes to a project developing an integrated model for N uptake prediction in grassland. Therefore, the N status of different soil and plant pools and N losses have to be assessed in relation to cuts at different times. The objectives were to (1) establish the N response curve of permanent grassland under controlled growth conditions, (2) evaluate the relationship between biomass and vegetation indices as measured with optical sensors, (3) estimate the fertilization-associated N_2O losses and (4) effects on the soil microbial biomass as the driver of mineralization in soils.

Method

The effects of inorganic N fertilization on plant growth and on C and N mineralization, microbial biomass and soil respiration in grassland soils was investigated in a 100-day pot experiment. Soil samples and plant sods were taken from an unfertilized control plot of a field trial on permanent grassland dominated by *Lolium perenne* L. in Kleve, Germany (51°46’54” N, 06°09’47” E, 13 m a.s.l.). The soil of the field trial is classified as gleyic Cambisol and silty clay. In the greenhouse, the fresh soil samples and sods were allocated to pots, each with a volume of 0.01 m^3 and adjusted to a water holding capacity of 50%. Reflecting the field trial design, samples were divided into three nitrogen fertilization levels and an unfertilized control with 7 replicates for each treatment. To this end, calcium ammonium nitrate was applied at 85, 170 and 340 kg N ha^{-1}. To mimic field conditions, fertilizer was applied in four portions at the beginning of the experiment and after each cut. During the greenhouse experiment, all pots were equipped with sensors monitoring soil temperature and gravimetric water content. Gas fluxes of CO_2 and N_2O were measured two to three times a week according to a closed dynamic chamber principle using a photo-acoustic gas analyser (Innova 1412i). Before each cut, the normalized differenced vegetation indices were determined using commercial hand-held optical sensors as means of indirect detection of plant biomass and N status. After cutting, the aboveground plant biomass was weighed. At the end of the experiment, soil samples were taken to analyse the extractable organic C and inorganic N fractions and the microbial biomass N (MBN) and C (MBC). Microbial biomass was estimated by chloroform-fumigation extraction including a pre-extraction step.

Results

Soil respiration rates were constant over time for all four fertilizer levels and cuts indicating no influence of inorganic fertilizer application on mineralization processes. However, N_2O fluxes showed significant differences between fertilizer treatments as expected. Thus, the cumulative N_2O flux of the treatment with 340 kg N ha^{-1} had increased 2.5-fold over the control plot on average; the application of 170 kg N ha^{-1} still showed 1.5-fold higher values in comparison to the control. Next to differences in total fluxes, an abrupt rise of the flux rate directly after fertilization was determined. Over time, emission rates decreased continuously until the next cut. Thus, our results confirmed former observations, that N_2O emissions in intensively managed grassland are less influenced by mowing, but rather by the N level. The N input therefore will be an important model parameter helping in predicting N losses.

On the other hand, MBC and MBN slightly decreased with increasing fertilization. Yet, contents of MBC ranged from 429 µg C (g soil)$^{-1}$ to 743 µg C (g soil)$^{-1}$, reflecting the resilience of the high microbial biomass in this intensively managed permanent grassland. In contrast to the microbial biomass, a clear increase of the inorganic N content with elevated fertilizer input was detected as expected. Contents of inorganic N at the largest fertilizer level were on average 43% higher than the control and 30% higher than the application with 85 and 170 kg N ha^{-1}, which has to be considered for future model development. Similarly, aboveground biomass increased with increasing fertilizer level. This difference was detectable using optical sensors and the normalized differenced vegetation index.

Conclusions

We were not able to detect any significant effect of inorganic N fertilization on the soil microbial biomass, probably due to its high level and the high soil organic C content of the grassland soil, which might buffer any possible effects. However, the amount of applied N influenced the activity of the microorganisms responsible for N_2O production. The expected clear relationship between N input and N_2O emissions on the one hand and plant biomass on the other hand under optimal moisture conditions in the presented experiment, will be used for future models aiming at N uptake prediction in permanent grassland. Future studies will further elaborate on the relationship between optical sensor data, N input, biomass development and N_2O emissions to provide a reliable data basis for the models.

GLOBAL AYALYSIS OF LIVESTOCK PRODUCTION AND NUTRIENT BALANCES

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Objectives

Livestock production is rapidly responding to changing markets and technological developments in many countries in the world. These responses have large influences on nitrogen (N) and phosphorus (P) balances, depending in part on the level of integration between crop and livestock production at regional and national levels. Integration of crop and livestock production is commonly defined by (i) the fraction of animal feed consumed that is produced on the farm or domestically, and (ii) by the reliance on external nutrient inputs. Our main hypothesis is that countries with rapidly increasing livestock numbers in specialized systems have rapidly increasing N and P surpluses, and that countries with low and stable livestock numbers have low N and P surpluses.

Method

Here we report on a global analysis of changes in livestock production, N and P surplus at country level between 1961 and 2010, using data from FAOSTAT and World Bank, and additional model calculations.

Results

We found that livestock density (LSU) and human population density increased roughly at the same rate globally, but with huge differences between countries. Countries with high export orientation ratio (EOR) of livestock products increased livestock numbers more strongly than countries without export. Extremely rapid increases in livestock number and extremely high LSU occurred in some Arab countries. Countries with a high livestock/crop product ratio and a high import orientation ratio (IOR) are characterized by limited agricultural land, high GDP and high population density per unit agricultural land, as in some Arab countries. We found positive relationships between LSU and N and P surpluses, suggesting indeed that livestock production has a greater influence on N and P surpluses than crop production within countries. There is however a large variation, which is in part related to differences between countries in the level of integration between crop and livestock production. As the information about the level of integration is scarce, we derived a number of proxies at national level, and related these proxies to the level of integration and N and P balances. We propose a two-dimensional, graphical approach, plotting the total 'new' N and P inputs on the X-axis and the total harvested crop and total animal production (in terms of N and P) on the Y-axis. We show that these relationships greatly differ between countries and relate to the levels of integration of crop and animal production, and animal protein intake per capita.

Conclusions

In conclusion, N and P surpluses at national level are related the level of integration between crop and animal production systems. Most ruminants by nature live in integrated systems, while pig and poultry systems increasingly become specialized, especially in rapidly developing countries.

SOIL MINERAL NITROGEN CONTENT AND NITROGEN UPTAKE BY CROPS AFTER THE USE OF DIFFERENT ORGANIC FERTILIZERS

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Objectives

Nitrates are one of the most critical contaminants of waters. In order to protect water sources from nitrates of agricultural origin a set of rules has been implemented on European level (Nitrate directive). In the Czech Republic so called nitrates vulnerable areas account for more than 40 % of total agricultural land. The Action plan, valid in these areas, asks for proper management concerning nitrogen fertilization. The Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ) is a control authority for the issues of Nitrate directive. With substantial growth in numbers of biogas plants in the Czech Republic has an urgent need of proper digestion residues management emerged.

The aim of this paper was to evaluate the impact of digestate, slurry and compost on mineral nitrogen content in topsoil, yield and nitrogen uptake by silage maize, spring barley and winter oilseed rape in vulnerable areas management.

Method

Field experiments were established in the Czech Republic (Central Europe) at three testing stations of ÚKZÚZ in S1 (49°33’45.700”N, 15°32’20.613”E), S2 (49°5’55.717”N, 15°52’29.782”E) and S3 (49°43’51.489”N, 16°30’11.644”E) which are situated in vulnerable areas. S1 is located on sandy loam soil in 505 m a.s.l, average annual temperature is 7.7 °C with 632 mm precipitation, S2 is on loamy soil in 425 m a.s.l, average annual temperature is 8.0 °C with 481 mm precipitation and S3 on sandy loam soil in 460 m a.s.l, average annual temperature is 6.5 °C with 624 mm precipitation.

For the purpose of this paper three experimental years (2013 - 2015) were evaluated. Crops were grown in the order: silage maize, spring barley and winter oilseed rape. Five treatments with different types of fertilizers were used: 1. control (unfertilized); 2. mineral N (Calcium ammonium nitrate); 3. slurry; 4. digestate (anaerobic, from agricultural biogas plant) and 5. compost. Fertilizers were directly applied to the silage maize and to the winter oilseed rape. Determining of the fertilizers doses was based on the presumed total nitrogen consumption in harvest: 150 kg N ha^{-1} to the maize and 80 kg N ha^{-1} to the rape. Digestate and slurry are in the category of quick-release nitrogen fertilizers, while the compost is classified as a slow-release nitrogen fertilizer. For this reason its application dose was doubled.

Following characteristic features were obtained: Dry matter yield (DMY, t ha^{-1}): fresh matter yield was converted into dry matter content, samples for dry matter determination were dried at 105 °C; Soil mineral nitrogen content (Nmin, mg N kg^{-1}) in topsoil after harvest and Nitrogen uptake (NU, kg N ha^{-1}) as the sum of the main and by-product. Determination of nitrate content in soil was performed by ion selective electrode, while ammonium nitrogen content was carried out spectrophotometrically following the indophenol method.

Statistical assessment of the results was performed between treatments in the STATISTICA 12.0 program (StatSoft, Tulsa, USA) with the Main effects ANOVA followed by the Tukey´s test at the level of significance $P<0.05$.

Results

The highest content of Nmin in the topsoil was observed after the use of mineral fertilizers, particularly after the harvest of silage maize (5.5 mg N kg^{-1} which means 45 % increase than control treatment). The lowest recorded values from all fertilized treatments were for the digestate treatment, where average values of Nmin after harvested maize and barley were about 48 % lower (3.8 mg N kg^{-1}) than for mineral N. Overall, the lowest values of Nmin in the topsoil were found after growing of maize and the highest after barley, although the crop was not directly fertilized. The content of the mobile fraction of nitrogen (N-NO_3^-) in the soil, which threatens surface and ground water, after application of digestate and compost was according to national standards on safe content.

The highest effect on average DMY of all experimental crops was observed for mineral N treatment: 15.0 t ha^{-1} of maize, 4.7 t ha^{-1} barley grain and 1.8 t ha^{-1} rape seeds. From the experimental crops winter oilseed rape had the highest response to mineral nitrogen fertilization (about 62 % higher than control and about 33 % higher than slurry). The highest values of DMY in comparison with other organic fertilizers were obtained after fertilization with slurry. Digestate decreased the DMY in average only from 5 % (14.2 t ha^{-1} maize) to 39 % (1.3 t ha^{-1} rape) compared to mineral fertilizers. Fertilizing with compost as a fertilizer with slow-releasable nitrogen was less effective than digestate with quick-release nitrogen.

The results of DMY of individual treatments correspond to NU by crops. The highest values of NU occurred after the application of nitrogen in mineral form: 170.4 kg ha^{-1} maize, 81.4 kg ha^{-1} barley and 74.5 kg ha^{-1} rape. The highest NU after organic fertilizing was reached on the slurry treatment: 159.6 kg ha^{-1} maize, 67.6 kg ha^{-1} barley and 55.4 kg ha^{-1} rape, which means 12 %, 20 % and 29 % increase compare to the control treatment. In comparison with the other treatments were lower values of NU found for digestate and compost treatments (147.1 and 150.2 kg ha^{-1} for maize, 58.3 and 66.6 kg ha^{-1} for barley and 50.4 and 46.4 kg ha^{-1} for rape).

Conclusions

It is evident from our results that the highest response to nitrogen fertilization was observed after the use of mineral fertilizers, which led to the highest yields of all crops and also to the highest nitrogen uptakes. However, the highest contents of mineral nitrogen in the soil were found after the harvest, which may pose a risk for ground water resources. From organic fertilized treatments the highest yields and nitrogen uptakes were proved for slurry. The use of this fertilizer resulted to the lowest mineral nitrogen content in soil after harvest of rape and it was a very suitable organic fertilizer in terms of maize yield. Digestate and compost treatments were slightly below the yields of slurry treatment. With lower influence on barley yield the digestate treatment showed its limited long term fertilizing effect. On the other hand the use of compost increased yields due to a slow release nitrogen effect in the second year after the application. The lowest content of mineral nitrogen in soil for digestate treatment was determined after the harvest of maize and barley, but there was also detected the lowest nitrogen uptake from all treatments, which suggests the loss of nitrogen into the environment. Digestates are organic fertilizers which due to the high proportion of available ammonia nitrogen are a relevant alternative to save mineral fertilizers. However, mainly in vulnerable areas it is necessary to properly manage their use with respect to different site conditions and cultivated crops.

USE OF SOIL ECa MEASUREMENT FOR EVALUATING SOIL SPATIAL VARIABILITY FOR NITROGEN MANAGEMENT IN SUPER-INTENSIVE OLIVE OIL TREE ORCHARDS

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Objectives

High-density olive crop systems require intensive irrigation and nutrition to improve yield and to sustain subsequent oil quality [1]. The enhancement of the water and nutritional status of olive trees benefits yield and oil quality [2]. However, intensive cropping practice is not without risks, for example, an excess of N negatively affects oil quality [3] [4]. Tree response to N application is closely linked to management practices and soil characteristics. In semi-arid conditions, soils exhibit great spatial heterogeneity, which is related mainly to soil depth, texture, and salt content, which together hinder the achievement of satisfactory N efficiency.

This study addresses the effect of soil variability on N management in the context of the optimization of oil tree production.

Method

The trial was conducted on a commercial adult olive plot (cv.Arbequina) in Torres de Segre (Lleida) over four years (2010-2013). The climate is continental Mediterranean-type. The area receives a mean annual rainfall of 324 mm, which is irregularly distributed, and annual ETo (Penman-Monteith) is 1101 mm. The trees were planted in 2002 at 4.5 m × 2.2 m growing in a soil of variable depth. The soil is silty-loam textured and calcareous (pH = 8) with an organic matter content of 1.5%.

The trees were irrigated by means of autocompensated drip emitters (2.3 Lh-1) spaced 0.6 m along a dripline. Irrigation water came from the Segre river, which is of good quality. Soil moisture was monitored continuously with ECH2O-10 capacitance probes (Decagon Devices Inc., Pullman, Washington, USA). Two irrigation treatments were crossed with four fertilization treatments, with four replicates randomly distributed in blocks. The following irrigation treatments were applied: FI, or irrigation applied as 100% of the water requirements throughout the year, according to the FAO methodology [5]; RDI (deficit irrigation), or restricted irrigation in summer scheduled as follows: March to June, 100% of the requirements; July to September 10th, 25% of the requirements, and September and October, 100% of the requirements.

Fertilization treatments resulted in the combination of two rates of N (0 and 50 kg N ha-1; N0 and N50 respectively) and two rates of K (0 and 100 kg of K2O ha-1; K0 and K100 respectively). Plant growth was assessed by means of pruning weight. Meanwhile, fruit yield, oil yield, and oil content on a fresh matter basis were used as productive indicators. Leaf and fruit nutrients were analyzed in July and at harvest time, respectively. Fruit oil content was determined by nuclear magnetic resonance (NMR). The variability of soil properties was determined measuring apparent electrical conductivity of soil (ECa) continuously and geo-referenced with a VERIS 3200 equipment (Veris Technologies, Inc., Salina, KS). Statistical analysis of the results was performed using the JMP-SAS software (JMP, Version 12 Pro. SAS Institute Inc., Cary, NC,1989-2014).

Results

N treatments significantly increased the nitrogen leaf content. The non-fertilized treatment (N0) resulted in a decline in leaf N content over the years. In contrast, the N treatment (N50) resulted in an increase in nutrient over the four years in all the treatments. Leaf N content was high in all cases, according to the standards for leaf N interpretation. Also, the main trend of the effect of year x N interaction indicated that N concentration in leaves declined and varied between years in plots that did not receive N and K were not applied.

Oil yield was not affected by irrigation, but N application enhanced production and was also positively affected by K application, thereby evidencing an additive effect of N-K on oil yield. Taken together, the results suggest that N derived from the mineralization of soil organic matter was insufficient to achieve high yields on non N-fertilized plots. Annual tree growth, estimated as pruning weight, was affected by deficit irrigation and significantly declined over the years on non-fertilized N plots, thereby also indicating a differential response of plant growth on unfertilized plots with respect to fertilized ones. A spatial statistic model including geoferenced results were analyzed by introducing a correction of model residuals calculus provided by initial soil ECa. The results show a strong influence of soil depth and salt content on the effects of N and K on yield and plant growth. Simultaneously, in all cases, trees in deep soil exhibited a lower yield and harvest index (as yield/vegetative biomass) than those on shallow soils. This experiment demonstrates that introduction of ECa measure in geo-analysis models constitutes a useful method for evaluation of N effects and to improve fertilization management.

Conclusions

By integrating limiting factors, the ECa soil measurement has the capacity to identify soil heterogeneity. Commercial equipment for soil ECa measurements currently provides a useful tool for proximal field mapping and for precise N management. This technique can be used at the field level at reasonable cost and confers a significant potential economic and environmental benefit.

References

[1] Naor, A. et al., 2013. Irrig. Sci. 31, 781-791.
[2] Erel, R. et al., 2008. J. Am. Soc. Hortic. Sci. 133, 639-647.
[3] Fernández-Escobar, R. et al., 2009. Eur. J. Agron. 31, 223-232.
[4] Erel, R. et al., 2013. J. Agric. Food Chem. 61, 11261-72.
[5] Allen, R.G. et al., 1998. FAO Irrigation and drainage paper 56. Irrig. Drain. 1-15.

MODELLING THE EFFECT OF POST-HARVEST MANAGEMENT MEASURES ON NITRATE LEACHING DURING AUTUMN AND WINTER

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Objectives

In Europe, nitrate (NO_3^-) leaching from farmland remains the predominant source of nitrogen (N) loads to ground- and surface waters. There is a serious risk of NO_3^- leaching during winter as residual soil mineral N content at harvest (RSMN) is often high. In this study, we evaluated NO_3^- leaching for different scenarios after cut grassland, silage maize, potatoes, sugar beets and winter wheat on a silt loam and a sandy soil in Flanders. Our research questions were: i) Can it be guaranteed that the threshold values of the Nitrates Directive (50 mg NO_3^- l^{-1} in ground- and surface water) will not be exceeded when applying maximum allowed fertilisation rates for these five crops; ii) What kind of post-harvest management measures are effective to reduce the NO_3^- concentration; iii) What is the effect of the variability of RSMN and weather conditions on NO_3^- losses during the winter period?

Method

Nitrate leaching and other soil N processes were simulated with the EU-rotate_N model using meteorological data of 23 autumn-winter seasons (1992-2015). First, we simulated a "worst-case" scenario with incorporation of crop residues five days after harvest of the main crop. We also simulated following alternative post-harvest management scenarios: i) sowing of winter crops (either catch or cash crops), ii) the removal of sugar beet leaves at harvest, and iii) the incorporation of straw after winter wheat. After winter wheat we also simulated a pig slurry application (60 kg total N ha^{-1}) before sowing mustard. All scenarios were simulated using real data of a selected representative silt loam soil and sandy soil in Flanders, using calibrated N mineralisation parameters and calibrated growth parameters for the catch crops. For cut grassland, the simulation started from the sowing of the grass in spring and ran until the 31st of March of the following year, but we assigned a RSMN content to the soil at the last mowing early November. All other simulations started at a given RSMN value at the harvest of the main crop and ran until the 31st of March of the following year. The assigned RSMN values were calculated from a large data set in previous studies and corresponded roughly to the RSMN found after applying the maximum allowed N fertilisation rates on the studied crops in Flanders [1]. We evaluated the different scenarios by comparing the mean NO_3^- concentration in ground- and surface water after dividing the simulated NO_3^- concentration at a depth of 90 cm by a factor of 2.1 to include natural attenuation processes occurring during transport towards ground- and surface water. As RSMN values also show variation due to differences in soil organic matter content and weather conditions during the growth of the main crop, we performed a Monte Carlo simulation to assess the combined effect of variability in RSMN and weather conditions on the variability in NO_3^- concentrations in the leaching water.

Results

In the worst-case scenarios, the simulated attenuated mean NO_3^- concentration (NC_{att}), expressed in mg NO_3^- l^{-1} for the silt loam and sandy soil, respectively, was lowest for cut grassland (18±4 and 27±6), intermediate for winter wheat (38±6 and 49±13), sugar beet (38±6 and 61±15) and silage maize (49±6 and 58±15) and highest for potatoes (76±10 and 86±20). Sowing winter crops resulted on average in a 6 to 83% reduction in NC_{att} in the silt loam soil and in a 5 to 59% reduction in the sandy soil. The reduction in NC_{att} strongly depended on the mean simulated N uptake of the winter crops, which varied between 18 and 92 kg N ha^{-1} and between 9 and 76 kg N ha^{-1} on the silt loam and sandy soil, respectively. Nitrogen uptake was lowest for grass and winter rye sown after the harvest of maize and for winter wheat after sugar beets due to the late sowing time. For undersown grass in maize, N uptake was 2 to 3 times higher than for grass, resulting in a NC_{att} below 50 mg NO_3^- l^{-1}. However, our simulations did assume the ideal development of the undersown grass during the maize growth, while it is known that the moment of undersowing a catch crop is very critical: sowing early induces a risk of competition with the main crop, while sowing late might result in a poor development of the catch crop. After potatoes, N uptake of winter crops was higher than after maize and sugar beets, but insufficient to result in a NC_{att} below the norm, and measures will be needed to reduce RSMN in order to comply with the requirements of the Nitrates Directive. After winter wheat, N uptake of catch crops was high and NC_{att} was strongly reduced, even with a pig slurry application at the time of sowing the catch crop, as this pig slurry application increased N uptake by about 40 kg N ha^{-1} on both soils. Crop residue removal after sugar beets and incorporation of winter wheat residues resulted on average in a 16 to 37% reduction in NC_{att} and in a 21 to 40% reduction on the silt loam and the sandy soil, respectively. Removal of sugar beet leaves strongly resulted in a larger decrease of NC_{att} than the incorporation of wheat straw.

Monte Carlo simulations showed that RSMN and NC_{att} were positively correlated for most scenarios and that the variability in NCatt due to different weather conditions increased with higher RSMN. Only for 8 out of 17 scenarios on the silt loam and for 4 scenarios on the sandy soil, more than 90% of the simulated NCatt values remained below the threshold value of 50 mg NO_3^- l^{-1}.

Conclusions

For cut grassland the simulated average NC_{att} did not exceed the threshold value of 50 mg NO_3^- l^{-1} on both soil types. In order to comply with the Nitrates Directive (under currently maximum allowed fertilisation rates), post-harvest management measures seem to be necessary on sandy soils for the 4 other crops, and on silt loam soils for silage maize and potatoes. Sowing catch crops in August, even after application of 60 kg N ha^{-1} as pig slurry, seems to be very effective. For crops which are harvested late in the season, the potential management options are limited. Potatoes are a problem crop because of the high RSMN values: as post-harvest measures did not reduce NC_{att} below the norm, it will be necessary to harvest potatoes earlier to allow a better development of catch crops or to reduce RSMN e.g. by fractionation of N fertilization or by growing more N efficient potato varieties. Undersowing grass in silage maize and removing N rich crop residues like sugar beet leaves are promising options to reduce NO_3^- leaching losses. However, to ensure that both practices will be implemented by farmers, it will be crucial to guarantee that the maize yield is minimally affected and that alternative uses for the harvested sugar beet leaves are lucrative.

References

[1] D'Haene, K. et al., 2014.. Agriculture, Ecosystems and Environment 192, 67-79.

NITROGEN APPLICATION OF ORGANIC FERTILIZER IN TIMOTHY (*PHLEUM PRATENSE* L.) SEED PRODUCTION

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Objectives

Timothy seed is an important crop in Central Sweden. Prevailing N recommendation in conventional timothy seed production is application of 35-40 kg N ha^{-1} in autumn and 80-120 kg ha^{-1} the following spring the seeding year. In older stands i.e. first and second seed year, autumn N application is not recommended. The availability of N in organic fertilizers is often lower than in conventional fertilizer, therefore autumn application may be of greater relevance in the first and second seed year of organic seed stands.

The objective was to develop N fertilization recommendations in organic Timothy seed production by investigating the effect of different distribution regimes of N during autumn and spring on seed yield and N leakage in fields of various stand ages. The granulated organic fertilizer Biofer was used.

Method

The investigations were carried out in six field experiments located at different sites in Central Sweden; Örebro County and Östergötland, established in Timothy seed fields 2012 and 2013. There were three experiments each year, in the cultivar SW Switch, in stands of various age; seeding year, first seed year and second seed year. A total rate of 120 kg N ha^{-1} applied as Biofer (10-3-1) was distributed in five different doses in autumn (9-29 September); 0, 30, 60, 90 and 120 kg^{-1}, and the rest the following spring (11 Mars-10 May), i.e. 120, 90, 60, 30 and 0 kg ha^{-1}, respectively. The five treatments had four replications and a randomized block design was used. An experimental seeder was used to broadcast Biofer at the soil surface. Biofer is a bone meal product commonly used in organic crop production in Sweden. The major part of N in Biofer is organically bound to proteins and about one tenth is ammonium nitrogen [1].

The trials were harvested and seed yield measured. Soil samples were collected at 0-30 cm and 30-60 cm from the surface on three occasions; late autumn (end of October or beginning of November), spring (before spring application of Biofer) and after harvest, for analyses of mineral N (NH_4-N and NO_3-N).

The software JMP 9.0 was used for statistical analyses. An ANOVA followed by Tukey's HSD test ($p<0,05$) was used to identify significant differences between treatments.

Results

Splitting the total rate of N as Biofer (10-3-1) between autumn and spring is beneficial for all ages of Timothy stands. Earlier findings in conventional trials demonstrated that splitting the N-application between autumn and spring was favorable in stands of the first seed year, but did not improve yield in older stands [2].

The results of two trials harvested the first seed year showed a small difference between the four treatments with doses 0, 30, 60 and 90 kg N ha^{-1} applied in autumn and 120, 90, 60 and 30 kg N ha^{-1} in spring. The seed yield ranged from 752 to 808 kg ha^{-1} in the trial 2012 and from 415 to 438 kg ha^{-1} in the trial 2013. All N applied in autumn showed the significantly lowest seed yield (736 kg ha^{-1} and 374 kg ha^{-1}, 2012 and 2013 respectively), but was not always significantly lower than all other treatments.

The results of two trials harvested the second seed year showed that seed yield tended to be highest when doses 30, 60 and 90 kg N ha^{-1} were applied in autumn and 90, 60 and 30 kg N ha^{-1} in spring, however, there were no significant differences between any of the treatments. The treatments with best performance in yield ranged from 554 to 564 kg ha^{-1} in the trial 2012 and from 711 to 728 kg ha^{-1} in the trial 2013, as compared to yields in treatments where all N was applied in autumn or spring ranging from 497 to 535 kg ha^{-1} and 675 to 688 kg ha^{-1}, in 2012 and 2013 respectively.

The results of the two trials the third seed year showed significantly higher yield in treatments with doses 0, 30 and 60 kg N ha^{-1} applied in autumn and 120, 90 and 60 kg N ha^{-1} respectively, applied in spring, than the treatment where all N was applied in autumn, in the trial 2012. Treatments with doses 30, 60, 90 and 120 kg N ha^{-1} applied in autumn and 90, 60, 30 and 0 kg N ha^{-1}in spring, tended to have higher seed yield ranging from 462 to 475 kg ha^{-1} compared with 437 kg ha^{-1} in the treatment with full N-dose applied in spring in the trial 2013.

Measurements of soil mineral N concentrations showed small differences between treatments. Only one of the six trials i.e. the seeding year trial harvested 2013, showed a significant increase in soil mineral N in late autumn. The increase was found in the treatments with autumn application of 90 and 120 kg N ha^{-1} with 15.7 and 19.6 kg N ha^{-1} compared with 8.6-11.6 kg N ha^{-1} in the other treatments.

Conclusions

Our recommendation is splitting the N dose between autumn (30-90 kg ha^{-1}) and spring when a total rate of 120 kg ha^{-1} as Biofer (10-3-1) is applied to Timothy seed stands of all ages. The results demonstrate that the risk of N leakage is insignificant when Biofer is applied accordning to our recommenations to Timothy stands.

Acknowledgements

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References

[1] Lundström, C., Lindén, W. 2001. Series B crops and soils Report 8, Department of Agricultural Research, SLU, Skara, Sweden.

[2] Wallenhammar, A-C, Anderson, L.E. 2002. NJF report 341. Grass and clover seed production, Ystad, Sweden 24-26, June 2002, p 129-136.

ASSESSING MICROBIAL ACTIVITY IN DIGESTATE-FERTILIZED CROPS WITH FERTIMETRO: A PATENTED DEVICE EXPLOITING BURIED COTTON THREAD BAITS TO OPTIMIZE N AND P FERTILIZATION

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Objectives

This study is part of a wider program aiming at the definition of ideal cropping strategies to limit CO_2 emissions while preserving soil fertility. These involve the application of anaerobic digestion effluent (digestate) as organic fertilizers. In our approach we applied digestate to plots where different crops were grown with or without arbuscular mycorrhizal fungi (AMF) inoculation. The analyzed responses, in addition to soil CO_2 emission and biomass production, were focused on soil microbial activity and its response to local supplementation of N or phosphorus (P). This was achieved by burying 'bait' threads of cotton in the first 15 cm soil layer, recovering the fibers after a week and measuring the occurred degradation by pulling them until breakage in a dynamometer. Plain threads were compared with some previously soaked in N or P solutions. Such approach in terms of method and device constitutes a patent from the University of Padova.

Method

The trial, began in 2014, included 48 growth boxes elevated 1.3 m above ground level [1] vegetated with: giant reed (*Arundo donax*) miscanthus (*Miscanthus x giganteus*), sunchoke (*Helianthus tuberosus*), corn (*Zea mays*), sorghum (*Sorghum bicolor*) and perennial ryegrass (*Lolium perenne*). On 1st April 2014, the digestate liquid fraction was spread for an amount corresponding to 250 kg N ha^{-1} and 27.4 kg P ha^{-1}. Half of the plots, during sowing or transplanting were inoculated with AMF (*Glomus intraradices*, *G. mosseae*, *G. etunicatum* and *G. clarum*) at 500 propagules/m^2. Four replicates were carried out. Soil CO_2 emission was evaluated adopting the static non-stationary chamber technique.

The biodegradation level of organic matter by soil microorganisms was assessed following a novel method and using a purposely defined patented device (University of Padova, Italy, PCT/IB2012/001157,June 13, 2012, Squartini, Concheri, Tiozzo) measuring the degradation of cotton and silk threads that are placed in the soil for a week (October 2014). A small vertical hole was made in the soil with a spade, then threads (15 cm long) were carefully placed vertically and the hole was filled with soil. The extent of degradation of these threads, compared to that of unburied controls, is taken as an index of the cellulosolytic (cotton) or proteolytic (silk) attitudes of the soil microbial populations. In each plot, three sets of threads (untreated, pre-treated with nitrogen, pre-treated with phosphorus) per fiber (cotton and silk) were buried. The nitrogen- or phosphorus- pre-treated versions of the threads, as defined by the above quoted patent, are used to assess to what extent such additions can further stimulate microbial activity in comparison to the plain untreated threads. Their residual resistance to breakage was determined using a digital dynamometer to measure the peak force required to rupture them by applying progressive tractional force. The thread resistance was calculated as: R = (Ri / Rni) x 100 (where: R= resistance percentage; Ri = rupture value of the thread buried in the soil; Rni = rupture value of a control filament when new). Resistance was converted into the degradation percentage (D) by subtracting resistance percentage values from 100.

Results

At the end of the first growing season giant reed showed a significantly higher dry biomass production in the mycorrhized plots (22.8±1.5 Mg ha^{-1}) in comparison with the non-mycorrhized (18.4±2.8 Mg ha^{-1}) ones. On the opposite, sorghum showed a significantly higher dry biomass production in the non-mycorrhized treatment (36.6±4.3 Mg ha^{-1}) than in the mycorrhized one (30.5±2.1 Mg ha^{-1}). No significantly different production was found between mycorrhized and non-mycorrhized plots for sunchoke (28.9±5.9 Mg ha^{-1}), miscanthus (19.0±2.0 Mg ha^{-1}), corn (32.0±1.7 Mg ha^{-1}) and lolium (7.9±0.9 Mg ha^{-1}).

Fertimetro data consisted in measurements of the extent of degradation (increased fragility of the buried threads) in the different plots with or without mycorrhization. For the plain control thread, microbial cellulolytic activity (cotton fiber weakening) was affected by crop species. Presumably, besides chemical allelopathy effects, this can in part reflect the evapotranspiration intensity linked to the amount of foliar biomass, which in turn can deplete soil water availability for microbial activity. Low levels of cotton thread degradation were observed for arundo and sunchoke in comparison to the high levels shown by miscanthus, corn, sorghum and ryegrass. Fertimetro results confirm the trend of soil CO_2 emissions measured during plants growing season (May-September) with the lowest CO_2 fluxes monitored for giant reed and sunchoke (median value 291.3 mg m^{-2} h^{-1}) whereas the highest ones were monitored for miscanthus, corn, sorghum and lolium with a median value of 460.5 mg m^{-2} h^{-1}. Furthermore, during growing season giant reed and sunchoke determined lower soil temperature (-6.5%) and moisture (-13.0%) than other ones, which showed an average value of 22.3°C and 28.2% respectively.

In the absence of mycorrhizal inoculation, N-treated and P-treated threads generally displayed higher degradation in comparison to the control, indicating nutrient limitation under those conditions. Considering all plant species, mycorrhizal inoculation determined significantly higher soil CO_2 emissions (median value 460.3 mg m^{-2} h^{-1}) than boxes without inoculation (median value 374.5 mg m^{-2} h^{-1}). In given crops (corn with threads +N) or miscanthus and sunchoke in threads +P), inoculating soil with mycorrhizae depressed microbial cellulolytic activity on the nutrient-supplemented cotton baits, which can be interpreted with competition phenomena or with excess nutrient availability in relation to its mobilization from bulk soil brought by the extending mycelium. Despite species-specific responses under mycorrhizal inoculation in terms of N and P availability, no specular trend was observed for biomass production. This result suggests that crop production also depends on the species-specific nutrients use efficiency and the mycorrhizal inoculation effect on it.

Conclusions

AMF inoculation increases giant reed and decreases sorghum dry biomass production whereas no effect seems to be exerted on the others species.

Fertimetro data indicate the usefulness of the thread baits system in assessing soil fertility and unraveling ongoing dynamics in the plant-soil–microbiome complex interplay.

It should be considered that results have been obtained in only one growing season (the first growing season for perennial species and in only one growing season for annual ones) in an organic agro-ecosystem. Further investigation are needed in the following years to confirm our findings when more stable conditions between plants and their cropped environment will be reached.

Acknowledgment

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References

[1] Morari, F. 2006. Soil Science Society of America Journal, 70(6), 1860-1871.

ASSESSMENT OF ECOSYSTEM SERVICES RENDERED BY AGROMINING OF NICKELIFEROUS SOILS: ASSOCIATION OF LEGUMINOUS AND HYPERACCUMULATOR?

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Objectives

Ultramafic soils, known for their physical and chemical anomalies, contain significant amounts of trace elements such as nickel (Ni) and present a hostile environment for plant growth and profitable agricultural production. Ultramafic flora includes the particular hyperaccumulators plants, able to accumulate high Ni-concentration in their shoots. Objectives of agromining are extracting strategic metals, with high economic values, from degraded soils and then improving their agronomic properties. Based on providing ecosystem services to society from these degraded soils, developing more efficient cropping systems for agromining can be achieved by association of hyperaccumulators and legumes through enhancing soil fertility. Our objective was to investigate whether *Lens culinaris*, can grow and form functional nodules (fix N_2) on a Ni-contaminated soil. Our main goal is to use *Lens culinaris* in rotation or co-cropping with a hyperaccumulator, on a natural ultramafic Ni-rich soil, in order to enhance the growth of hyperaccumulator plants and Ni phytoextraction.

Method

We performed a two months mesocosm study in controlled conditions based on three treatments: lentil and ryegrass separately sown in soils with increasing Ni concentrations and lentil sown in sand also with increasing Ni concentrations. The soil was previously cultivated with nodulated pea, thus naturally containing *Rhizobium leguminosarum* and was artificially contaminated with different concentrations of nickel sulfate (0-90 mg Ni kg^{-1}).We used the ^{15}N natural abundance ($\delta^{15}N$) technique to estimate the proportion of N in lentils that could be ascribed to biological nitrogen fixation (BNF), i.e. fixed from the air (%Ndfa). We used ryegrass (*Lolium perenne* L.) grown in additional contaminated pots as non-fixing control plants to estimate $\delta^{15}N$ of the N uptake from soil. We used lentils grown on sandy substrate and inoculated with a *Rhizobium* strain to estimate the $\delta^{15}N$ of the legume when completely dependent on N_2. Biotic parameters investigated were: nodule numbers, Ni, carbon (C) and nitrogen (N) in plant organs, plant biomass, nitrate reductase activity (NRA), chlorophyll and carotenoids in shoots. Different abiotic parameters were also investigated on soil: pH, cation exchange capacity (CEC), total Ni concentration, Ni-DTPA, exchangeable Ni^{+2}, ammonium and nitrates, C and N concentrations. The experiment had a completely randomized block design with three replicates. Variance analysis was carried out on all data using one-way ANOVA (Tukey test with a confidence interval of 95%). Also, normality tests and k-sample comparison of variances were analyzed. Furthermore, all the parameters studied were submitted to PCA. These statistical analyses were done on XLSTAT software.

Results

Most of the physicochemical and biological parameters were significantly affected by the Ni concentrations. Nodule number per plant was lower under high soil-Ni than control (0 mg Ni kg^{-1}). Nodules lost their capacities to fix N_2 at highest Ni concentration (90 mg Ni kg^{-1}). For many parameters, there were no significant differences between control and treatments up to 60 mg Ni kg^{-1}. Decreased atmospheric N_2 fixation should be related to decreased symbiotic activity of microbes at highest Ni soil concentration. These outcomes affected Ndfa and shoot biomass which were negatively correlated to Ni additions to the soil. Shoots and roots of contaminated treatments showed greater Ni concentrations. Ni-accumulation in plants reduced plant biomass and roots stored higher Ni-amount than shoots as reported by previous studies. Physiologically, stress caused by Ni-phytotoxicity had a contradictory effect on chlorophyll content in leaves. It is known that trace metals have a negative effect on the chlorophyll content reducing photosynthesis. Our hypothesis regarding the increase of chlorophyll in fresh leaves at highest Ni concentration was associated to the reduction of plant biomass: pigments were concentrated in smaller leaves. Thus, the ratio of total chlorophyll content to leaf area is higher. Added soil-Ni deleteriously affected NRA. Ni inhibited nitrate translocation from roots to shoots and then reduced the amount of leaf nitrate. This fact implied a lower NRA. In addition, the metabolites issued from the photosyntetic metabolism are essential in the process of the nitrate reduction. Therefore, the reduced photosynthesis affected the nitrates absorbtion and reduction. Shoots N and C contents were also significantly decreased by soil-Ni concentrations which limit nutrient and water uptake from the soil and thus reducing the biomass production and dry matter accumulation. Also, the nitrogen fixed from the air and nitrates assimilation from the soil was reported to be reduced by the heavy metal toxicity and consequently reducing plant N content. No amounts of ammonium were detected in our soil. This was due to the main destiny of ammonia in the soil to nitrate by the process of nitrification. In general, ammonia was found to be present in low amounts in comparison to nitrates. Soil pH and CEC decreased with increasing soil-Ni concentrations and this was due to the complexation of Ni^{2+} to soil surface sites and to the Ni^{2+} exchange with other cations from CEC, in both cases there is release of surface H^+ ions. Furthermore, the stability of the Ni onto the organic particles and the polymerization of cation-bound organic matter diminished the CEC in the soil at high Ni concentrations. Soluble N pool in the soil and nitrate ions were reversely affected by soil-Ni concentrations due to reduced ability of lentils to absorb nutrients at higher Ni concentrations.

Conclusions

Our results confirmed that the lentil is able to grow on a soil containing elevated amounts of Ni-DTPA similar to those generally found in serpentine soils. This legume could be used in association with a hyperaccumulator plant (co-cropping or rotation) with the aim of optimizing the Ni agromining by the hyperaccumulator. Our study established that lentils can tolerate high concentrations of available nickel in the soil, although physiological stress is induced in the presence of significant concentrations of this trace metal. Lentils can still produce nodules that fix nitrogen from the air for most of the range of Ni additions tested here that are at least one order of magnitude above acceptable levels for most crops and typical from serpentine soils. The quantity of available Ni found in the serpentine soil, which will be used in the future work, is in the range of the concentrations investigated in this experiment. Our upcoming work will be to test *Lens culinaris* in inter- or co-cropping with a hyperaccumulator plant, *Alyssum murale*, to enhance its biomass production by providing nitrogen and permit this hyperaccumulator to extract more valuable Ni.

DOES BIOCHAR REDUCE AMMONIA EMMISIONS FROM DIFFERENT AMENDMENTS TO AGRICULTURAL SOILS?

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Objectives

Atmospheric ammonia (NH3) is a key air pollutant effecting eutrophication and acidification of ecosystems (1), and agricultural systems are pointed out as the main anthropogenic source of atmospheric NH3, either from N fertilizer use or animal production and manure spreading (2). Biochar affects N cycling in soils and offers potentially tightens the N cycle in agricultural ecosystems. Biochar can take up N via ion exchange, remove NH3 via adsorption, and stimulate immobilisation reducing NO3 leaching.
Biochar can efficiently adsorb NH3 (3)], potentially reducing NH3 losses by volatilization, and can be applied to soil to improve soil fertility and mitigate climate change(4).

The objective was to evaluate the effect of biochar application to soils, with different background uses (mixed and organic farming), on the sequestration of N. Biochar was applied at different rates, amended with urea and compost, as N sources, and NH3 emissions were measured from soil - amendment mixtures.

Method

Two different soils were collected from agricultural fields with different farming practices backgrounds (mixed and organic farming). In the mixed farming system, fresh poultry manure and mineral fertilizers are usually applied to soil, while in the organic farming system soil is regularly amended with compost produced with a mixture of poultry manure and vegetable crop residues collected from a greenhouse. Soil was collected from the 0-20 cm layer from both fields, air dried and sieved (< 2.0 mm).
Six different treatments were performed on each soil type: control unamended soils (CM, CO); application of biochar at 5% and 10% rates (MB5, MB10); application of urea (U) or of compost (O) in amounts equivalent to 170 kg N ha-1; application of urea + biochar at 5% and 10% rates (UB5, UB10); application of compost + biochar at 5% and 10% rates (OB5, OB10). Urea was added to the soil from mixed farming system and the compost was applied to the organic farming soil. All amendments were performed at the beginning of the experiment in sufficient number to allow destructive triplicate sampling at each sampling time. When applicable, biochar and compost were mixed to the soils and urea was diluted in water and applied to the soil surface. Soil + amendments mixtures, watered with distilled water at 60% water holding capacity previously determined, were placed in plastic containers linked to polyurethane foam ammonia collectors placed 1cm above the soil + mixture surface (5). For each sampling date, 36 foam absorbers were collected (3 replicates per 6 treatments per 2 soil types), in a total of 5 sampling dates (T1 = 2 days, T2 = 4 days, T3 = 7 days, T4 = 9 days, T5 = 11 days). Temperature and relative humidity were monitored during this period (6 hour intervals).
For N-NH4 analysis, foam absorbers were washed with 200 mL of distilled water and vacuum filtered. Ammonium nitrogen was determined with a segmented flow autoanaliser.
Data was interpreted using analysis of variance (ANOVA) using Statistica ®. Fishers LSD tests were used to show the significant differences at 95% confidence.

Results

Biochar application at both rates to the mixed farming soil significantly decrease ammonia volatilization, compared to control. Ammonia volatilisation decreased between CM and MB5 (for T1 and T2), and MB10 (for T1, T2 and T3); between U and UB5 (for T1 and T2), and UB10 (for T1, T2, T3 and T4). Comparing CM to MB5 the decreased was 38% at T1 and 61% at T2. MB10 treated samples showed 64% reduced losses at T1, 54% at T2 and 46% at T3.
When urea was applied to the soil and also amended with biochar, there was also a decrease effect on ammonia volatilization in many cases. Comparing between U and UB5 ammonia losses decreased 25% at T1 and

47% at T2. UB10 reduced losses by 76% for T1, 43% for T2, 37% for T3 and by 46% for T4. Biochar can thus reduce N losses by volatilisation from the agricultural soil system. Other authors (6) have also found that NH3 volatilisation from 15N-labelled ruminant urine declined by 45% after incorporating either 15 or 30 t ha-1 of biochar to soil. Mandal et al. (2016) obtained NH3 volatilization decreases as high as 71% from a urea treated soil, after biochar application. Furthermore, the captured NH3 has the potential to be used later by the plants since it is bioavailable in soils (3).

No significant effect of biochar application was observed in treatments where organic farming soil was used, as biochar did not seem to impact on ammonia volatilization from this soil type. This was probably a consequence of the cumulative use of compost as an alternative to the application of fresh organic residues (fresh poultry manure) or mineral fertilizers (urea), which may have increased soil organic matter content in this soil. However, in this case most NH3 emissions may have occurred during poultry manure composting (7) were significant NH3 losses can take place. However not addressed in the present work, biochar can also be applied during composting to reduce NH3 losses by volatilization (8). The effect of biochar as a tool for nitrogen sequestration from soils, seems to be more efficient in soils with less organic matter content which is consistent with previous findings that state that biochar has a nutrient adsorption effect (3). Reductions in NH3 loss vary with N source and biochar characteristics. Manure derived biochars may act as N fertilizers. Short- and long-term implications on N immobilisation and mineralization are specific to soil-biochar combinations and further studies are required to predict N cycling responses. As an environmentally beneficial agricultural management tool, the most promising aspects are: the reduction of NH3 volatilisation, the development of slow release N fertilisers and the reduction of N2O emissions using fresh biochar additions to soils

Conclusions

Agricultural systems should ensure food production with minimal negative impacts on the environment. Agricultural soils are a major source of NH3, which can be lost by volatilisation following the application of organic and chemical fertilizers. Losses must be prevented to mitigate climate change and reduce economic losses for farmers. Biochar has potential to be an N input and a mitigation agent for environmentally detrimental N losses. When urea was added to the soil from the mixed farming system, greater NH3 emissions were observed, and reduction in those emissions due to biochar application ranged from 25% to 76%, thus promoting the mitigation of nitrogen losses into the environment and promoting a more efficient use of N. NH3 volatilisation was lower from the soil having an organic management history, and biochar amendment to soil had no effect on NH3 emissions in this case. However in this case, the main NH3 emissions could have occurred during composting and biochar could also be placed at this time to uptake NH3.

Further studies need to be done to quantify to what extend the biochar application may contribute to nitrogen sequestration in soil.

References

[1] Sutton et al. 2009. Springer ISBN978-1-4020-9120-9
[2] Beusen et al. 2008. Atmos.Environ. 42:6067-6077.
[3] Taghizadeh-Toosi etal. 2012a. Plant Soil 350:57-69.
[4] Lehmann et al. 2011. Soil.Biol.Biochem. 43:1812-1836.
[5] Alves et al. 2011. R.Bras.Ci.Solo 35:133-140.
[6] Taghizadeh-Toosi et al. 2012b. Plant Soil 353:73-84.
[7] Peigné and Girardin 2004. Water Air Soil Pollut. 153:45-68.
[8] Steiner et al. 2010. J.Environ.Qual. 39(4):1236-1242.

N_2O FLUXES FROM AN AGRICULTURAL SOIL IN GERMANY DURING A COMPLETE CROP ROTATION: UNCERTAINTIES, ENVIRONMENTAL INSIGHTS AND MODEL PERFORMANCE

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Objectives

The objective of this presentation is to report on the outcomes of a 3 years (2013, 2014, 2015) N_2O emissions monitoring campaign on an agricultural soil in North-Western Germany. The field experiment aimed at identifying differences in N_2O emissions for fertilization with two N forms: calcium ammonium nitrate (CAN) and urea. This talk will focus mainly on the following aspects of the information generated by the campaign:

- Analysis of uncertainty for individual flux determination (i.e. measuring method induced uncertainty)
- Analysis of uncertainty for averaged fluxes (i.e. measuring method induced uncertainty + spatial variability induced uncertainty)
- Analysis of daily and cumulative N_2O fluxes for 2013, 2014 and 2015: flux dynamics for each year, effect of fertilizer forms on yearly cumulative emissions, differences among years
- Comparison between measured and modelled (LandscapeDNDC) N_2O fluxes

Method

The experimental field (51°57'51.3"N 7°18'39.2"E) is located close to the city of Münster. It consists of an agricultural soil (sandy loam, 16.8 % clay, pH = 5.7, soil organic C = 1.0 %) cultivated with a rotation of winter barley (2013), oilseed rape (2014) and winter wheat (2015). The average yearly total precipitation is 759 mm.

The treatments consisted of control (no nitrogen fertilization), N fertilization with CAN and N fertilization with urea. Nitrogen amounts and splitting were different in each of the three years, and followed the local common management practice for each of the crops. All treatments started in 2003 and were replicated 4 times.

N_2O (and CO_2) fluxes were determined with the manual chamber + gas chromatography method. From 2013-03-07 to 2015-12-31 fluxes were determined on 259 days between approximately 9:00 am and 11:00 am. During the first 26 sampling dates gas samples were taken 0, 20 and 40 minutes after chamber closure. For all following sampling dates, samples were taken 0, 15, 30, 45 and 60 minutes after chamber closure.

If less than three concentrations were available for one chamber closure, the flux was considered not available. Fluxes were calculated with linear regressions through all remaining data points.

The coefficient of determination (R^2) and the normalized root mean squared error (NRMSE) of the linear regressions were used as metrics for the uncertainty in each daily flux determination. The coefficient of variation (CV) was taken as metric for the uncertainty in the averaged daily fluxes (4 replicates). All calculations were done in R.

The ancillary data collected during the monitoring campaign will be used to simulate N_2O fluxes with the LandscapeDNDC model.

Results

Analysis of uncertainty for the individual fluxes shows, in the vast majority of the cases, a R^2 above 0.8 and a NRMSE below 0.15 for fluxes above 5 g N_2O -N ha^{-1} day^{-1}. Below this value the uncertainty in the magnitude of the fluxes tends to increase very quickly. Fluxes below this magnitude are frequent and they contribute in a non-negligible way to the yearly cumulative fluxes. The uncertainty in the determination of the CO_2 fluxes was vastly smaller, and this indicates that the measuring protocol was applied according to best practice. A small number of the measured negative N_2O fluxes are characterized by a relatively high R^2 and low NRMSE: it is a strong indication that the soil acted as a N_2O sink under some circumstances. However, negative fluxes were infrequent and of relatively small magnitude.

The uncertainty of the averaged daily N_2O fluxes was quantified by means of the CV. The uncertainty in the averaged daily fluxes has two sources: i) uncertainty in the quantification of the individual flux and ii) difference in fluxes among replicate plots for the same treatment (i.e. spatial variability). The coefficients of variation for the averaged daily fluxes are relevant: for averaged fluxes above 5 gN_2O-N ha^{-1} day^{-1} the average coefficient of variation equals 55.9 %. Below this value the CVs increase quickly.

The daily N_2O fluxes during the three years show strong temporal variability, but the pattern for the two fertilized treatments is very similar during the whole measuring period.

Total cumulative emissions (g N_2O-N ha^{-1}) were:

1. 2013: Control = 854 ± 156; CAN = 1899 ± 296; urea = 1726 ± 211
2. 2014: Control = 1438 ± 1231; CAN = 6031 ± 1215; urea = 4566 ± 1608
3. 2015: Control = 810 ± 412; CAN = 1966 ± 400; urea = 2716 ± 560

The fertilized treatments clearly show higher pre-harvest emissions relative to the controls, while cumulative post-harvest emissions are much less affected by direct N inputs. For the control, post-harvest emissions amounted to 89, 95 and 57 % of the total in 2013, 2014 and 2015 respectively. For the two fertilized treatments they were approximately 55, 46 and 31 % in each of the three years.

The comparison between measured N_2O fluxes and N_2O fluxes simulated by LandscapeDNDC will allow better data interpretation.

Conclusions

Data on N_2O emissions from long term field experiments provide the benchmark for the validation of simulation models like LandscapeDNDC. It is thus important to carefully evaluate the "uncertainty level" of measured emissions. The measuring protocol used in this study generally provides "reliable" individual flux estimates if the magnitude of the flux is above 5 gN_2O-N ha^{-1} day^{-1}. However, the CVs of the averaged daily fluxes show that the spatial flux variability is a major source of uncertainty. If cumulative fluxes are evaluated, the temporal variability has to be considered as third source of uncertainty: this aspect is not discussed here but high frequency measuring campaigns show that N_2O fluxes can vary considerably even within 24 hours.

We observed a consistent seasonal pattern in the daily fluxes over three years: pre-harvest emissions are clearly enhanced by N fertilization while the difference in post-harvest emissions between the control and the fertilized treatments is much smaller.

In none of the three years was a significant difference detected between CAN and urea. The most significant difference which was observed is that among years: emissions in 2014 where significantly higher relative to 2013 and 2015 for both fertilized treatments (but not for the controls). The crops were cultivated in different years and a rigorous comparison is thus not possible; nevertheless, the data indicate that oilseed rape induced higher emissions relative to the cereals.

INTERNATIONAL TRADE OF ANIMAL FEED AND DECOUPLING OF NITROGEN AND PHOSPHORUS CYCLING IN CROP AND ANIMAL PRODUCTION; CASE-STUDIES OF ELEVEN COUNTRIES

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Objectives

International trade of crop and animal products has contributed to the specialization and agglomeration of crop and animal production systems, which altered nutrient cycling. Animals in specialized farming systems are fed increasingly with maize and soybeans. This has increased animal productivity, and resulted in uncoupling of crop and animal production, but with large differences between countries. To explore "why are countries so different in the trade of maize and soybeans, and what are the impacts on nitrogen (N) and phosphorus (P) cycling?", three hypotheses were examined: (i) trade of maize and soybeans, is related to the specialization of animal farming in net importing countries, and to the specialization of crop systems in net exporting countries, (ii) changes in the import of maize and soybeans are reflected by changes in nutrient surpluses at country levels, and (iii) policy measures may reduce the impacts of the specialization of crop and livestock production.

Method

A country-specific analysis was carried out of changes in the trade of maize and soybeans and changes in livestock production (pigs, poultry, dairy cattle and beef cattle) characteristics between 1961 and 2011, using data derived from national statistics (e.g. FAOSTAT). The impacts of these changes on N and P cycling were based on additional model calculations. We selected seven major importing countries[1], which together accounted for 30-60% of the total global trade of maize and soybeans, depending on year. Similarly, we selected four main exporting countries[2], which accounted for 65-85% of the total trade of maize and soybeans.

Results

We observed that changes in the import of maize and soybeans are related to changes in livestock density (LSU) for importing countries, however with large variations between countries. For example in China, increases in pig number were significantly related to increases in the import of maize and soybeans ($p<0.05$), and increases in poultry number to that of soybeans. For exporting countries, the growth rate of maize and soybeans was larger than the rate of increase of the livestock production.

Embedded N and P in imported maize and soybeans used for feed was about 27% and 19% of the total amounts of N and P in traded crops, respectively. Main importing countries have specialized livestock production systems, based on import of maize and soybeans. Increases in imports over time were clearly related to increases of N and P surpluses in for example China, The Netherlands and Germany. Nutrient management policies have greatly reduced the N and P surpluses in the Netherlands and Germany, and possibly will do so in China in the near future.

Main exporting countries (USA, Brazil, Argentina) of maize and soybeans have large areas of agricultural land per capita, but also have specialized and economically highly competitive livestock production systems, which are spatially disconnected from the farms specialized in maize and soybeans production. India is a special case; it has little agricultural land per capita but recently became an exporter of maize and soybeans and at the same time greatly increased its poultry production.

Conclusions

In summary, changes in the international trade of maize and soybeans reflect in part specialization of crop production and animal production in exporting countries and specialization of livestock production in importing countries. These contrasting patterns affect the nutrient cycling within and between countries, and affect also the N and P surpluses in those countries. The results of our study provide new insights into relationship between international trade of feed and the specialization of crop and livestock production system as well as their impacts on N and P balances.

References

[1] Importing countries (China, Japan, Indonesia, Germany, Netherland, Spain, France)

[2] Exporting countries (USA, Brazil, Argentina, India).

ARABLE MAIZE FOLLOWING PERMANENT GRASSLAND - IMPACT OF TILLAGE ON GREENHOUSEGAS-EMISSIONS, CARBON-BALANCE AND NITRATE-LEACHING

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Objectives

Silage maize is the primary energy source for intensive dairy and biogas production in Germany. Consequently, to comply with an increasing demand, the maize acreage has expanded steadily. This was accompanied by land use changes, i.e. the conversion of permanent grasslands, which generally implies a depletion of soil carbon and nitrogen stocks, favouring greenhouse gas (GHG) emissions such as N2O, CO2, CH4 and nitrate leaching depending on sward age in short-term. With respect to an increasing demand of biomass as well as climate protection and sustainable intensification there is an increased need for beneficial production systems (e.g. ley systems) while keeping environmental burdens as low as possible. Consequently the aim of the current field experiment is to identify mitigation potentials of direct seeding in comparison to conventional soil cultivation practice for silage maize following grassland in northern Germany.

Method

Measurements of this study were conducted at the experimental station 'Hohenschulen' situated in the Eastern Upland of Schleswig-Holstein, northern Germany. The dominating climate is temperate-humid with a mean annual temperature and precipitation of 9.7 °C and 1007 mm in 2015, respectively. Typical soil types are Luvisols and Pseudogley-Luvisols with mostly a sandy-loam texture. The experiment is designed as a randomized split plot layout with three replicates. Prior maize seeding the 10 year old grassland sward was herbicide killed (glyphosate) in March 2015. Seeding was conducted in two treatments: Conventional tillage (CT) and no-till practice (NT). For CT the old grassland sward was first rotovated (-10 cm) and then ploughed (25 cm) followed by a rotary harrow for seedbed preparation. In NT treatments seeding was conducted using a direct seed drilling machine which slits open the soil for grain deposition and reseals it afterwards. In addition to different tillage treatments N-fertilization varied in two levels (0 and 180 kg N ha 1 a 1).

GHG emissions, nitrate leaching, yield and soil parameters gathered from CT and NT were compared with a 4 cut clover-grass sward composed of original grassland (CO). CO2, N2O and CH4 gas flux measurements started in March 2015 with the use of the closed static chamber method [1]; [2]. N2O and CH4 samples were generated weekly and subsequent to management practices such as tilling, ploughing, seeding and fertilization. Soil respiration and the net ecosystem exchange (NEE) of CO2 was determined every 2-4 weeks during growing season. In the present study round opaque chambers were used to gain ecosystem respiration data, whereas transparent chambers came into use for NEE. Nutrient losses through leaching processes were measured using ceramic suction cups installed within the field plots. Furthermore continuous growth sampling for both above- and below-ground biomass production was realized throughout the whole year.

Results

First results show a slight advantage of NT compared to CT for N2O losses. Overall N2O emissions from maize were three- or twofold higher than from CO for the fertilized and unfertilized treatment, respectively. Highest emission peaks were measured just after grassland conversion in CT as well as for fertilizer application in NT. For CT maximum N2O fluxes were slightly lower than for NT maize and shifted in time by about one week, probably due to more unfavourable soil conditions for denitrification, such as low soil water contents and higher O2 concentration [3]. Further evaluation of soil water contents and soil mineral nitrogen data might reveal potential dependencies of N2O emission peaks on these abiotic factors.

Short term CO2 emissions immediately after grassland conversion, first by rotary cultivator loosening the old sward followed by mouldboard plough, showed a distinct increase in carbon emissions during the first six hours, probably because of released CO2 from soil pores. Mid-term CO2 emissions are currently being evaluated.

Conclusions

First results indicate that different soil properties after CT and NT have a strong influence on GHG emissions. For a comprehensive evaluation of both maize sowing systems in terms of global warming potential a detailed consideration of the two major greenhouse gases is necessary, as well as indirect emissions (e.g. nitrogen leaching) have to be taken into account. To assess the over-all environmental impact the total carbon budget (carbon export from harvested products and carbon inputs through above- and belowground biomass production) also needs to be considered.

References

[1] Mosier, A. R. & Hutchinson, G. L. 1981. Nitrous oxide emissions from cropped fields. Journal of Environmental Quality. Vol 10, no 2.
[2] Drösler, M. 2005. Trace gas exchange and climatic relevance of bog ecosystems, Southern Germany. Dissertation, Technische Universität München.
[3] Baggs, E.M., Stevenson, M., Pihlatie, M., Regar, A., Cook, H. & Cadisch, G. 2003. Nitrous oxide emissions following application of residues and fertilizer under zero and conventional tillage. Plant and Soil, 254: 361-370.

EVALUATION OF THE SUB-GRID VARIABILITY OF MODELS SIMULATING ATMOSPHERIC NITROGEN FLUXES AT THE REGIONAL SCALE FROM MODELS INTEGRATING PROCESSES AT THE LANDSCAPE SCALE

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Objectives

Atmospheric concentrations and dry deposition rates of ammonia (NH3) may be high near the nitrogen sources and strongly decrease a few hundred meters away. The high spatial variability of NH3 concentrations and deposition rates makes it difficult to simulate accurate regional maps. To quantify the impact of deposition on nearby ecosystems, local models with high resolution are usually use, but they cannot be applied at large scales. Averaging NH3 fluxes in grids of models operating at the regional scale may lead to under- or over-estimation of the NH3 fluxes. They cannot highlight hotspots of NH3 deposition and their impacts on ecosystems. The study aims at quantifying NH3 deposition from two models, one operating at the local scale and the other at the regional scale. Results will provide insights for using the knowledge on sub-grid variability in local models to improve the nitrogen fluxes simulated in grids of regional models.

Method

Several models of local and regional deposition of NH3 were developed either based on Gaussian or Eulerian dispersion schemes. The NH3 deposition schemes range from deposition velocities to multi-layer approaches being the most common scheme. Their spatial scales range from a few meters to several kilometers, with models being more adapted to very short range and others to regional NH3 deposition. A few models take into account wet and aerosol deposition, as well as chemical reactions in the gas phase.
OPS-st is the short term version of the Operational Priority Substances (OPS) model, which is a regulatory model used to calculate the concentrations and deposition rates of air pollutants at local and national scales in the Netherlands [1]. OPS-st includes a module to calculate the contribution of local sources to receptors by using the Gaussian plume theory.

CHIMERE is an Eulerian off-line chemistry-transport model [2]. External forcing are required to run simulations: meteorological fields, primary pollutant emissions, chemical boundary conditions. Using these input data, CHIMERE calculates and provides the atmospheric concentrations of tens of gas-phase and aerosol species over local to continental domains.

Hereafter, NH3 sources were assumed to be at the ground level. OPS-st and CHIMERE were used to simulate the daily average deposition of NH3 for different grid sizes from data of the WRF meteorological database. This dataset was chosen since it was already used in the CHIMERE model, it was simple to modify for different scenarios and it covered all Europe. To compare the predictions from both models, several hypothetical scenarios were designed to reproduce the heterogeneity of NH3 fluxes and concentrations within domains of a few hundred square meters. Few parameters were modified in both models to have the same initial conditions and settings for the different scenarios. Changing parameters and input variables gave the possibility to simulate contrasted studied cases and compare the results simulated by both models.

Results

Patterns of NH3 dry deposition were spatially heterogeneous, depending on the model, the distance of the receptors from the source and the grid size. NH3 dry deposition in OPS-st was very local (i.e., a few meters from the source) and the total amount decreased very rapidly as a function of the distance. This highly localized deposition was also accompanied by a heterogeneous distribution over the domain area: dry deposition next to the source was higher when the grid size was smaller.
Results showed that NH3 deposition at 2 km downwind might represent up to 60 % of the total dry deposition. This distance might increase with increasing source height, increasing atmospheric stability, increasing wind speed and decreasing roughness at the surface. The predominant factors controlling short range depo-

sition were turbulent mixing at the source height which was influenced by wind speed, atmospheric stability and surface roughness. Increasing wind speed led to decreased local deposition of NH3 that was due to more dilution of the NH3 emitted by the source and deposited downwind. The change of the deposition distance with the different resolutions was accompanied by a change of the deposition peak next to the source. However, this difference disappeared after about 2 km from the source, even when deposition was higher far from the source at coarse resolution. All model inputs were identical, but a few variables contributed to an additional bias between models (e.g., source height, wind speed, wind direction) although simulated outputs (e.g., emission rate, exit velocity, boundary layer height) might produce higher bias between both models.

On the one hand, the Eulerian model represents the turbulence through the vertical diffusion coefficient which depends on the meteorological conditions. On the other hand, the Gaussian equation derives from the same dispersion equation as in the Eulerian model, but it assumes a constant and homogeneous wind. Thus, the plume evolution simulated with the Eulerian model represented well the plume dispersion at long range, but underestimated the dispersion at short range. Gaussian models, used on short-range experiments, better represent this behaviour by adapting the dispersion to the distance from the source.
A strong positive correlation was shown between dry deposition velocity and wind speed. Dry deposition decreased with increasing wind speed in all meteorological conditions. This result was consistent with previous studies that showed that the magnitude of dry deposition strongly depends on wind speed. NH3 transport was highly affected by the aerodynamic driving force of the wind speed. High wind speed tended to increase friction velocity that accelerates NH3 transport.

Conclusions

A theoretical and statistical comparison of an Eulerian model (CHIMERE) with a Gaussian plume model (OPS-st) was performed on simplified hypothetical scenarios. We showed that it is not possible, on theoretical cases, to have the same dispersion pattern near the source with the Eulerian model and with the Gaussian model. The Gaussian model was equivalent to the Eulerian model in which the diffusivity depends on the distance from the source. With this theoretical underestimation of dispersion and dry deposition for CHIMERE model near the source, we performed a statistical comparison between the dry deposition outputs of both models.

Although CHIMERE could not accurately reproduce the dispersion and deposition near the source in a theoretical case, it produced acceptable averaged results for the whole simulation domain. One advantage of CHIMERE is that it may be used in much more complex cases of inhomogeneous turbulence than the cases for which it was conceived. However, NH3 deposition near the source could be improved by using spatial statistical relationships given by the OPS-st model to redistribute NH3 dry deposition near the source without modifying the code of the Eulerian model.

References

[1] Van Jaarsveld, J.A. 2004. The Operational Priority Substances model. Description and validation of OPS-Pro 4.1. RIVM-report 500045001. RIVM, Bilthoven, The Netherlands.
[2] Menut, L., Bessagnet, B., Khvorostyanov, D., Beekmann, M., et al. 2014. CHIMERE 2013: a model for regional atmospheric composition modelling. Geoscientific Model Development, 6(4), 981-1028.

ANAEROBIC DIGESTION OF ORGANIC MANURES AND EFFECTS ON NITRATE LEACHING ESTIMATED UNDER DANISH CONDITIONS

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Objectives

Part of the organically bound nitrogen (N) in manure and organic waste is converted to inorganic N by anaerobic digestion (AD) in biogas plants, and it influences both the fertilizer value of the manure and N leaching. The objective of this work was estimate long-term effects of AD of organic manures on N leaching under Danish conditions using a novel model. This also included effects of contrasting soil and climatic conditions and estimation of the temporal effect of AD when using different types of feedstock inputs in the biogas plant.

Method

Calculations of long-term N leaching were compared after application of untreated or digested manures using a new model described in detail by [1]. The change in the relationship between inorganic N and organic N by digestion is particularly important for the long-term leaching of N, and the model was used to calculate the long-term impact of digestion on N leaching. The proportion between organic N and inorganic N was assessed for different manure types. Based on a review of a number of old experiments in which N leaching was compared after application of mineral fertiliser and manure, we found that leaching from applied organic N and inorganic N is approximately similar in the first year after application. We used the empirical N-LES4 model [2] to estimate the first-year leaching from application of inorganic N and organic N in fertilisers in typical crop rotations on both dairy and plant production farms. Leaching estimates in the N-LES4 model is influenced by crop type, soil clay content and water drainage, and leaching estimates have been made for two contrasting conditions in Denmark: on sandy soil with a high precipitation and on loamy soil combined with low precipitation. The long term leaching of mineralized organic N is higher than for spring-applied inorganic N as N mineralization also takes place during autumn/winter when there is little or no crop N uptake [3, 4]. Based on calculations with the FASSET model mineralized N was assumed to be leached with a leaching factor that is twice as high as that for spring-applied inorganic N. The long-term time course of leaching was calculated using a model for the temporal mineralization of manure N. A similar average mineralization course was used for organic N in all manure types.

Results

With the current Danish fertiliser legislation total N inputs to land are unchanged after AD and an expected higher fertiliser value of the digestate is not accounted for in fertiliser planning. Under such conditions unchanged N leaching is estimated after the 1st year relative to the supply of untreated biomass/manure, while over a 10 year horizon a reduction in N leaching of 1.0 to 1.4 % of the manure total N input is estimated on loamy soils and a reduction of 1.9 to 2.7 % of the manure N input on sandy soils with high precipitation. Over a 50-year horizon, the corresponding reduction in N leaching after digestion is estimated to 1.5-2.2 % of the manure N input on loamy soils and 2.8-4.2 % on sandy soils. For example this means a long-term (50 yrs) reduction in N leaching of 2.5-7 kg N/ha by application of 170 kg total N/ha in manure. After AD of manures the fertiliser value is expected to increase by about 8 % points [1]. If mineral fertiliser N application is reduced correspondingly this results in a further reduction of N leaching equivalent to 1.0-1.8 % of total manure N application.

Scenarios with different combinations of manure and biomass were compared. Utilization of bioenergy crops like maize-silage for co-digestion in biogas production was estimated to increase N leaching depending on the proportion of N supplied with the energy crop. By use of high proportions of maize silage N leaching will exceed that from untreated manure with the present regulation due to a higher organic N input to land. For example it is estimated that application of 12 % maize-silage (by fresh weight) results in a slight increase of N leaching in the first year equivalent to 1-2 % of the manure N input while after 50 years there is no significant change in leaching compared to using undigested manure. Similarly, slightly increased long-term N leaching can be expected if new wastes, like household wastes, are introduced for land application using anaerobic digestion. This occurs because the input of total N per hectare will increase by such practice, as the extra organic manure input with a low N utilisation rate replaces inorganic N with a higher utilization rate.

Conclusions

A new simple model was developed and used for estimating the temporal effect of anaerobic digestion of organic manures on N leaching under Danish climatic conditions. The calculations indicate no effect of AD on N leaching in the first year, but with time an increasing reduction is estimated and after 50 years a leaching reduction equivalent to 1.5-4 % of the yearly manure total N input is estimated. This applies when total N application is unchanged with and without AD. A further reduction in N leaching can be achieved if the higher expected fertiliser value after AD is accounted for and mineral fertiliser N application is reduced. By addition of new organic inputs to biogas plants, e.g. in the form of a maize silage energy crop, the reduction in N leaching decreases and may even cause higher N leaching than by use of the untreated manure.

References

[1] Sørensen P., Børgesen C.D. 2015. DCA report no 65, Aarhus University.
[2] Kristensen K., Waagepetersen J., Børgesen C.D., Vinther F.P., Grant R., Blicher-Mathiesen G. 2008. DJF Plant Science no 139. 1-25.
[3] Thomsen I.K., Kjellerup V., Jensen B. 1997. Plant and Soil 197, 233-239.
[4] Sebilo M., Mayer B., Nicolardot B., Pinay G., Mariotti A. 2013. PNAS 110, 18185-18189.

THE EFFECTS OF SOIL TYPE AND CAULIFLOWER CROP RESIDUE PLACEMENT ON NITROUS OXIDE AND AMMONIA EMISSIONS

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Objectives

The decomposition of vegetable crop residues, e.g. from Brassica species, can cause substantial nitrous oxide (N_2O) and ammonia (NH_3) emissions due to their high nutrient and water contents. One promising approach to reduce these harmful emissions is the right choice of post-harvest tillage technique. The published results on the effects of different crop residue placement techniques on N_2O and NH_3 emissions so far do not give a consistent picture. One of the key issues is the diverse experimental conditions, in particular with respect to soil characteristics. To shed light on the soil-specific effects of residue placement technique on N_2O and NH_3 emissions, we studied the effects of cauliflower crop residue placement and soil type in a full factorial experiment.

Method

The experimental factor "soil type" was realized by taking advantage of a unique open-air facility featuring three different soils with contrasting soil texture (loamy sand, silt loam, sandy clay loam). The facility was established south of Berlin in 1972 where average annual precipitation sum is 500 mm yr^{-1} and the mean annual temperature is 9.8 °C. In this facility, cauliflower was grown according to common agricultural practice (protective nets, irrigation) and fertilized inorganically according to soil mineral N target values and expected N uptake. The crop residues were removed fresh, immediately slashed, and applied at rates equivalent to 154 kg N ha^{-1}. The experimental factor "residue placement" comprised four levels: complete removal of residues after harvest ("control"), surface application of residues and incorporation three weeks later ("mulch"), incorporation of residues by mixing ("mix"), incorporation of residues by plowing ("plow"). Emission sums of N_2O and NH_3 were derived from linearly interpolated gas flux measurements. Flux measurements of N_2O were obtained by applying the closed-chamber technique in combination with gas chromatography (4 samples per measurement). For NH_3, a passive filter trap method was used in combination with the ventilated closed chambers. The experimental duration lasted for 7.5-months, starting with cauliflower harvest.

Results

The addition of cauliflower crop residues generally increased both N_2O and NH_3 emissions as compared to the control for a period of 1-2 months. The N_2O emission sums (7.5 months) induced by residue application, i.e. after subtraction of the soil-specific control emission sums, were significantly affected only by residue placement, not however by soil type or the interaction of the two factors. The results suggest that cauliflower residues incorporated by plowing always cause higher N_2O emissions (2.3-3.4 kg N_2O-N ha^{-1}) than after surface application (0.4-0.9 kg N_2O-N ha^{-1}) or incorporation by mixing (0.7-1.3 kg N_2O-N ha^{-1}), irrespective of the soil type. This can be explained by the concentration of water and nutrients in a layer of burrowed crop residues after plowing, which most strongly supports the formation of anaerobic denitrification hot-spots. Apparently, this may also be true in a well-aerated soil, such as the loamy sand, which exhibited soil bulk water contents around 30 % water-filled pore space. Here, fresh patches of nutrient-rich residues can presumably create microsites that are at least temporarily independent of the abiotic conditions in the bulk soil. Yet, it cannot be ruled out that other source processes contributed significantly to N_2O emissions, especially in the loamy sand. In contrast, NH_3 emission sums induced by crop residues were significantly affected by residue placement, soil type, and the interaction of the two factors. Multiple comparisons revealed that this translated into significant differences among residue placement treatments in the loamy sand but not in the silt loam or sandy clay loam. In the loamy sand, the emissions increased in the order plow < mix < mulch ($0.2 < 1.0 < 1.9$ kg NH_3-N ha^{-1}). These results principally corroborate findings of other studies in that incorporation generally reduces NH_3 emissions substantially in comparison with surface-application. As far as the soil-type specific effect of residue placement is concerned, the results suggest that NH_3 emissions can be expected to be low in fine-textured soils with high cation exchange capacity, even when residues are surface-applied. In contrast, in coarse-textured soils with low cation exchange capacity the technique of residue application has a decisive impact on NH_3 emissions, which decrease with the deepness of incorporation. This result may be limited to situations where plant sap can be easily leached from the surface layer of residues to the upper mineral soil. In this context, the preparation of crop residues, viz. slashing in the present study, is presumably of particular importance.

Conclusions

Incorporating fresh and slashed cauliflower crop residues by plowing appears to produce the highest N_2O emissions in a range of soils whereas surface-application may primarily increase NH_3 emissions in coarse-textured soils with low cation exchange capacity. Future studies can be focused on testing the assumption of local and temporal independence of crop residue patches in terms of abiotic conditions or the contribution of different soil depth intervals to gaseous N emissions after application of crop residues.

LOW USE OF NITROGEN IN THE COLUMBIAN INDUSTRY OF SUBSTRATE GROWN CUT FLOWERS

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Objectives

1. Evaluating nitrogen content adjustment in the fertirrigation formula used for substrate grown minicarnations *cv.* Rony in the Bogota plateau.
2. Determining nitrogen content in substrate, foliar tissue and leachate at different phenological stages of minicarnation *cv.* Rony
3. Proposing and evaluating an alternative nitrogen content for the fertirrigation formula of minicarnation *cv.* Rony.

Method

The trial was carried out in the facilities of *Marengo* Agrarian Center, which belongs to *Universidad Nacional de Colombia*, is located in the municipality of Mosquera (14 km from Bogota) and makes part of the Bogota campus. A weighing lysimeter was employed as supporting tool for fertirrigation decision making. Minicarnation plants (*Dianthus caryophyllus* L.) cv. Rony were grown in a substrate made up of re-used rice husk, new rice husk and plant residue compost in percentages of 60, 30 and 10%, respectively, at a planting density of 24.7 plants.m^{-2}of greenhouse area. The irrigation system consisted of two 14 mm driplinesper bed, equipped with self-compensating emitters at 15 cm spacing and flow rate of 1.1 L.h^{-1}.
The experimental design was a repeated measures one with three between subjects factors (lixiviate, plant tissue and substrate), and a single within-subject factor (time). Three samples of lixiviate, three of substrate and three of total plant tissue were taken every seven weeks. The experiment was monitored for a period of 28 weeks. Statistical differences among treatments were identified in SAS 9.2.
Two treatments were applied: Treatment 1 (T1), which followed commercial growing criteria, and Treatment 2, with a modified formula. From planting to week 16, T1 contained the following compound formula (mg.L^{-1}): N, 220; P, 30; K, 130; Ca, 120; Mg, 40; Fe, 2.5; Cu, 1; Zn, 0.5; B, 2; Mo, 0.1. This formula was adapted from weeks 17 to 28 as follows: N, 165; P, 25; K, 190; Fe, 3; Zn, 1 and B, 1.5. In T2, the conventional formula was modified in its N content. During the vegetative phase, it contained (mg.L^{-1}): N, 110; P, 30; K, 130; Ca, 120; Mg, 40; Fe, 2.5; Cu,1; Zn, 0.5; B, 2; and Mo, 0.1.During the productive phase, modifications for T2 were: N, 90; P, 25; K, 190; S, 127; Fe, 3; Zn,1; and B,1.5, with no variation in all other elements. Both treatments were daily applied through 3 to 4 irrigation pulses per bed, each of which poured 70 to 80 L, depending on climate conditions.

Results

Under both treatments, N content was observed to increase during the first seven weeks of the experiment, reaching values that ranged between 3.2 and 3.6%, which can be considered normal according to foliar tissue reports by Ortega [1]. Later on, these values decreased until week 28, with average values of 2.4% for T1, and 2% for T2. Under both treatments, and according to usual standards, the crop's N assimilation values obtained during this period, which were found to be below 3%, would indicate deficiency of this nutrient. However, no deficiency symptoms (such as plant color changes) were observed.

According to Vélez [2], carnations grown in burnt rice husk show decreased N percentages in plant tissues, with values ranging between 1.89 and 2.67%, which are similar to those reported in the current work for T1 and T2. This, coupled to the fact that the plants were not affected by the N dropobserved along plant growth, demonstrates that said reduction was due to age and concomitant needs.

As to substrate measurements, significant differences in nitrogen content were found during week 1 under both treatments, when no nutrient solution had been applied. Thereafter, and except for significant differences recorded on week 28, no additional ones were found for the substrate-time interaction.

Substrate N content remained steady from weeks 7 to 21. In analyzing this nutrient across phenological stages, Botero and Flórez [3] report that it shows relatively lower levels during the first weeks, after which it goes up, to decrease during the final weeks before cutting. While T1 exhibited this behavior, T2 determined regular N levels all along the experiment. In this respect, Vélez [2] has observed that in all phenological stages, N percentages are inversely correlated with burnt rice husk proportion.

Maximizing crop productivity requires precision in N supply. This not only implies an optimal application of this mineral, but an optimal ammonia - nitrate - urea ratio in irrigation water as well. In greenhouse flower production, wherein irrigation results in a rapid flow through the radical zone, only $NH_4^+$and NO_3^- are usually applied, their ratio being used to balance rhizospherepH over time [4].

Conclusions

The N content modification treatments did not affect growth rate or stem length. Optimal exportation quality (99.63 cm stem length) was obtained under T1. Nonetheless, T2 allows reaching national market quality and 10% exportation quality.

A variable NO_3^+ concentration was observed under T1. In contrast, nitrate leaching under T2 showed stable behavior. This indicates that N concentration can be modified without affecting plant development. In this way, nitrate dumping in superficial and underground waters can be reduced.

In sum, N concentration reduction as applied in T2 constitutes a feasible option in carnations.

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References

[1] Ortega R., D. 1997. Fertirrigación en cultivos de flores. In: Silva M., F. (ed.) Fertirrigación, Sociedad Colombiana de Ciencia del Suelo, Colombia. p.136-147.
[2]Carvajal, N. A. V., Roncancio, V. J. F., and Rivera, A. F. 2014. Comportamiento de Variables Químicas en un Sistema de Cultivo sin Suelo para Clavel en la Sabana de Bogotá. Rev. Fac. Nal. Agr. Medellín, 67(2), 7281-7290.
[3] Botero, A. y Flórez V. 2012. Cambios en la composición química de los sustratos en el cultivo de clavel. In: Avances sobre fertirriego en la floricultura Colombiana. Universidad Nacional de Colombia. Bogotá. p. 124-132.
[4] Bar-Yosef, B., Mattson, N.S. and Lieth, H.J. 2009. Effects of NH_4^+: NO_3^-urea ratio on cut roses yield, leaf nutrients content and proton efflux by roots in closed hydroponic system. ScientiaHorticulturae,122(4), 610-619.

EFFECT OF WOOD ASH AND ROCKDUST ON CLOVER GROWTH AND DINITROGEN FIXATION

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Objectives

Bioenergy production with recycling of nutrient-rich by-products for agricultural or forest production can contribute to a circular economy. Wood ash not only contains high concentrations of nutrients (and potential pollutants) but also is a liming agent. Basaltic rockdusts are by-products from quarries and are sold and promoted as soil amendments. This study aimed to investigate if application of wood ash or basaltic rockdust can increase N_2 fixation by red clover (*Trifolium pratense* L.) grown in mixture with perennial ryegrass (*Lolium perenne* L.) on an inherently acid and nutrient-poor soil.

Method

A fully randomised pot experiment (4 replicates) testing amendment with by-products was revisited. Samples from treatments with bottom ash derived from mixed deciduous wood or basaltic rockdust, and a non-amended control were selected for analysis.

Topsoil was used from a postglacial silt loam which originated from mainly granitic and sandstone bedrock and had semi-natural grassland vegetation. The soil was sieved through 8×18mm mesh and homogenised before use. Portions of 6 kg dry weight were weighed to each pot and the amendments added after which all soil portions were homogenised. The ash was applied at 0.14 kg m^{-2} conforming to the maximum allowable 7-year application rates for trace elements as stated by the Swedish Environmental Protection Agency. Application rates for the rockdust surpassed these limits on the assumption that element availability was low; application thus followed the supplier´s recommendation (5.0 kg m^{-2}).

A mixture of red clover (cv. Nancy) and perennial ryegrass (cv. Helmer) was sown and thinned to 10 plants of each species per pot *ca* 2 weeks after emergence. Pots were also sown with pure ryegrass to serve as reference plants. The pots were kept in a fenced outdoor area and irrigated with deionised water to complement precipitation during the growing season and subsequently over-wintered at 0°C. Pots were returned to the outdoor area in April and harvested 15 June, 20 July and 20 August 2010. The clover was between the stem elongation and early flowering stage at all three harvests. Shoot material was force-dried at 50°C in perforated plastic bags, weighed, milled in a Grindomix GM 200 cutting mill and dry matter content determined on subsamples. Care was taken at all stages to prevent sample contamination. Samples were analysed for total N (LECO CN2000) and ^{15}N abundance. N_2 fixation was estimated by the ^{15}N natural abundance method [1] using the ryegrass in pure stands as reference crop and the lowest determined delta ^{15}N value as B value [2].

Results

Clover dry weight at the first cut was significantly highest on the ash amended soil (218 g m^{-2}), lower in the rockdust amended soil (145 g m^{-2}) and lowest on the control soil (85 g m^{-2}). Differences were significant also at the second cut. However, there were no significant differences at the third cut. This growth period had hot and dry weather which induced water stress in the pots, and most so in the ash amended treatment which had the highest electrical conductivity (not shown).

The ash amended crop accumulated significantly more total N (5.5 g m^{-2}) than the control (2.7 g m^{-2}) at the first cut, while the rockdust amended crop was intermediate (3.9 g m^{-2}) and not significantly different from the control. However, the total N concentration in the clover was higher in the control treatment (3.2% and 3.6%) than in the rockdust (2.7% and 2.9%) and wood ash (2.5% and 2.1%) treatments during the first and second cuts, respectively. The higher N concentration in the control treatment with its low biomass and lower concentration in the amended treatments suggests an N dilution effect caused by the increased biomass accumulation [3]. Dahlin *et al*. [4] found that Mg and Mo most likely limited clover growth on this soil, and this limitation was apparently alleviated by the application of ash and to some degree by the rockdust application. Other factors may also have contributed, though, such as differences in leaf:stem ratio and low numbers of rhizobia limiting N_2 fixation.

The percentage of clover N derived from air ranged 74-78% at the first cut and increased slightly to 87-91% at the third cut, with no significant differences between the treatments. The amount of fixed N in clover in the first cut was thus significantly higher in the ash amended clover (3.8 g m^{-2}) than in the control (1.7 g m^{-2}), with the rockdust-amended clover intermediate (2.7 g m^{-2}) and not significantly different from the control. The second cut showed the same trend, but differences were non-significant. Soil N used by the clover was significantly higher in the ash-amended plants (1.3 g m^{-2}) than in the control (0.6 g m^{-2}) with the rockdust amended clover intermediate (0.9 g m^{-2}). This suggests that increased mineralisation of soil N due to increased pH decreased the need for fixed N which may have contributed to the no-effect on the percentage N derived from air despite increased total N accumulation. The results confirm earlier work that N_2 fixation is generally driven by plant N demand as determined by biomass accumulation and availability of soil N.

Conclusions

The ash amendment increased N fixation and plant growth strongly in the clover. Plant growth increased to a lower degree on rockdust amended soil, but the N fixation was not significantly higher than in the control.

The study suggests wood ash high in nutrients but low in pollutants can be successfully used as a multi-element soil amendment to enhance clover growth on low-fertility soils. However, further studies including field experiments are required.

Acknowledgements

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References

[1] Jarrell, W.M., Beverly, R.B. 1981. Advances in Agronomy 34, 197-224.
[2] Dahlin, A.S., Edwards, A.C., Lindström, B.E.M., Ramezanian, A., Shand, C.A., Walker, R.L., Watson, C.A., Öborn, I. 2012. European Journal of Agronomy 43, 33-39.
[3] Cole, C.V., Heil, R.D. [SD2] 1981. In: Clark, F.E., Rosswall, T. (eds) Terrestrial Nitrogen Cycles, Ecological Bulletins, 33, 363-374

GUIDING FARMERS TOWARDS SMART FERTILIZATION AND A BETTER SOIL QUALITY IN BELGIUM AND THE NETHERLANDS

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Objectives

The LIFE-Demeter project (project partners: Flemish Land Agency (B), Ghent University (B), Nutrient Management Institute (NL)) wanted to develop an integrated approach to tackle the environmental problems (low soil quality, polluted water) caused by unsustainable soil management in Flanders and the Netherlands.

Specific objectives:

-increasing awareness amongst all agricultural stakeholders about the benefits and principles of a sustainable soil and nutrient management in daily farm practices.

-developing a decision support tool at field level integrating the major aspects of sustainable soil management: soil organic matter optimization and N and P fertilization. The tool will translate results of scientific research into practical recommendations to farmers. The more farmers will use the tool and implement the tool›s advices, the more the considered environmental problems (soil quality, polluted water) are improving.

-training farmers and advisors in the use of the tool. This will facilitate adoption of the tool and increase sustainable environmental results.

Method

The EU LIFE Demeter project created a unique integrated approach to improve both soil and water quality.

Development of the decision support tool, named Demetertool

The Demetertool operates as an online open-ended tool, whereby input can be specifically adjusted for each farm. The tool works with limited input and a user-friendly interface to enhance its success.

The Demetertool consists of an organic matter module (carbon evolution in the soil, using the Roth-C model) and a nutrient module (N and P balances) and operates on the field level. Following input of basic management and soil information of the field, the Demetertool offers farmers a soil balance-based N fertilizer advice, a long-term prediction of soil organic carbon stock evolution as well as a simple P-balance for a given crop rotation. These practical recommendations aim at a more integrated sustainable management of both nutrients and soil organic matter on an individual plot scale.

To maximize its usefulness, the tool was tested by experts, by 80 Flemish and Dutch farmers and 20 farm advisors of the Flemish Land Agency.

Validation of the decision support tool - field monitoring study

The Demetertool was validated with a group of 80 farmers in Flanders and the Netherlands. For each of the participating farms, the farm and soil management was studied. Two fields per farm were extensively monitored during 3 years. For each field soil analyses were performed (%C, pH, plant-available P, K and Mg, mineral N in the soil profile) and applied manure was analysed. Based on the soil analyses a fertilization advice was generated with the Demetertool. At the end of the growing season the applied fertilization was compared to the given advice and crop yield and residual nitrate in the soil profile were measured and discussed with the farmer.

Farm guidance

During the project Flemish farmers were visited and guided by the counselors of the Flemish Land Agency individually. During these visits, the counsellors advised the farmers about a more environmentally friendly farm management. Dutch farmers visited study group meetings, in which measures to improve their management were discussed.

Results

A decision support tool for sustainable soil management was developed and validated in Flanders and the Netherlands. Farmers were trained in using the webtool and about the principles of sustainable soil and nutrient management. To support this, information sheets were developed. Out of these methods came forth a set of results.

Since 2015, the decision support tool (Demetertool) is online. The freely available tool offers farmers a hands-on report about both the organic matter evolution and the nutrient management (nitrogen and phosphate) on their land. Moreover, farmers can change their inputs in the tool all the time and thus make simulations to calculate how much they can improve their soil quality significantly even by taking simple measures s.a. green crops, changing rotations and manure types,...
The Demetertool may be considered as a successful tool , appreciated by farmers and advisors as proven by the high number of active accounts (>500) since the tool was launched online.

The participating fields in the monitoring study had a loamy, sandy loam or sandy texture in Flanders and a sandy texture in the Netherlands. In Flanders soil organic matter content was low in the loamy and sandy loam soils: 63 and 50% of these fields had an OM content lower than 2% OM, respectively. In the Netherlands, 6% of the participating fields had an OM content lower than 2% OM and 59% below 3% OM.
On 36% of the participating fields the applied N by the farmer was in accordance with the advice generated by the Demetertool. 33% of those fields had a residual nitrate content in autumn above the limit of 90 kg nitrate-N/ha. On 34% and 30% of the participating fields the farmers applied more or less N than the recommended dose, respectively. This resulted in a residual nitrate content above the limit in 39 % and 19% of the fields, respectively.

The field monitoring study and guidance of the farmers resulted in a list of frequently asked questions most farmers have. Based on these questions, key topics were selected to create practical information sheets. This resulted in the information package: “A successful harvest on a healthy soil”.

Until now, this package contains information sheets about 15 topics: Green crops, Soil acidity, Plant nutrients, Working with the Demetertool, Soil structure and compaction, Crop rotation, Organic matter, ...

This information package is freely available in both a digital as a paper version and is used frequently by farmers and by advisors as teaching material. In 2016, also students in agricultural studies and new farmers will be addressed to work with both the Demetertool and the information package.

Conclusions

The Demeter project has delivered a decision support system that can help farmers to optimize nutrient and soil organic matter management simultaneously at field level. Calculations illustrate the potential of the DST as a unique and valuable tool for fertilizer recommendations and management of soil organic matter.

The information package “A successful harvest on a healthy soil” developed during the project is a useful and practical tool for farmers and students to learn more about sustainable soil and nutrient management.

The project results and products were mainly launched in 2015, as the Demeter project ended in 2016. To maximize the practical use of the project results, the three complementary partners cooperating in the Demeter project will consolidate these results in the long term. These partners are the Flemish Land Agency (BE), the Nutrient Management Institute (NL) and Ghent University, Department of Soil Management (BE).

The partnership created a long term action plan to guarantee awareness raising and maintaining the use of the Demetertool and information sheets after the projects end. Part of this plan is a set of communication actions s.a. social media, news messages, event communication, ... but also a maintained farm guidance in the form of group sessions and teaching sessions amongst students. The project partners will promote replication of the Demetertool in other European regions and countries.

Acknowledgements

Demeter is a LIFE+ project. The EU LIFE+ programme finances projects that contribute to the development and implementation of environmental policy and legislation.

PARAMETRIC CONSTRAINTS ACROSS PROCESS-BASED MODELS IN SIMULATING NITROUS OXIDE EMISSIONS FROM ARABLE FIELDS

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Objectives

The development and selection of process-based models requiring a limited number of readily available input parameters for accurate quantification of agricultural greenhouse gas (GHG) emissions and the identification of mitigation options is a significant objective. Of particular importance is the quantification of the fluxes of nitrous oxide (N_2O), a potent and stratospheric reactant having a large emission uncertainty. Several models are currently used to predict a GHG emissions in different ecosystems, DNDC [1], DailyDayCent [2] and ECOSSE [3]. In Ireland, some models have been tested/validated but the results have not been sufficiently robust for use in the inventory process. The availability of multi-year N_2O flux data and input parameters measured at field scale facilitated model comparison exercises. The main objectives were to simulate daily N_2O emissions using common input parameters, evaluate their seasonal/annual fluxes and emission factors (EF) together with an examination of differences between model outputs and measured datasets.

Method

Data on inputs and management practices were collected from field experiments conducted at the Teagasc, Oak Park, Carlow Research Station (Sandy loam-loam in texture, free draining, Euteric Cambisol). The experiments consisted of conventionally-tilled spring barley crops receiving N fertilizer (CAN) at 135-159 kg N $ha^{-1}yr^{-1}$ and crop residues at 3 t $ha^{-1}yr^{-1}$ over 8 years. Sampling of N_2O fluxes were carried out using static chambers at 0, 30 and 60 min intervals between 9 and 11 AM every week and more intensively (twice weekly) following fertilizer application, and measured using gas chromatography with an ECD. Simulations using three dynamic models (ECOSSE v5+, DNDC v9.4 and DailyDayCent) were performed and the comparative performance was evaluated against the effect of the measured variables on N_2O emissions. The datasets were collated and compiled to prepare a list of common input parameters with respect to site characteristics and management practice and either default or module-based datasets, including 30 year meteorological data (1982-2011) to initiate the models. Detailed site characteristics and input parameters can be found elsewhere [4,5,6].

The models were run (with initialization of soil C pool at steady state equilibrium values with crop residue inputs and N as NO_3^- concentration measured immediately before the start of the experiments) using the common input parameters. The outputs were collated and converted into standard units for comparison with measured datasets. The simulated values of N_2O were compared and validated quantitatively with measured and/or outsourced values. An evaluation of the consistency of seasonal (crop growing period)/annual N emissions with simulated values was carried out. Equal weights on all simulated values were placed to test the model fits for all data points. Seasonal and annual EFs over the simulation period were calculated by subtracting cumulative measured and model outputs of unfertilized controls from that of the fertilized treatments and dividing by the respective N inputs. Where applicable, an analysis of variance for significance at $p<0.05$ was performed and the exact 95% confidence intervals calculated using both SAS v. 9.3 (SAS Inc.) and MODEVAL.

Results

The maximum N_2O fluxes measured over 8 years was 17.6 g N $ha^{-1}d^{-1}$ (except one i.e. 56.0 g N $ha^{-1}d^{-1}$) and a minimum of -8.0 g N $ha^{-1}d^{-1}$ for the fertilized, and 6.6 versus -10.4 g N $ha^{-1}d^{-1}$ for the unfertilized fields. The simulated N_2O fluxes varied largely between the fertilized (80.0-100.9 g N $ha^{-1}d^{-1}$) and unfertilized (24.5-56.5 g N $ha^{-1}d^{-1}$) fields, with the highest peaks coming from DailyDayCent. Regardless of the models, the simulated N_2O fluxes were consistent over the years but none of the models predicted fluxes less than zero or captured the daily N_2O fluxes for the unfertilized field. The results contrast with the measured values, where a sink of N_2O occurred under conditions of high moisture and low nitrate level. The total bias and error differences for N_2O fluxes were within their 95% confidence levels indicate the quite high predictive potential of the models. However, only the ECOSSE-simulated values showed a significant relationship (R^2=0.33, p<0.05) with the measured ones under fertilized conditions. These findings are in line with some previous reports [e.g., 2,5,7] although the overall performance depended mainly on the daily fluxes.

Based on an 8-year average, the DNDC-simulated total N_2O fluxes for the fertilized (207 kg N ha^{-1}) and unfertilized (81 kg N ha^{-1}) fields were 2-15 times lower than the estimates using the other 2 models. The variations among the model estimates and their relationship with key driving forces (e.g., soil water and NO_3^-) are assumed to be limited by functions that produce and release N_2O. However, results using ECOSSE are in broad agreement with the literature values for total N_2O emissions measured from crop fields (0.7-3.5 kg N $ha^{-1}yr^{-1}$) [8].

The DNDC and DailyDayCent models significantly (p<0.01) underestimated seasonal/annual N_2O fluxes compared to ECOSSE and the corresponding EFs were 0.09, 0.31 and 0.52%. Similar overall underestimations, particularly using the earlier versions of DNDC, have been reported [4,5]. The DailyDayCent model also underestimated the N_2O EF (44%), with similar findings using DayCent (~25%), when compared with the default annual value [9]. This may be attributed to the limited number of field measurements, as this could result in associated large uncertainties, and use of default values for both DNDC and DailyDayCent. In contrast, the ECOSSE model, on average, increased the EF by 35%, but was within a closer range of the measured estimate. This is in line with estimates made using the previous version of ECOSSE [10] although lower than the IPCC default value (1%). Overall, the estimation of EFs using simulated values is constrained by total flux differences between the fertilized and unfertilized fields. This indicates the need for adoption of an appropriate methodological compromise and consideration of other factors controlling N_2O emissions.

Conclusions

Both DNDC and DailyDayCent underestimated daily and total N_2O fluxes compared to ECOSSE. The ECOSSE provided an improved prediction of fertilizer-induced N_2O fluxes and thereby EFs. There are clear constraints in terms of the processes and driving forces (e.g. growth parameters, soil moisture) to predict precise N emissions. Further refinement and validation of all models, including sensitivity tests of site characteristics, land use and management, and climate are recommended. This will provide improved agricultural GHG estimates for upscaling to the national level and for identification of mitigation options.

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References

[1] Li, C., Frolking, S., Harriss, R. 1994. Gloabl Biogeochemical Cycles 8, 237-254.
[2] Del Grosso, S.J., Ojima, D.S., Parton, W.J., et al. 2002. Environmental Pollution 116(S1), S75-S83.
[3] Smith J.U., Gottschalk, P., Bellarby, P.J., et al., 2010. Climate Research 45, 179-192.
[4] Abdalla, M., Wattenbach, M., Smith, P., et al. 2009. Geoderma 151, 327-337.
[5] Abdalla, M., Rueangritsarakul, K., Jones, M., et al. 2012. Water Air & Soil Pollution 223, 5155-5174.
[6] Khalil, M.I., Kiely, G., O'Brien P., Müller, C., 2013a. Geoderma. 193-194, 222-235.
[7] Bell, M.J., Jones, E., Smith, J., et al. 2012. Nutrient Cycling in Agroecosystems 92, 161-181.
[8] De Gryze, S., Wolf, A., Kaffka, S.R., et al. 2010. Ecological Applications 20, 1805-1819.
[9] Del Grosso, S.J., Mosier, A.R., Parton, W.J., Ojima, D.S. 2005. Soil & Tillage Research 83, 9-24.
[10] Khalil, M.I., Richards, M., Osborne, B., et al. 2013b. Atmospheric Environment 81, 616-624.

SIMULATING SUSTAINABLE NITROGEN AND PHOSPORUS USE ON FARM LEVEL IN ACCORDANCE TO FERTILISING LIMITS IN FLANDERS

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Objectives

Council Directive 91/676/EEG concerning the protection of waters against pollution caused by nitrates form agricultural sources sets out that catchments of ground and surface waters that are at risk of being polluted should be designated as nitrate vulnerable zones. In these NVZ's an action programme should be outlined every four years implementing compulsory measures to decrease losses of nutrients to the aquatic environment.

A key measure in action programmes is the limitation of fertilizer application rates. In consecutive action programmes, Flanders has decreased nitrogen fertilization limits to reach equilibrium between fertilisation and crop requirement. To further improve water quality, Flanders' 5th action programme (2015-2018) differentiates nutrient management measures between regions and farms according to their regional and individual impact on water quality. This further increased the complexity of the legislation which further enhanced the need for a decision support tool. Since 2008 the Flemish Land Agency offers a Balance Simulator.

Method

The decision support tool (DST) Balance Simulator is developed by the Flemish Land Agency and was made available for use by farmers for the first time in 2008. The aim is to support farmers in reaching a better nutrient use efficiency and at the same time help them to adopt legislation after each review of the action programme. To enhance the use of this DST by the individual farmers, this tool is developed in Microsoft Excel and can easily be downloaded from the website of the Flemish Land Agency (www.vlm.be). The Balance Simulator runs on the farmer's computer, which ensures full confidentiality of the data that are filled in to make simulations. The programme is updated annually to implement changes in legislation, correct flaws in the programme and improve the performance.

In a first stage, the farmer needs to answer several questions about his farm management (crop or livestock production), the objectives of using the balance simulator (use as a fertiliser plan and fertilisation account in function of the legislation) and the simulations he wants to make, leading to a customised DST tailored to the farm. In a second step the farmer needs to provide data at both the farm and the parcel level. At farm level information is requested on livestock production, manure production and transport from and to the farm, inputs of mineral and other organic fertilizers. At parcel level the farmer supplies the crop type, acreage, soil type.

Results

Based on the production and inputs of nutrients in the farm as well as the different crops and their acreage, the farmer distributes the available nutrients between the parcels of the farm in order to obtain a sustainable fertilisation plan. This will result in a real-time calculation of farm gate balances and parcel level balances.

With this information the farmer can make decisions or simulations to improve the farm nutrient management: how much manure needs to be exported off the farm, which nutrient flow is out of balance, what is the effect of derogation on the farm, what if manure of other farmers is accepted, what are the possibilities of manure treatment techniques, is there space for expansion of the farm, etc.

The Flemish Land Agency uses different methods to enhance the use of the Balance Simulator by farmers. The simulator is free for download from the website www.vlm.be. In winter period sessions are held were farmers can practise the use of the programme. In spring the advisory service of the Flemish Land Agency starts with the assistance of individual farmers who have to deal with restrictions due to bad practices: meanwhile the possibilities of the programme are shown.

In the period 2008-2015 2,056 farmers were reached through practical sessions. The winter period 2015-2016 has not yet come to an end, but already 531 farmers (27 January) were reached. In the period 2008-2014 4,476 downloads were registered, but some of them are counted twice with the sessions. On the other hand many downloads are on account of (private) suppliers of farmers: in these cases it is not known for how many farmers the programme is used. In 2015 there were 859 downloads due to the starting of the new action programme.

From 2016 on, other pathways will be explored to spread the use of the programme more efficiently: e.g. asking suppliers of farmers to persuade farmers to practise the use of the programme in groups.

Conclusions

The differentiation between farms and regions, for measures to improve nutrient management which was introduced in Flanders' fifth action programme in execution of the Nitrates Directive, has increased the complexity of the legislation which further enhanced the need for a decision support tool. The Balance Simulator helps farmers to overview the consequences of new legislation and how to deal with it.

The use of Balance Simulator by the individual farmers is increasing and will be further enhanced following several strategies.

NITROGEN LEACHING OF AUSTRIAN'S ARABLE AREAS UNDER THE PERSPECTIVE OF GREENHOUSE GASES EMISSIONS

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Objectives

Agricultural production causes greenhouse gases emissions, which have to be evaluated and reported annually at national scale according to IPCC guidelines. The guidelines require the estimation of indirect nitrogen soil emissions via leaching and runoff. The ratio of these nitrogen emissions and the sum of total nitrogen inputs and mineralization potential of crop residues is termed factor $Frac_{LEACH}$. Without better information a $Frac_{LEACH}$ of 0.3 has to be used for the national inventory reports. In this study a country specific $Frac_{LEACH}$ value for arable land in Austria was calculated, considering typical crop rotations, management practices and different soil qualities at the main intensively used agricultural areas.

Method

The IPCC $Frac_{LEACH}$ value can be calculated by dividing the nitrogen losses by the sum of all nitrogen inputs and mineralization potential of crop residues. Therefore, we used the physical based SIMWASER/STOTRASIM model to calculate the nitrogen losses through leaching and the crop mass which is the basis for the amount of residues left on the field. Nitrogen inputs via mineral and organic fertilizers were taken as proposed in the Austrian fertilization guideline. There are eight major agricultural production areas in Austria, which can be subdivided into 87 minor agricultural production areas (MAPAs). The delineation of these areas was based on landscape and climatic characteristics and typical farm characteristics (size, type of farm, etc.). The simulations were done for the 17 MAPAs with the highest contribution of arable land (coverage of 65 % of total arable land). Within each of these 17 MAPAs three soil qualities (poor, mean and good = 10%, 50% and 90%-percent quantile of the distribution of effective field capacity) were investigated. Soil information was obtained from the Austrian Soil map which provides information on soil type including layering, layer depth, textural composition and organic carbon content. This basic soil information was converted from maps into quantitative parameter sets within SIMWASER using a large soil database that was established during SIMWASER development. Typical crop rotations, land management practices and fertilization practices, especially the type of fertilizer and the time of application, were obtained from the Austrian agricultural chamber for each of the 17 MAPAs. A total of 35 crop rotations were analysed. Combined with three soil qualities, this resulted in 105 simulation runs. Annual harvest data for the relevant crops provided by the Austrian Statistical Office where used for the model calibration.

Results

Concerning the effect of soil quality as reflected by the simulation runs of 'poor', 'medium' and 'good' soil qualities, overall the 'poor' soils exhibit 36 % higher nitrogen loss through leaching compared to 'medium' soils, while the 'good' soils release 13 % less nitrogen to groundwater.

In our simulations, all 'medium' and 'good' soil scenarios resulted in lower $Frac_{LEACH}$ values than the IPCC default of 0.3. With a few exceptions, also the 'poor' soil conditions gave lower $Frac_{LEACH}$ values than proposed by the IPCC. For the 'poor' soil conditions, the mean $Frac_{LEACH}$ was estimated as 0.21 with a standard deviation of 0.09. Smaller values of $Frac_{LEACH}$ were simulated for the 'medium' and 'good' soil conditions with 0.14 and 0.12, and standard deviations of 0.07 and 0.06, respectively.

Only in four MAPAs, and in those only for the 'poor' soil conditions, the IPCC default value was exceeded. These MAPAs are already in the focus of public efforts to reduce nitrate concentrations in the groundwater, which underpins the validity of the model simulations The highest values for $Frac_{LEACH}$ (between 0.33 and 0.36) were simulated in MAPAs with very high groundwater recharge either because of high annual rainfall and/or low effective field capacity.

However, low effective field capacity alone does not necessarily cause high values of $\mathrm{Frach}_{\mathrm{LEACH}}$. For instance in two MAPAs with low effective field capacity (50 - 70 mm · m^{-1}) $\mathrm{Frac}_{\mathrm{LEACH}}$ values are only 0.13 to 0.18. This is caused by a direct effect of the crop rotation, which included forage crops for one third of the six years lasting crop rotation for these MAPAs. As is known from previous studies nitrogen losses and therefore $\mathrm{Frac}_{\mathrm{LEACH}}$ is much lower for grassland than for arable land. Therefore, considering the whole crop rotation, the long term mean for $\mathrm{Frac}_{\mathrm{LEACH}}$ is balanced although higher losses might occur during the years of maize or cereals growing.

In general there is a positive correlation (r = 0.61, spearman correlation) between $\mathrm{Frac}_{\mathrm{LEACH}}$ and groundwater recharge and a negative correlation (r = -0.58) between $\mathrm{Frac}_{\mathrm{LEACH}}$ and effective field capacity. Fertilization had the lowest impact on the $\mathrm{Frac}_{\mathrm{LEACH}}$ value (r = 0.33) although the impact is stronger for the individual soil classes. A surprisingly high negative correlation exists between $\mathrm{Frac}_{\mathrm{LEACH}}$ and the crop residues (r = -0.71). An explanation could be that crop rotations with higher share of catch crops which are usually not harvested show reduced nitrogen losses through leaching but increase amount of crop residues left on the field. Additionally, straw from cereals remaining on the soil has a wide carbon-nitrogen relation (~100:1), which immobilizes inorganic nitrogen and decreases nitrogen leaching.

Conclusions

Consideration of the areal contribution of each simulated MAPA and including different soil qualities within each MAPA leads to a weighted average of $\mathrm{Frac}_{\mathrm{LEACH}}$ on arable land in Austria of 0.16. If one accounts for nitrogen losses through lateral pathways by a 30% increase the value for Austrians arable land increases to 0.20. Including grassland (share of 51 %) leads to an overall $\mathrm{Frac}_{\mathrm{LEACH}}$ of 0.11 for all agricultural land.

In general, the Austrian fertilization guideline provides suitable thresholds for fertilizer application. However, within sensitive regions with low effective field capacities and/or high groundwater recharges, high nitrogen losses may occur. An overall maximum long term nitrate concentration of seepage water from the simulations would be 27 mg l^{-1} which is below the threshold for drinking water of 0.50 mg · l^{-1}. However, it should be noted that in some years, higher nitrate contributions to the groundwater occurs. These might be compensated by low contributions in other years, but may lead to concerns for drinking water supply. Further, irrigation was not included in the analyses but might increase nitrogen losses to the groundwater. Choice or adjustments of the crop rotation, e.g. the integration of forage crops, are able to significantly lower the long term $\mathrm{Frac}_{\mathrm{LEACH}}$ values and nitrogen losses. During the growth period, the crops directly control nitrogen consumption. Beneficial effects also occur when residues are left on the field after harvest.

OPTIMIZING N-TRANSFER IN WINTER-WHEAT CROPPING SYSTEMS THROUGH MICROBIAL N-IMMOBILIZATION

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Objectives

N-leaching is a serious issue in respect of groundwater pollution, indirect GHG emission and energy balance. Several studies showed the possible impact of tillage intensity and crop residue composition [1]. But there is a lack of information about options to reduce N-leaching by actively manipulating microbial immobilization with respect to its total amount and timing. Microbial activity is strongly connected to the availability and C/N ratio of the soils organic biomass [2]. Therefore we tested approaches to manipulate the soil conditions in a field experiment by application of different organic materials. The focus has been set on crops with problematic high N-contents after harvest i.e. oilseed rape (WOSR) and faba beans (FB). Followed by winter-wheat these crops cause a high risk of nitrate leaching. In parallel we strive to simulate the mineralization, leaching and N-uptake processes after harvest using the obtained experimental data for parametrization and validation.

Method

The field experiment consists of two local common crop compositions (WOSR - wheat - barley and FB - wheat - barley). Organic biomass is applied with four substrates differing in their C/N ratios (straw of the preceding crop, wheat straw, saw dust and complete straw removal). The following winter-wheat is fertilized with four different N-levels (from none to more than optimum) allowing to determine the effect of biomass application on optimum N-rates and thereby N-transfer effects. After harvest of WOSR and FB, during the fallow period and during parts of the winter-wheat growth period effects of biomass application on nitrogen turnover will be observed by recording of GHG emissions (closed-chamber method, [3]) and Nmin contents.

Results

First data obtained in autumn 2015 suggest different turnover rates in dependency of the substrate treatment. Wheat straw incorporation shows the strongest effects on N2O-emission rates and Nmin retention, which could be signs of immobilization.

Conclusions

During the growth period 2016 the leaf area index and thereby N-uptake dynamics will be observed. Together with the yield data the results will be statistically analyzed and used for the evaluation of a soil-plant model. If indicated the experimental design will be adjusted before the next post-harvest period.

References

[1] Henke, J., Böttcher, U., Neukam, D., Sieling, K., Kage, H., 2008. Evaluation of different agronomic strategies to reduce nitrate leaching after winter oilseed rape (Brassica napus L.) using a simulation model. Nutr. Cycl. Agroecosystems 82, 299-314. doi:10.1007/s10705-008-9192-0
[2] Abiven, S., Recous, S., Reyes, V., Oliver, R., 2005. Mineralisation of C and N from root, stem and leaf residues in soil and role of their biochemical quality. Biol. Fertil. Soils 42, 119-128. doi:10.1007/s00374-005-0006-0
[3] Lapitan, R.L., Wanninkhof, R., Mosier, A.R., 1999. Methods for stable gas flux determination in aquatic and terrestrial systems, in: Bouwman, A.F. (Ed.), Developments in Atmospheric Science, Approaches to Scaling of Trace Gas Fluxes in Ecosystems. Elsevier, pp. 29-66.

EFFECT OF A NITRIFICATION INHIBITOR ON NITROUS OXIDE AND AMMONIA EMISSIONS FROM A MAIZE CROP

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Objectives

Improving the Nitrogen Use Efficiency (NUE) of N fertilized cropping systems is a crucial issue both from economic and environmental points of view. For that purpose, one of the potential technological strategies is the use of nitrification inhibitor (NI) which inhibits the ammonium oxidation into nitrate Nitrification gives rise to N losses via both nitrate (NO3-) leaching and the greenhouse gas nitrous oxide (N2O) emissions. In this way the DMPP (NI) provide an opportunity to act against N losses from agro-ecosystems. The objective of this study was to assess the use of DMPP (3,4-dimethyl pyrazole phosphate) and DMPSA (3,4-dimethylpyrazol succinate) (NI) under Mediterranean conditions in order to reduce N2O emissions from agricultural fields. We also aimed to investigate the potential effect of using NI on NH3 emissions from an irrigated maize crop fertilized with pig slurry (PS) and Calcium Ammonium Nitrate (CAN) in split application.

Method

The experiment was conducted in “la Chimenea” field station located in the central Tajo river basin near Aranjuez, (Madrid, Central Spain). The soil type is a silty clay loam (Typic Calcixerpt), calcareous and rich in organic matter and basic pH (8.2). Four plots (40 m × 40 m) were selected and arranged, according to treatments, in a randomized complete block design with two replicates per treatment. Since each plot was 1.600 m2, the settlement of more than 2 replicates per treatment could not be performed [1]. The application of fertilizers was adjusted to provide 200 kg total N ha-1 for all treatments in split application.

The first fertilization comprised two different treatments: (i) pig slurry (PS); (ii) pig slurry mixed with the nitrification inhibitor DMPP (provided by EuroChemAgro) with a weight-based proportion of inhibitor in the mixture of 0.81 % (i.e., 5 kg DMPP ha-1) (PSNI). Pig slurry was homogeneously applied by surface spreading and subsequently incorporated up to 10 cm on 20th April 2015 at a rate of 50 kg N ha-1 and maize was sown on 30th April 2015 at a density of 75.000 seeds ha-1.

At the second fertilization (23rd June 2015), CAN (calcium ammonium nitrate) synthetic fertilizer was applied to the soil surface in granular form by hand at a rate of 150 kg ha-1 with and without the nitrification inhibitor DMPSA (provided by EuroChemAgro) in the PS and PSNI treated plots, respectively. A control treatment (C) was used as semi-control as no N fertilizer was applied in these plots. Irrigation started on May 28th (25.9 mm) and finished on the 2nd September. Total water applied to the crop through sprinklers was c. 900 mm

Results

The application of DMPP with PS (PSNI) in the first fertilization had a non-significant difference with C treatment. Oppositely, significantly higher N2O fluxes were measured in plots without DMPP. All the treatments became of the same order of magnitude 16 days following the first fertilization. On the other hand, as a result of the second fertilization (23rd June 2015), N2O emissions were surprisingly higher in plots where the NI had been applied. This was thought to be associated to favoured denitrifying conditions due to intense irrigation. In any case, differences between cumulative fluxes from PS and PSNI at the end of the measurement period were not significantly different.
For both treatments, the highest daily losses of NH3 occurred one day after the application of the fertilizers, afterwards, almost no NH3 losses were measured in the 28 following days. The use of NIs did not affect significantly cumulative NH3 emission The average NH3 cumulated emission from PSNI and from PS plots amounted to 3.0 and 3.1 kgN-NH3 ha-1, respectively. At the end of the experiment, NH3 losses from PS only reached 5.5% of the TAN applied, while losses from PS+DMPP amounted to 5.1%. . Absence of sig-

nificant differences was attributed to the implementation of NH3 abatement application practices for both organic (mechanical incorporation) and synthetic (incorporation with irrigation water) fertilizers [2].

Soil NH4+ content varied significantly with time being driven by N application. Pig Slurry applied with DMPP delayed the NH4+ peak concentration by 10 days but induced a peak concentration about 3 times higher (highest values reached 64.55 mg N- NH4+ kg-1 dry soil) compared to PS alone (highest value reached 39.14 mg N- NH4+ kg-1 dry soil). After peaking, the gradual decline of NH4+ during the experiment could be due to nitrification, NH3 volatilization, N uptake by vegetation and microbial immobilization.

Total biomass was increased by fertilizers comparting to the control plots, no significant differences were detected between plots fertilized with and without DMPP
Yield scaled N2O emissions (considering grain yield) was higher in fertilized plots than in C. Although no significantly different, the application of DMPP led to higher yield scaled N2O emissions (17.4 and 16.4 mg N2O kg-1, for PSNI and PS, respectively).

Conclusions

Considering the two fertilizations separately, cumulative N2O fluxes appeared to be dropped by 58% relative to PS treatment in the pre-seeding treatment.
It is likely that Mediterranean climate enables optimal effects of DMPP over both N2O and NH3 emissions since hot and dry conditions enhance both nitrification and slurry infiltration. Accordingly, applying DMPP with PS could be an efficient option for mitigating N2O fluxes from crop fields in Mediterranean agro ecosystems but this should be done under dry conditions and slurry should be incorporated in order to avoid the probable increase of NH3 emissions associated to the use of DMPP.

When irrigation started, after fertilization with CAN, emissions of N2O were higher in the plots treated with CAN+DMPSA (PSNI) although differences were not significant comparing to CAN alone (PS). At the end of the cropping period, plots treated with NIs were associated with higher N2O emissions in comparison with PS+CAN plots although no significant differences were found. Emissions were low possible due to soil conditions (e.g. high soil moisture) favoured by irrigation and leading to denitrifying soil conditions. Emissions of NH3 were decreased by the application of NIs, without significant differences between N fertilized plots. This would have been associated to an application of the fertilizer following NH3-abatement strategies (e.g. incorporation of the slurry and CAN, physically and with irrigation, respectively).

NITROGEN MINERALISATION AND GREENHOUSE GAS EMISSION FROM SOIL APPLICATION OF SLUDGE FROM SLUDGE TREATMENT REED BED SYSTEMS

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Objectives

Sludge Treatment Reed Bed system (STRB) is a technology to dewater and stabilize sludge from wastewater treatment by simple gravity filtration and mineralisation. This creates a solid sludge residue of a quality that makes it suitable as fertiliser on agricultural land. However, there is little information about the main effects on N mineralisation and greenhouses gas (GHG) emissions in soil after the sludge residue application. In this work we evaluated the effect of treatment time (degree of stabilization) of sewage sludge residue in a vertical profile from three different STRBs on soil N mineralisation and GHG emissions after it is applied to soil.

Method

Sludge residue was collected at three different STRB in Denmark: Helsinge STRB (Hel) Stenlille STRB (Ste) and Himmark STRB (Him). At the last day of the resting period (without input of sludge), eight sampling points were randomly chosen in each STRB. At Hel and Him, the cores were taken to a depth of 100 cm, whereas at Ste the cores were only 40 cm deep (the total depth of this STRB). Three cores from each point were taken. One from each point was mixed into homogeneous samples, whereas the two remaining cores were cut into depth fractions, each of 10-cm. Grounded and dried sludge samples were used to estimate total carbon (TC) and total nitrogen (TN) using an elemental analyser. Mixed and different depths samples were used in an incubation experiment. Sandy loam soil from the CRUCIAL field trial in Taastrup (Denmark) was amended with the different sludge samples at rate of 2% (dry weight). Water content was adjusted to reach pF 2 (24% water w/w and 60% Water filled pore space). On days 0, 1, 3, 7, 14, 42, 80 and 160 of the incubation, a destructive sample was analysed for ammonium and nitrate N (sum of these termed inorganic N (IN) in the following). On day 0, 1, 3, 5, 7, 21, 42, 80 and 160, a static chamber (kilner jars) was used to estimate CO_2 and N_2O emissions, taking gas samples after sealing (time 0) the jar and again after two hours of incubation. All the gas samples were analysed by gas chromatography.

Results

Main properties of the sludge residue varied across the depth of the profile. In general, an increase of dry matter content from 20 to 27 % was observed in the deeper samples, suggesting that the STBR system is effective for sludge dewatering due to water drainage and evapotranspiration from the reed beds. However, a reduction in TN and TC content was found for the deeper samples, which could be due to the mineralisation of the sludge residue along the profile and plant uptake of mineralised N in the reeds. Similar results were reported by Nielsen and Bruun [1]. At the end of the incubation, the IN mineralised out of the TN applied was higher for the Hel and Him samples with 31 and 28 % of TN, respectively. In both, the IN production was significantly higher in the samples from the surface layers, reducing to around 16 % in Hel and 21 % of TN in Him in the deeper samplings. However, these differences were not observed in Ste, which was related with a higher C/N ratio in these samples. Yoshida et al. [2] observed a similar reduction in the N mineralisation in the samples from the deeper layers compared to the samples from the surface layers. These findings suggest that during the stabilization of the sludge, a significant part of N could be lost through volatilization, denitrification and leaching, but also that N uptake by reeds could be significant. At the same time, the C compounds in stabilized sludge have been reported to be more recalcitrant; furthermore, low N mineralisation in deeper layers can be expected. Correspondingly, for the samples from all three STRB plants lower CO_2 emissions from the deeper layers was observed. The highest CO_2 emissions were observed for the samples from the surface layers which could be related with the high content of labile organic matter and nutrients in the fresh sludge, serving as substrates for microbial decomposition processes and increase gas emissions from microbial respiration. Nielsen et al. [3] found a decrease in the labile organic C in the deeper layers from STRB systems.

Soil N_2O emissions decreased significantly with the application of sludge from the deeper layers compared to the samples from the surface layers, indicating that the stabilization of the sludge reduced the amount of organic matter for the denitrification process. However, the fertilisation with samples from the surface layers, with low dry matter content and high TN and TC is a substrate source for denitrifiers and therefore higher N_2O emission could be expected. The mixed samples for the three different STRBs systems resulted in very low N_2O emissions and as low as the values of the sludge from deep part of the profiles.

Conclusions

This study supports that STRB is an appropriated technology to stabilize sewage sludge, increasing the dry matter content and decreasing the availability of labile compounds. Application of less stabilized residue sampled in the surface part of the reed bed results in higher soil N mineralisation but also higher CO_2 and N_2O emissions. However, the combination between fresh (surface samples) and stabilized (deeper samples) is a good solution to reduce soil N_2O emissions, while still obtaining a high N availability in soil.

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References

[1] Nielsen, S., Bruun, E. W. 2014. Environmental Science and Pollution Research 22, 12885-12891.
[2] Yoshida, H., Nielsen, M. P., Scheutz, C., Jensen, L. S., Christensen, T. H., Nielsen, S., Bruun, S. 2015. Acta Agriculturae Scandinavica, Section B - Plant Soil Science 65, 506-516.
[3] Nielsen, S., Peruzzi, E., Macci, C., Doni, S., Masciandaro, G. 2014. Water Science and Technology 69, 539-545.

A PROPOSAL OF NITROGEN BALANCE IN A HIGH DENSITY OLIVE ORCHARD.

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Objectives

Fertilization of the olive tree (Olea europaea L.) is a cultural practice with the objective of covering nutrients exported by the plant [1]. One of the most essential nutrients for plant growth and production is nitrogen (N), which plays an important role and is usually the most consumed by the plant [2]. One of the tools used to program plant fertilization is the N balance, which considers the difference between inputs and outputs of this element. The objective of this experiment was to estimate the inputs and outputs of N in a very high density orchard related to tree response and soil conditions, particularly nitrogen availability.

Method

The trial was conducted on a commercial very high density olive orchard (cv. Arbequina) in Torres de Segre (Lleida) in northeast Spain for three years, 2010, 2011and 2012. The climate is continental Mediterranean. The average annual rainfall was 324 mm, irregularly distributed, and mean evapotranspiration (Penman-Monteith) was 1101 mm. The trees were planted in summer 2002 at 4.5 m × 2.2 m, (1010 trees ha-1) growing on a moderately deep soil. The soil was silty-loam textured and calcareous (pH = 8) with an organic matter content of 1.5%, and electrical conductivity (EC 1:5) of 1.4 dS m-1 (due to the presence of gypsum). Irrigation was based on water balance, applying 100% of the water needs of the plant throughout the growing season, according to the methodology of FAO [3]. To calculate the balance of nitrogen, two treatments of this element, N0 without N, and N50 with the application of 50 kg ha-1 of nitrogen with a N-32 (16% urea, 8% ammonium and 8% nitric) were weekly applied by fertigation. Statistical analysis of the results was performed using the JMP-SAS software (JMP, Version 12. SAS Institute Inc., Cary, NC, 1989-2014).

The nitrogen balance (kg ha-1) is expressed by the following equation [4]:

Nitrogen balance (kg ha-1) = N inputs - N outputs = N inorganic final - N inorganic initial = ΔN inorganic

Inputs calculated were the mineralization of organic matter, irrigation and rainfall N supply and the amount of N fertilizer applied. Outputs were calculated from crop and pruning exportations and N losses by denitrification [5] and leaching.

Results

Nitrogen exports by the crop and pruning material were 20 and 33 kg ha-1year-1 respectively for N0, and 30 and 62 kg ha-1year-1 for N50. This difference was due to a higher olive yield and nitrogen concentration in pruning material and fruits in N50 trees [6]. The amount of nitrogen lost by denitrification was negligible compared to other outputs, with values which did not exceed of 2 kg ha-1year-1, and with higher values for N50 due to the presence of large quantities of nitrate in the soil [7], [8]. No leaching losses were recorded because of a low rainfall and high evapotranspiration. The average amount of nitrogen provided by irrigation water and rainfall was 8.8 and 6 kg ha-1year-1, respectively. The mineralization of organic matter was 40 and 43 kg ha-1year-1 for N0 and N50 respectively.

During the three years period, the average of nitrogen balance was positive with values of 19.6 kg ha-1 for N50 and 9.5 kg ha-1 for N0. Distortions of nitrogen balance may be due to other factors which are difficult to quantify and not directly mentioned in this work like, 1) the mineralization of the pruning material and mowed weeds (because pruning residues were chopped and left onto the orchard), 2) natural leaf abscission [9] and 3) rhizodeposition contribution [10].

Conclusions

Nitrogen application significantly increases yield, vegetative growth and nutrient in plant tissues. The positive results for N balance can be explained as an adaptation of olive trees to different soil N availability conditions by equilibrating their vegetative growth and fruit yield.

References

[1] Hidalgo and Pastor. 2002. Vida Rural. February, pp: 46-50.
[2] Fernández-Escobar et al. 2008. Environmental and Experimental Botany 64: 113 - 119.
[3] Allen et al. 1998. FAO Irrigation and drainage paper 56: 1-15.
[4] Fernández-Escobar et al. 2012. Scientia horticulturae 135: 219 - 226.
[5] Maris et al. 2015. Science of the Total Environment 538, 966-978.
[6] Rufat et al. 2014. Agricultural Water Management 144: 33-41.
[7] Germon and Couton. 1999. Courrier de l'environnement de l'INRA. 38: 67-74.
[8] Henault et al. 1998. Biology and Fertility Soils 26:199-207.
[9] Rapoport. 2008. In: El cultivo del olivo. Junta de Andalucía/ Mundi-Prensa, España.
[10] Scandellari et al. 2010. Agriculture, Ecosystems and Environment 136, 162-168.

AMMONIA AND GHG EMISSIONS IN FRESH DIGESTATE LAGOONS IN SPAIN: A COMPARATIVE ASSESSMENT BETWEEN COVERED AND UNCOVERED STORAGE

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Objectives

Future trends of EU policies, aimed at increasing the use of clean energy, foster the spreading of anaerobic digestion plants that process organic materials like manure. Thus, the digestate production is increasing across Europe, although its efficiency as organic fertilizer and environmental concerns has not been widely studied as in the case of raw manure.

Gaseous emissions from fresh digestate lagoons might differ from those of untreated slurry due to the differences in their physical-chemical properties, such us lower dry matter and higher mineralized nitrogen and pH, which may enhance NH_3 emissions.

The purpose of this study is the evaluation of NH_3, N_2O, CH_4 and CO_2 emissions in two fresh digestate storage lagoons: an uncovered lagoon of 950 m^2 and 2,500 m^3, and a covered lagoon of 1,450 m^2 and 3,500 m^3 of storage capacity. Two different techniques have been used: dynamic chambers and a located extraction system respectively.

Method

The experiment took place in Almazán (Soria, Spain) from 30th June to 2nd July 2015. All measurements were performed at three time intervals: morning (10:00 - 11:30 a.m.), noon (1:00 - 2:30 p.m.) and afternoon (4:00 - 5:30 p.m.). The environmental conditions and the digestate temperature were monitored during the assay. The digestate from both lagoons was sampled and analysed in laboratory. The storages were at full capacity at the time of the trial and receiving approximately a flow rate of 100 m^3/day of fresh digestate.

Gas samples were analysed using a photoacoustic analyzer Bruel and Kjaer 1302, equipped to perform continuous measurements of NH_3, N_2O, CH_4, CO_2, and water vapour. The following sampling methodologies were used:

Dynamic chamber methodology in the uncovered lagoon

The digestate was poured directly into this lagoon and the emitting source was the whole surface. The method followed was an adaptation of the methodology developed in IRSTEA [1].

Six rectangular chambers (60 x 34 x 40 cm) were distributed evenly on the surface. One was placed directly in the discharge zone (hot-spot), two in the nearby and the other three chambers were placed away from there.

A clean air flow was passed through the interior of the floating chambers, simulating a natural air flow of 2.5 l/min (3.3 m/s wind speed), via polyethylene tubes. The samples from each chamber (outlet) were brought to the photoacoustic through teflon tubes and analyzed.

Located extraction system in the covered lagoon

10 safety valves (30 cm high - 13 cm diameter) evenly distributed around the perimeter of the lagoon represent the only emission points of the storage system. The stored gas was release freely without any forced draught.

Air flow rate in the valves was estimated measuring air speed with a hot-wire anemometer. The air samples were taken 40 cm above the base of the cover using a teflon tube. This tube was fixed in a PVC pipe also covered inside with teflon in order to avoid NH3 adherence (1 m high - 16 cm diameter) and placed over the valves monitored. 5 measurements were performed over 8 hours.

Results

During the sampling period, average temperatures were higher than usual in this region varying between 28 - 34 ºC and the wind blew gusty along the three days.

The average values analysed in digestate samples of the uncovered lagoon were: $N_{Kjeldhal}$: 3.10 kg/m^3, $N_{ammoniacal}$:2.66 kg/m^3, dry matter: 2.8% and volatile solids: 57.1%. In the case of the covered lagoon: $N_{Kjeldahl}$:2.37,

$N_{ammoniacal}$:1.99 kg/m^3, dry matter: 3.23% and volatile solids: 59.5%.

Uncovered lagoon

Average NH_3 emission ranged between 0.33 and 0.50 mg/m^2/min and didn't vary during the three days of measurements ($P>0.05$).

Emission level was below the values previously reported in scientific literature. It might be related to the low ventilation rate applied in this study (2.5 l/min).

The coefficient of variation of the average emission rates varied between 42 and 47%, due to the spatial and temporal heterogeneity of the emissions.

Concentrations up to 132 mg NH_3/m^3 were measured at fresh digestate discharge area (hot-spot) being 2-3 times higher than the average emission rate of the lagoon.

Ammonium concentration in digestate showed no differences between the closest and the furthest area of the lagoon to the discharge point. Thus, differences in the emission rate were not significant ($P>0.05$).

N_2O emission was negligible at uncovered lagoon, although some low positive concentrations were detected after digestate discharge (1.2 mg/m^3) associated to the aeration of digestate.

Daily average CH_4 and CO_2 emission rates (biogas) ranged between 64.7 and 125.0 mg/m^2/min, and 215.1 and 336.9 mg/m^2/min, respectively. Biogas losses were within the ranges reported in the scientific literature for raw slurry, although CH_4:CO_2 ratio (25:75) was lower. Biogas emission differed between two zones of the uncovered lagoon, being higher in those areas where dry matter and volatile solids content of digestate analyzed were higher. Additionally, this zone was stirred through a pump, which could also contribute to enhance the emission level.

Covered lagoon

The average exit speed of gas at safety valves was low (0.030-0.127 m/s), which was close to the detection limit of the hot-wire anemometer (± 0.03 m/s). Moreover, the speed of the circulating atmospheric air could have increased the uncertainty of the measurements and the estimation of the exhaust gas flow. Ammonia (4.2, 5.7 and 9.8 mg/m^3) and CH4 (16.8, 15.9 and 79.0 mg/m^3) daily average concentrations within the valve system were slightly higher than those measured in the ambient air. Emission losses in the covered lagoon, (NH_3: 4.4 to 7.1 mg/min and CH_4: 11.6 to 64.0 mg/min) estimated for the whole lagoon were reduced nearly 100% in relation to the uncovered lagoon (NH_3: 313- 477 mg/min; CH4: 484-937 g/min). N_20 emissions were also negligible.

Conclusions

In the uncovered lagoon, the dynamic chamber methodology used let notice the heterogeneity of the gas emission in the lagoon surface (VC > 30% in all the cases). NH_3 average emission rates (0.33 to 0.50 mg/m^2/min) were lower than the data found in scientific papers. It may be influenced by the use of lower air flow in the measurements (closer to real conditions). No N_2O emissions were detected and biogas emissions (CH_4: 64.7 to 125 mg/m^2/min and CO_2: 215-336 mg/m^2/min) were similar to scientific bibliography data, although emissions varied significantly on the lagoon surface, showing higher values in those areas where the dry matter and volatile solids content of digestate were higher.

In the covered lagoon the emission concentration of NH_3 (3.2 to 20.3 mg/m^3) and CH_4 (8.5 to 151 mg/m^3) in the valves were slightly higher than in atmospheric air and the emission rates (NH_3: 4.4 to 7.1 mg/min and CH_4: 11.6 to 64.0 mg/min) were reduced almost 100% compared to the uncovered lagoon (NH_3: 313-477 mg/min; CH_4: 484-937 g /min). No N_2O emissions were detected. Thus the cover is a useful measure in mitigating emissions of NH_3 and CH_4.

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References

[1] Peu, P., Beline, F., Martinez, J. 1999. Journal of Agricultural Engineering Research 73, 101-104

WINTER COVER CROPS IMPACT ON PLANT NUTRIENTS IN AN ORGANIC CROP ROTATION

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Objectives

In crop rotations winter cover crops (WCC) can play a certain role in organic matter and plant nutrient formation. Under Nordic conditions the selection of crops for winter cover crops is quite limited. The aim of the present research was to explain the biomass and nutrients (N, P and K) formation by certain winter cover crops in an organic crop rotation. The effects of WCC on the following main crop yields were monitored.

Method

The field experiment was situated at the experimental station of the Estonian University of Life Sciences in Eerika, Tartu, Estonia (58°22'N, 26°40'E). The soil type of the experiment area was sandy loam *Stagnic Luvisol* according to the World Reference Base classification (FAO 2014). The experiment was set up in four replications with each plot (60 m^2) in a systematic block design. In a five-field crop rotation, barley under sown with red clover, red clover, winter wheat, pea and potato were grown in succession in three organic systems. System Org 0 followed only the rotation. In system Org I, green manures as winter cover crops (WCC) were used: after winter wheat – mixture of winter oilseed rape and winter rye, after pea – winter oilseed rape and after potato – winter rye were grown. In System Org II, green manures as WCC were used with the application of fully composted cattle manure with the amounts of 20 t ha^{-1} for potato and 10 t ha^{-1} for both cereals. Seeding rate for winter oilseed-rape was 6 kg ha^{-1}, for winter rye 220 kg ha^{-1}, for mixture of rye and oilseed-rape 180 and 6 kg ha^{-1}, respectivey. In Org I and II systems all plots had green plant cover in winter. After the previous main crops were harvested the soil was immediately cultivated and WCC were sown with a Kongskilde sowing machine (row line width 12.5 cm). In all systems, the red clover was cut and then ploughed into the soil. The aboveground biomass of WCC were measured before their incorporation into soil by ploughing at end of April (2013, 2014, 2015). Total nitrogen and carbon contents of oven-dried samples were determined by dry combustion method on a varioMAX CNS elemental analyzer (Elementar, Germany).

Results

One way to reduce nitrogen/nutrient leaching and increase the soil organic matter/nutrient content is to use WCC. Our results showed that WCC biomass production depended on a crop species grown and growing year. On average, the winter rye produced the largest amount of biomass 893 kg ha^{-1} compared to rye and oilseed rape mixture 717 kg ha^{-1} and oilseed rape 577 kg ha^{-1}. However there were big differences between the years. The average biomass of WCC was lowest in 2013 and highest in 2015 ($p<0.05$). In autumn of 2012 there were problems with excessive wetness and the following winter was very long which suppressed the development of WCC. Also, the different WCC showed large differences in biomass production and in above-ground plant parts N binding. In system with green manures (Org I) the total biomass of WCC varied from 39 kg dry matter ha^{-1} of winter oilseed rape (in 2013) to 2174 kg dry matter ha^{-1} of winter rye (in 2015). Winter rye had also the best N binding ability: 15 kg ha^{-1} in 2013 and 99 kg ha^{-1} in 2015, whereas the winter oilseed rape fixed only 1 kg ha^{-1} in 2013 and 36 kg ha^{-1} in 2015. The low biomass of winter oilseed rape in 2013 can be explained by the extremely long winter in 2012/2013 which damaged the crop. The co-influence of cattle manure (Org II system) increased the amount of biomasses as well as N, P and K contents in all WCC but differences between Org I and II systems were not significant. Winter rye was also the most effective binder of phosphorus ($p<0.05$). There were no significant ($p<0.05$) differences between WCC in terms of potassium binding.

The winter cover crops within crop rotation supply N for the subsequent crop. After the WCC are incorporated into the soil the N mineralization process starts, thus part of the mineralized N becomes available for the following main crop. The main crop yields in Org 0 system was lower compared to other two systems where WCC probably helped to increase the yields. WCC and their combination with cattle manure application increased significantly grain yields of barley and, pea, as well as potato tuber yield (in 2013). Our results showed that lower crop yields and nutrient uptake under Org 0 system resulted with somewhat lower surpluses of N but the N use efficiencies were higher.

Conclusions

Winter rye, winter oilseed rape and their mixture as winter cover crops enrich crop rotation with organic matter, N, P and K whereas the winter rye was the most effective. A tendency occurred that the use of cattle manure increased the organic matter and nutrient formation in all WCC. Winter cover crops and their combination with cattle manure increased the yields in all rotation crops compared to a system in which no WCC were grown.

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MONITORING FERTILIZATION EFFECTS ON GROUNDWATER NITRATE POLLUTION

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Objectives

Nitrogen fertilization and irrigation both are playing an increasingly major role in crop production of the Mediterranean countries. Excess nitrogen fertilizer use is one of the phenomena as result of cropping factors and increased irrigation. However, fertilization induces nitrate losses to groundwater bodies especially during the rainy winter months and irrigation season in summer. Winter and early spring crops such as wheat and corn, receiving a large amount of N fertilizers (up to 380 kg N ha-1), contribute to NO3 losses to shallow groundwater by intensified seasonal rainfall. Therefore, the objectives of this research in a 9,495 ha irrigated land was 1) to determine temporal losses of NO3 concentrations to shallow groundwater wells, 2) to evaluate the affects of nitrogen fertilizers on concentration levels from 2010 to 2014.

Method

The research area Akarsu Irrigation District (9,495 ha) is located in the Mediterranean coastal region comprising the most intensively cropped and irrigated area of southern Turkey. The average annual rainfall in the experimental area was 640 mm on average. The soils of the study area are mostly alluvial, deep and high in clay, calcium carbonate and pH, but low in organic matter, and have wide cracks during the dry summer months.

The major crops of the District were wheat (Triticumaestivum), corn (Zea mays L.), citrus (Citrus sinensis L.), cotton (Gossypiumhirsutum L.) and various vegetables during the study years. Digitalized cropping-pattern maps showed that over 70% of the total irrigated land was covered by citrus and fruit trees, wheat and corn in the years under study. The most common irrigation practice in the location is gravity (surface) irrigation except irrigation of citrus and the other fruit trees.

The N fertilizer application rates for the crops varied between 60 to 380 kg N ha-1, with an average of 250 kg N in the 5 years. Information on fertilizer rates and fertilization practices was recorded through farmers' interviews by using questionnaires. Based on the cropping pattern, N fertilizer application continues year-around except a few months in early fall when no crops are fertilized in the field. Wheat and first-crop corn exist in winter and rainy spring are determined as excessively N receiving crops. The hydrological year (HY) in the District was considered to start on the 1st of October and finish at the end of September in the following year. The irrigation season (IS) covers the period from April the 1st to September the 30th, and the rest of the year was considered as the non-irrigation season (NIS).

The water samples were taken from 108 observation wells in January, April, July and September of each year to assess the NO3 concentrations. All water samples were analyzed for NO3 concentrations for each sampling period,and were mapped at GIS media. Soil mineral nitrogen (Nmin) was also determined in three depths to determine plant available N in a rooting depth (0-90 cm).

Results

Based on the cropping pattern done twice a year during the 5 years, the main crops of the District were mainly field crops as wheat, corn, cotton and citrus and fruit trees which were consisted of over 70% of the total crop coverage. Wheat and corn planted in late fall and early springwere excessively fertilized with nitrogen fertilizers without detailed soil analysis and expert recommendation. Local survey study showed that N fertilizer rates applied to the common crops increased 10to 35% in the last 5 years resulting in excessive mineral N build-ups in soil profiles and thus in the groundwater and irrigation return flows. Even though based on the expert recommendations wheat and the first crop corn need to be fertilized with total amount of

180 and 240 kg N ha-1, these crops recently receive 265 and 380 kg N ha-1, respectively, as combination of basal and surface applications. Therefore, these regular inorganic N fertilizers quickly dissolve in the soil by heavy winter and spring rains plus irrigation practices, and possibly leachto shallow groundwater. Since the both crops (wheat and corn) were in their dormant-to-early growth stages, most of the nitrate-N form subjected to leaching to groundwater and drainage. In addition, total of 70 to 130 kg Nmin ha-1were measured in a rooting depth.

Average nitrate concentrations in groundwater samples collected in January and March/April were higher than that of the other sampling periods and exceeded the critical threshold level (>50 mg L-1) in substantial area of the district. The groundwater nitrate values between 30-50 mg L-1 were potentially in the pollution risks (up to 41%) because of excessive N fertilization of wheat and corn. The lower NO3 concentrations up to 20 mg L-1 were also common in the 60 to 90% of the total area throughout the hydrological years (October 1st to Sept. 30th of the following year) except in mid winter to early spring. It is also a regional reality that these two crops will remain as the major field crops of the region because of their economical value and adaptability to the Mediterranean climatic conditions. Especially wheat will also be preferred as a rotational crop for many years allowing the growth of soybean, second crop corn and sesame after its harvest. In addition, citrus as a perennial tree significantly contributes to NO3 leaching to shallow groundwater and drainage in the study area.

Conclusions

Since there are considerable amounts of pre-plant soil mineral nitrogen in the rooting depth, and also groundwater nitrate concentrations are high in some locations, regional N fertilizer recommendations need to be considered and closely applied at the farmers' level.

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EFFECT OF COVER CROP BIOMASS APPLICATION AS A GREEN MANURE ON REDUCING NITROUS OXIDE EMISSION

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Objectives

The cultivation of a winter cover crop as green manure is strongly recommended to improve soil quality and reduce the dependence of chemical fertilizers in temperate cropping systems. However, its biomass application as green manure promotes greenhouse gas (GHG) emissions by providing a readily available C and N substrates. It is likely that improved crop production strategies will conflict with mitigation of GHG emission. However, little is known about the effect of cover crop biomass application on the emission of N_2O, which is a main GHG emitted from upland conditions and has 310 higher global warming potential (GWP) than CO_2 on mole base, in temperate cropping lands.

Method

In this field study, the mixture of barley (Hordeum vulgare R.) and hairy vetch (Vicia villosa R.) seeds with 75 % recommended dose (RD 140 kg ha^{-1}) and 25 % RD (90 kg ha^{-1}), respectively, were seeded in early November, 2011 and 2012, and harvested in early June 2012 and 2013, respectively. Total aboveground biomass was 36 Mg ha^{-1} (fresh weight basis with 43-69 % moisture content). In order to determine the effect of cover crop biomass application on N_2O emission, different recycling ratios of 0, 25, 50, 75, and 100 % of the total harvested biomass were incorporated as green manure one week before corn transplanting in a typical temperate upland soil. For comparison, chemical N fertilizer was applied with different levels from 0 to 200% of standard amount of N fertilizer (190 kg N ha^{-1}).

Results

Daily mean N_2O emission rates and total N_2O fluxes were significantly ($p<0.05$) increased with increasing application rates of cover crop biomass and chemical N fertilizer (urea). There was no difference on N_2O emission factor between chemical fertilization and cover crop biomass application with around 0.03 kg N_2O-N kg^{-1} N, but cover crop biomass application as green manure significantly reduced seasonal N_2O fluxes by 76% under same levels of N addition. Corn productivity also significantly ($p<0.05$) increased with biomass application, but the highest grain yield (14% increase over the control) was observed for 75% recycling.

Conclusions

Conclusively, cover crop biomass application as green manure might be suitable to sustain crop productivity with suppressing N_2O emission impact in temperate cropping system.

DIAGNOSIS OF N LOSSES IN CROPPING SYSTEMS IN WATER PROTECTION AREAS

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Objectives

Addressing the issue of agricultural pollution in water protection areas (WPA) requires assessing the impact of agricultural activities at regional scale. The main objective of this work was the diagnosis of the nitrogen losses of cropping systems in 7 contrasting water protection areas (WPA), in order to improve water quality and favor environmental-friendly systems. We aimed at involving stakeholders of each WPA, considered as local experts, to avoid results disconnected of the reality of farmers of the region. We used, adapted and developed, the framework described in Dupas *et al.* (1), consisting in describing the diversity of cropping systems and soils at the territory levels using local expert knowledge, and in assessing the nitrate losses in the territory with the modelling tool Syst'N (2). In this presentation, we will detail 3 contrasting WPA.

Method

The first step of this work was the selection of 7 contrasting territories in terms of size, production, pedoclimatic characteristics and issues. The second step consisted in developing a typology of cropping systems and soils in each WPA, taking account of the local diversity, as the WPA were too large to enable an exhaustive description of the territory. We built the cropping system typology in collaboration with extension services or farmers so as to mix their local knowledge and data provided by local databases or regional statistics. The method was based on farmer logics considering nitrogen management. Soil types were defined with local pedologists and by using regional databases. The allocation of cropping systems in the WPA was also provided by the local experts or by making assumptions. Those descriptions were then translated in inputs for the DSS Syst'N; Syst'N includes a dynamic model simulating N fluxes in air-soil-plant system at a daily time step, and enables to view nitrogen losses results at different time scales. A third step was the Syst'N simulations in each WPA, including stages in which parameter optimization was required to fit field measurements (mineral N stocks in soil, N uptake by crops). The last step was the shaping of results that could be adapted to the specific issue of each WPA. However for all the WPA the results were expressed at the rotation scale or for two successive crops.

Three WPA will be presented here (called H, B and L), varying in terms of size (90 to 1300 ha), level of involvement of stakeholders, type of agriculture (crops *vs* livestock).

Results

A general result is that despite of the successive steps of the approach, interactions between local experts and researchers were regular and useful during the whole study, strengthened in the WPA where the stakeholders were deeply involved in the process and where a dynamic had already been created at the local scale.

As a result of the development of the typologies, tables combining agricultural practices linked with nitrogen management and soils were produced to report the diversity of cropping system in the WPA, regarding the functions affecting nitrogen losses.

The DSS Syst'N required in nearly all the WPA expert knowledge or measurements to parameter situations and provides more correct results, which asks the question of the reliability of some results. In cases where crops where not parameterized in the DSS, we used other crops having the same behavior regarding N dynamics. We could not perform the assessment in one of the WPA for which the DSS was dot adapted, because of the high stocks of ammonium in soil.

We will illustrate the results of 3 WPA in the presentation.

WPA H: This small WPA is characterized by i) a strong involvement of the local extension services and ii) extensive livestock production (presence of permanent grasslands). As expected, the N losses are more significant under short crop rotations (cereals-maize) than under grassland. Soil characteristics and efficiency of cover crops in winter may affect significantly the nitrate losses. Simulation results could be used by the extension services as a way to make farmer and other stakeholders discuss.

WPA B: This WPA is characterized by i) an existing dynamic at the territory level and collaboration with agricultural scientists, and ii) crop production dominated by oilseed rape and cereals. The results confirmed the efficiency of the actions set up in the initial program, consisting in the generalization of cover crop for short and long period between two commercial crops. The results emphase the high risk due to application of agricultural manure during summer before winter cereals. And tomorrow, these results will permit to assess the nitrate losses under the whole agricultural fields of the area.

WPA L: This WPA is characterized by i) an existing program to improve water quality and ii) two contrasting soil zones including a vulnerable alluvial zone. The results confirmed the efficiency of the actions set up in the existing program, consisted mainly in allocating permanent grasslands in the alluvial zone.

Conclusions

This study enabled the development of N loss diagnosis in contrasting WPA, by building typologies describing the territory with local experts. We were able to get the nitrogen management issue further, even if we can't already know how or if the stakeholders will use this work! The next stages are parallel: 1) improving the DSS Syst'N, considered as user-friendly, to make the simulations more reliable by taking into account available field measurements, 2) developing the interactive and dynamic N diagnosis as a tool to help stakeholders to lead agricultural evolutions in the WPA.

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References

[1] Dupas R, Parnaudeau V, Reau R, Jeuffroy MH, Durand P, Gascuel-Odoux C. 2015. Integrating local knowledge and biophysical modeling to assess nitrate losses from cropping. Environmental modeling and software, 69, 101-110.

[2] Parnaudeau V., Reau R., Dubrulle P. 2012. Un outil d'évaluation des fuites d'azote vers l'environnement à l'échelle du système de culture : le logiciel Syst'N. Innovations Agronomiques 21, 59-70. http://www6.inra.fr/ciag/Revue/Volume-21-Septembre-2012.

MANAGEMENT PRACTICES OF MISCANTHUS × GIGANTEUS STRONGLY INFLUENCE SOIL PROPERTIES AND N_2O EMISSIONS

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Objectives

Miscanthus × giganteus, a perennial C4 crop, is presented as a promising energy crop. Main variations in management practices concern harvest time and N input rate. These practices strongly modify the N and C cycles in the soil, influencing N_2O emission and the crop GHG balance which has to be beneficial. Whereas the effect of N input on N_2O emissions was often investigated, the effect of fertilizer form and harvest time in miscanthus remains poorly documented. The purpose of this study was to investigate the effect of an early or late harvest on soil parameters and N_2O emissions and the effect of fertilizer form (NH_4 or NO_3) on N_2O emissions.

Method

The study was carried out on the Biomass & Environment long term experiment located in Estrées-Mons (80) in the north of France (49.872 N, 3.013 E). This experiment was set up in 2006 and compares the production and the environmental impacts of different bioenergy crops including Miscanthus × giganteus [1]. In our study, we focused on fertilized miscanthus (120 kg N ha^{-1} yr^{-1}) and the two harvest-time treatments: early harvest (EH) in October and late harvest (LH) in February. In 2014 and 2015, these treatments were combined with two N fertilizer forms. We applied to each harvest-time treatment either 120 kg N ha^{-1} of potassium nitrate (EH-NO_3 and LH-NO_3) or 120 kg N ha^{-1} of ammonium sulphate (EH-NH_4 and LH-NH_4). N_2O and CO_2 fluxes were measured after fertilization, from April to August, on each of the 4 treatments and at a daily time step using automatic dynamic chambers (3 replicates). Soil samplings (0-5, 5-15 and 15-30 cm) were carried out every 10 days to determine pH, water content, NH_4^+ and NO_3^- contents in each layer. Soil temperature (0-10 cm) and volumetric water content (0-30 cm) were also measured continuously using T107 and CS616 probes (Campbell Scientific). Total soil carbon was measured in 2015 before the fertilization while dissolved organic carbon (DOC) was measured at three dates in 2014. The effect of the 4 treatments on soil parameters and N_2O emissions was tested using variance analysis. Multiple regression analysis was also realized on log transformed fluxes to analyse how soil parameters influence N_2O emissions.

Results

The cumulative N_2O emissions during five months were strongly higher ($P < 0.0001$) in LH than EH (4207 vs 893 g N_2O-N ha^{-1} respectively), with no main effect of fertilizer form or year, although climatic conditions differed between the two years (precipitation = 364 and 73 mm in 2014 and 2015, respectively). A significant interaction between form of fertilizer and year was however observed.

The LH treatment is characterized by an important accumulation of leaves falling during winter resulting in a thick mulch which maintained significantly higher soil water content even during the dry period in 2015. The average WFPS was 80% during both years in LH treatment versus 65% in 2014 and 46% in 2015 in the EH treatment. Such a difference can explain a large part of the variance in N_2O fluxes. Indeed the daily N_2O fluxes (log transformed) were found to be strongly correlated with WFPS ($R^2 = 0.55$). Emissions may also have been stimulated in LH by the higher amount of NO_3^- in the soil, especially in the 15-30 cm layer, probably due to a delayed crop N uptake in this treatment as shown previously at the same site [2]. The LH treatment had a greater soil carbon content (16.3 g C kg^{-1}) than LH (13.1 g C kg^{-1}) which could further stimulate N_2O emissions by denitrification. However no difference was detected for DOC between treatments and CO_2 fluxes were higher in EH than LH, which suggests a greater microbial activity in EH.

By varying the fertilizer form we expected changes in emissions associated to a different stimulation of nitrification and denitrification with NH_4 or NO_3 input. We often observed higher N_2O fluxes in the NH_4 treatments but no clear effect of fertilizer form could be detected on cumulative emissions ($P = 0.18$). However, we observed a significant decrease in pH after NH_4 fertilizer applications. The average NH_4 contents in each plot were strongly correlated with soil pH (R^2=0.65). The multiple regression analysis carried out on physico-chemical soil parameters (0-30 cm) showed that pH was the second factor driving N_2O emissions after WFPS. pH is known to have a strong effect on N_2O reduction to N_2, modifying the denitrification contribution. Both factors explained 65.7% of the variance of N_2O emissions showing that crop management strongly influences N_2O emissions on miscanthus.

Conclusions

The use of Miscanthus × giganteus as a bioenergy crop increases both in Europe and in France, but few studies have measured the environmental impact of these new systems and the influence of management practices. We have shown that harvest time strongly influenced N_2O emissions, with on average 4.7 times more emissions with a late harvest than an early harvest for a common N rate of 120 kg N ha^{-1} yr^{-1}. This difference is mainly due to the higher soil water content induced by the presence of mulch with a late harvest. The fertilizer form did not affect directly N_2O emissions. However NH_4 fertilizer induced a decrease in pH that stimulated N_2O emissions most probably through less efficient reduction of N_2O to N_2. Management practices should then be chosen carefully to maximize the benefits of bioenergy crops.

References

[1] Cadoux S, Ferchaud F, Demay C et al. 2014. GCB Bioenergy, 6, 425-438.
[2] Strullu L, Cadoux S, Preudhomme M, Jeuffroy M-H, Beaudoin N. 2011. Field Crops Research, 121, 381-391.

IMPLEMENTATION OF NITROGEN DYNAMICS IN THE DECISION SUPPORT SYSTEM ÖKO-SIMPHYT TO IMPROVE MANAGEMENT PROCESSES IN ORGANIC POTATOES

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Objectives

Organic potatoes have high profit margins. Recently ongoing specialization among organic potato farmers as well as fluctuating market prices increase cropping risks and jeopardize farmers' income. Hence, key factors of yield development need to be considerably optimized such as nitrogen-supply and the control of late blight epidemics [1], [2].

For german organic potato farmers the decision support system (DSS)'ÖKO-SIMPHYT' (Isip.de) was developed to control late blight epidemics based on copper applications. However, this DSS is only based on weather data and epidemiological models. Recently, it was shown that besides late blight the nitrogen uptake of the crop has a higher impact on yield in organic potatoes than expected. Therefore, in an EC project research was performed to implement a nitrogen vegetation model of potatoes in the DSS in order to improve copper spraying (and termination) strategies based on potential yield and thus offer means to reduce copper in organic potatoes.

Method

The presented study based on four year field trials (2012-1015) at the experimental sites Neu Eichenberg (51.37 N, 9.91 E, 220 m a.s.l.) and Frankenhausen (51.24 N, 9.26 E, 200 m a.s.l.). Long term (1970-2000) weather conditions are characterized with an annual precipitation of 650 mm and a mean temperature of 8.5°C for Frankenhausen and 620 mm / 7.9°C for Neu Eichenberg. Soil is classified as a silty loess luvisol on both experimental sites. For Frankenhausen carbon and nitrogen content was 1.02% and 0.11%, the content of phosphorus, potassium and magnesium was 83, 97 and 82 mg*kg^{-1} dry soil, respectively. At Neu Eichenberg nutrient status in carbon and nitrogen was 1.02% and 0.11%. Phosphorus, potassium and magnesium was 59-140, 92-100 and 92-110mg*kg^{-1} in dry soil, respectively.

Experimental design considers four basic Treatments (pest management, maturity type, N-fertilization and time) which changed over time. Pest management was realized up to three treatments corresponding to organic or conventional management (control [non Cu], conventional, 2 times ÖKO-SIMPHYT). The maturity type, which reflects development differences and yield potential risks in potato varieties, differed in very early, early, and mid early varieties. N-fertilization (BIOILSA® 11) was applied in 3 levels (low (field status), mid (40 kg*ha^{-1} N) and high (70 -100 kg*ha^{-1} N)). Yield development was determined with up to 10 sequential harvests in the field trials by collecting data on canopy biomass and tuber yield.

Soil NO_3-N dynamics were determined in 2 soil layers (0-30; 30-60) up to 10 times during vegetation period. N-content of the above ground biomass and tubers was analyzed. Late blight was regularly assessed according to James et al. (1971).

The results of the field trials were used to model the basic Nitrogen dynamics in the potatoes and in the soil. For soil, above ground biomass and tuber development mathematical time based functions were developed (e.g. Richards `curve for tuber-N development) to complete the existing ontogenetic model. As second step, a high correlating intervention point (BBCH 60) was implemented in the model to setup N-dynamics during vegetation period and to adapt the operational procedure (e.g. the termination of copper spraying).

Results

As expected weather conditions were one of the main drivers which influenced results of the field trials. Two main phenomena were observed which influenced results in the shown experiments in these years. In dry years (2013 and 2015) water was the yield limiting factor: The yield was below average and reached 30t*ha^{-1} in both years. N-content in above ground biomass was not affected (results were between 3 and 4 % in dry matter). A rapid phonological development in above ground biomass was observed which affected tuber growth potential and the tuber vegetation period. Yield potential was reached at an earlier date compared to wet years and dry matter content was high. More rain in July (2015) nearly doubled the yield of the mid-early variety (50 t*ha^{-1} at the end of vegetation period 2015).The very early variety wasn`t affected that much. Under humid conditions, essentially in 2012, late blight development became the yield limiting factor. Copper spraying resulted in a plus in yield of 10 t*ha^{-1}. The effects of fertilization corresponded to water availability, too. NO_3-N-dynamic showed a maximum in mineralization (between 50 and 100 kg*ha$^{-1)}$ at 10 to 25 days after plant emergence.. Already at the first sequential harvests (mostly 50 – 60 days after planting) plants went into a N-limited situations, according to the theories of Duchenne et al. ([3]).

Modelling these results, time based functions were selected for NO_3-N-dynamic, for above ground biomass-N and tuber N-development and implemented in the existing web application of ÖKO-SIMPHYT. For NO_3-N-dynamic and above ground biomass-N a Gaussian function was chosen. Tuber-N development is modelled with a Richard`s curve. Additionally a first Intervention point (phonological development stage 60, begin of flowering) was implemented to adjust the predicted growth situation to the actual growth stage . A threshold for predicted yield potential was integrated, which is linked to the recommended plant disease management strategy given by the ÖKO-SIMPHYT model.

Conclusions

The results of this study improved the decision support tool ÖKO-SIMPHYT. The basic ontogenetic model was complemented by a nitrogen dynamic model for the vegetation period in organic potatoes. This tool will allow farmers to get a more transparent overview about growth and development of their potatoes. Supporting points in the web application offers the possibility to correct the estimated model during vegetation period. Spraying decision and management opportunities will become more comprehensive for farmers. Furthermore, it will be necessary to improve the web application by additional interventional points which are easy to estimate and which correlate to the actual growth development.

References

[1] Finckh, M. R., Schulte-Geldermann, E., Bruns, C. 2006. Potato Research 49, 27–42.
[2] Palmer, M. W., Cooper, J., Tétard-Jones, C., Średnicka-Tober, D., Barański, M., Eyre, M., Shotton, P.N., Volakaki, N., Cakmak, I., Ozturk, L., Leifert, C., Wilcockson, S.J., Bilsborrow, P.E. 2013. European Journal of Agronomy, 49, 83-92.
[3] Duchenne, T., Machet, J.M., Martin, M. 1997. In: Lemaire D.J. (ed.) Diagnosis of the Nitrogen Status in crops p. 119-130.
[4] James, C. 1971. A manual of assessment keys for plant diseases. American Phytopathological Society, ASP Press, St. Paul.

AMMONIA EMISSION FROM TWO LAYING HEN FACILITIES DIFFERING ON MANURE AND VENTILATION MANAGEMENT.

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Objectives

Ammonia (NH_3) is one of the main pollutant gases associated with poultry operations [1]. Laying farms with more than 40,000 hens are obliged to implement best available techniques according to Directive 2010/75/EU (IED) adopted to mitigate pollutant emission. According to existing literature, strategies to reduce NH_3 emission from laying hen sector are most effective if they are applied at facilities or during manure land spreading. In EU, intensive laying hen farms had to adopt Directive 1999/74/EC on animal welfare in Europe in 2012, changing from conventional to an enriched cage (EC) system. In this sense, there is still scarce information on NH_3 emission from EC laying facilities. Improving the knowledge on such losses will allow identifying practices to mitigate NH_3 pollution. The objective was to assess NH_3 losses at two EC laying hen facilities located in different climatic zones, in which ventilation systems and manure management were also different.

Method

The study was performed at 2 laying hen farms from the Basque Country (northern Spain), which were located in Oceanic (OF farm) and Mediterranean (MF farm) climatic conditions, respectively. 52,000 Lohmann-Brown hens were allocated at OF whereas 39,000 hens were reared in MF facility. OF was ventilated through 18 fans within a tunnel ventilation system. On the contrary, side ventilation system was installed at MF by using 15 fans. Manure management at OF consisted of full manure removal every 3 days whereas one third of accumulated manure was daily removed at MF. MF facility was equipped with an outdoor manure drying tunnel. This drying tunnel used warm air sent flushed by the fans from the facility to dry manure.

Ammonia (NH_3) concentrations were continuously monitored from June to December 2012 at OF and during year 2015 at MF. Ammonia was measured by using a calibrated INNOVA 1412 Photoacoustic multi gas analyser coupled with an INNOVA 1309 multipoint sampler (LumaSense, Denmark). Twelve sampling tubes were distributed into 8 exhaust fans (outlet) and 4 windows (inlet). Five sensors (Onset, HOBO U12-013, USA) were used to record air temperature at both facilities. An automated system regulated indoor temperature through a window opening and fan activation system. Air cooling was activated at both facilities in summer conditions. Mean percentage of operation of each fan was recorded every 5 minutes through an electronic datalogger system (Binary Devices S.L., Spain). Total airflow rate was calculated by integrating the number of operating fans every hour and the individual airflow rate of the fans (Estimated values: 38000 $m^3\ h^{-1}$ for OF; 32000 $m^3\ h^{-1}$ for MF).

Ammonia emission was calculated according to the following equation:

$$E = (C_{outlet} - C_{inlet}) * V$$

Where E is the emission ($mg\ h^{-1}$), C_{outlet} and C_{inlet} is the outlet and inlet NH_3 concentration ($mg\ m^{-3}$) and V is the ventilation rate in the building ($m^3\ h^{-1}$).

Results

Mean NH_3 emission rates during both experimental periods were 117.6 mg d^{-1} hen^{-1} and 142.4 mg d^{-1} hen^{-1} at OF and MF, respectively. Emission rates ranged from 73.3 to 175.4 mg d^{-1} hen^{-1} at OF and from 76.4 to 198.3 mg d^{-1} hen^{-1} from at MF. These values were within the emission range previously reported (54.0 to 169.9 mg d^{-1} hen^{-1}) by other authors at EC facilities [2],[3]. Ammonia emission rate was monthly higher at MF facility except in June, when hens were still in a pre-laying stage. The difference observed at OF and MF farms were not attributed to nutritional factors as crude protein (CP) content of the concentrates supplied averaged 17.5%. We suggest that the different ventilation rates (VR) recorded in OF and MF considerably affected on the performance of NH_3 losses. A regression model conducted at MF showed the strong positive relationship existing between VR and NH_3 emission rate ($r^2 = 0.92$; $P < 0.05$) when the amount of manure accumulated on belts is constant. Ventilation rates averaged 4.1 and 6.8 m^3 hen^{-1} h^{-1} at OF and MF, respectively. Mean temperatures were 19.0ºC in both summer seasons whereas temperature tended to be higher in OF conditions (14.6ºC) than in MF (10.7ºC) during autumn period. Despite the atmospheric temperature was slightly colder at MF, VR was higher to ensure air through the outdoor manure drying tunnel. In addition to ventilation practices, NH_3 emission rates from OF also highlighted the importance of manure management in the volatilisation process. Despite VR at OF was 60% of value reported at MF, mean NH_3 rate accounted for 82.5% of the emission at MF farm. As manure accumulation period was occasionally longer than the average 3 days (up to 5 days accumulated on belts), it would have contributed to enhance partially NH_3 losses at OF.

Conclusions

The present study concluded that either ventilation or manure management are the main factors affecting on NH_3 volatilisation at EC laying hen facilities. Increasing VR at facilities is directly related to higher NH_3 losses, especially when manure management is constant. However, under variable manure removal frequency, accumulation period should be reduced as much as possible to reduce NH_3 emitted from the animal house.

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References

[1] Alberdi, O., Arriaga, H., Calvet, S., Estellés, F., & Merino, P. (2016). Biosystems Engineering, 144, 1–12.
[2] Shepherd, T.A., Zhao, Y., Li, H., Stinn, J.P., Hayes, M.D., & Xin, H. (2015). Poultry Science, 94, 534-543.
[3] Fabbri, C., Valli, L., Guarino, M., Costa, A., & Mazzotta, V. (2007). Biosystems Engineering, 97, 441-455.

COMPARISON OF NITROUS OXIDE EMISSION FACTORS FROM COVER CROP BIOMASS AMENDED UPLAND AND PADDY SOILS DURING CROPPING PERIODS

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Objectives

Nitrous oxide (N_2O) is an important globe warming gas and a destructive agent of ozone in the stratosphere. A major concern is the increasing contribution of chemical fertilizers to atmospheric N_2O buildup. There is only a limited understanding of the contributions from crop residues. Nitrous oxide is produced from the biological nitrification and denitrification process in soils. It is well known that much higher N_2O is emitted from upland than paddy soil, generally due to higher N fertilization and favorable aerobic condition for biological nitrification. Therefore, most N_2O emission studies were conducted in upland soils, but very rare in rice paddy soils. In particular, this N_2O emission factors were developed on centering chemical fertilizer-induced factor, but its emission factors induced from organic matters were not developed systematically well.

Method

In this two year field studies, in order to determine N_2O emission factors induced from organic amendments, the mixture of barley and hairy vetch was cultivated in upland and paddy soils during the fallow season, and its biomasses were harvested in the next early June before main cash crop cultivation. Total aboveground biomass productivities were 35-36 Mg ha^{-1} (fresh weight basis). The harvested biomass was finely chopped (size 5-10 cm), and applied with different recycling ratios (0-100% of the aboveground biomass) in upland for corn cultivation and in paddy soil for rice cultivation. Nitrous oxide emission rates were monitored using the closed chamber method once a week interval.

Results

Seasonal N_2O fluxes significantly increased with increasing cover crop biomass application, but N_2O emission factor which was determined using N_2O-N flux changes to total N input changes was significantly higher with 0.032 kg N_2O-N kg^{-1} N in upland soil during corn cultivation than 0.005 kg N_2O-N kg^{-1} N in paddy soil during rice cultivation. The N_2O emission factor induced from organic residues of upland soil was approximately three times higher than the IPCC default 1% value. In contrast, N_2O emission factor in paddy soil was one second times lower than the IPCC default values.

Conclusions

In Korea, IPCC Tier 1 methodology, assuming that 1% of N input as fertilizer is directly emitted, could be developed considering agricultural land use under crop residues applied condition.

NITROUS OXIDE AND NITRATE LOSSES - INFLUENCING FACTORS IN WILLOW CROPPING INVESTIGATED BY MODELLING

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Objectives

Bioenergy crops are expected to play an important role in securing the energy supply and mitigating greenhouse gas emissions. However, to increase the yield, mineral N fertilizer and sewage sludge fertilizer are normally applied which might in turn increase the risk of soil N2O emissions and also nitrate leaching. This paper thus focuses on the N2O emissions and soil nitrate leaching and their influencing factors for a conventional Swedish willow bio-energy plantation.
The following research questions were addressed:
1. What influencing factors are found for N2O emissions and nitrate leaching, respectively?
2. What is the optimum fertilization amount rate to minimize N2O emissions in relation to gain in biomass?
3. What is the possible impact of drainage on the willow biomass growth and also N losses?

Method

We calibrated a detailed process-oriented model, CoupModel with a number of measured high resolution data obtained from the Skrehalla field experiment site in Grästorp, Sweden (N58o16' E12o46'), having willow (Salix viminalis). The site has heavy clay soil with pH 5.8 (±0.1). Soil C/N ratio was 12 (± 0.4) for the first 0-50 cm soil layers. The site was drained by a tile pipe drainage system, depth of ~ 1 m and 10 m spacing.
The field experiments started in 2012, the year before the fifth harvest. NH4NO3 was added in June 2012, 100 kg N ha-1. Harvesting was performed 29th of March and sewage sludge from a local waste water treatment plant was then added in May, in total 270 (80-460) kg N ha-1.
The current general model structure setups and basic parameterizations were based on previous usage of CoupModel on similar ecosystems. The calibration and uncertainty analysis method used in this study is the Generalized Likelihood Uncertainty Estimation (GLUE). For the GLUE calibration, a number of high resolution data including biotic and abiotic variables were used together with eddy covariance measurements of CO2 and N2O fluxes. The application of mineral fertilizer was assumed to directly add ammonia and nitrate to the soil surface N content pool. Sewage sludge was analogously treated as "Faeces" in the model, adding to both soil mineral and organic pools, and assumed to be mixed into the soil surface. The initial conditions of the willow plants are defined by measured plant growth biomass data. Soil physical structure was defined by soil water retention curves derived from pedo-functions from measured soil texture fractions. Where measured data show large variations, coefficients with high uncertainties were included into calibration. Since initial values for total soil organic matter content was unknown, this was subject for calibration. Meteorological data, hourly resolution, was used as model forcing.

Results

A detailed investigation of the period, June to July 2012 and May to October 2013 shows an emission peak in June 2012 to be closely connected to the soil surface water content variation induced by rainfall soon after mineral fertilizer application. Despite some discrepancies in capturing the measured peaks, the simulated emissions after commercial fertilizer addition were 0.05 (0.02 to 0.15) g N2O-N m-2, similar to what was measured in the year of 2012, 0.035 g N m-2. The simulated emissions after adding sewage sludge in 2013 were estimated to be 0.2 (0.1 to 0.37) g N2O-N m-2 which was slightly higher than measured, 0.17 g N m-2. After the mineral fertilizer addition leaching was estimated to 0.66 (0.34 to 1.08) g NO3--N m-2 yr-1, where high leaching was found connected to intense rainfall, also being a period with high N2O emissions. Sewage sludge application resulted in lower nitrate leaching, 0.2 (0.05 to 0.35) g N m-2 yr-1. Our modeling also describes the leaching of dissolved organic N (DON), which is simulated to be 0.14 (0.13 to 0.15) g DON-N m-2 for the first year but only 0.02 (0.01 to 0.03) g N m-2 for the second year. The simulated leaching dynamics was linked to precipitation patterns, where the total precipitation in 2012 was 919 mm yr-1, much higher than the 30 years mean 683 mm yr-1 (data from a nearby SMHI station), while 2013 was dry with only 524 mm yr-1, which explains the small soil nitrate leaching in 2013 despite sludge application. The relatively low N2O emissions and soil nitrate leaching can also be explained by large plant N uptake, simulated to be 108 (83 to 133) kg N ha-1 in 2012, and 147 (108 to 186) kg N ha-1 in 2013. Therefore the plant nitrogen uptake is the dominating controlling factor in the soil N cycle, leaving relative small amount of available N for N2O production and nitrate leaching.

Conclusions

Our modeling indicates that N2O emissions are mainly produced by the nitrification process, most influenced by soil water content and the amount of fertilizer added. The modelled soil nitrate leaching was negatively influenced by the denitrification and positively by water drainage flow. Model sensitivities indicate that to minimize the N2O emissions in relation to biomass gain, the application rate of mineral fertilizer should be within the range of 50 to 100 kg N ha-1, sewage sludge within 150 to 300 kg N ha-1. The high sensitivity to drainage suggests that an optimum drainage is of need both to achieve high plant yield and minimize N losses.

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References

[1] He, H., Jansson, P. E., Svensson, M., Meyer, A., Klemedtsson, L., and Kasimir, Å. 2015 Ecological Modelling, 10.1016/j.ecolmodel.2015.10.030

A NETWORK TO MEASURE AND ANALYZE VARIABILITY IN SOIL NITROGEN MINERALIZATION AT THE FIELD SCALE IN BRITTANY (FRANCE)

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Objectives

Increasing efficiency of nitrogen (N) fertilizer use and decreasing losses to the environment (e.g. NO3 leaching) requires accurate predictions of soil N mineralization under field conditions. Predicting soil N mineralization is challenging given its high variability and the factors that influence it, such as soil properties, field management and climate. Experimental measurements have shown that models developed in France (e.g. the Comifer model [1]) are not suitable for predicting soil N mineralization in the Brittany region of France. The lack of references for this region prohibits calibration and parametrization of these models. In this context, INRA and the Brittany Chamber of Agriculture created a network of agricultural fields to create a reference dataset for soil N mineralization. The aim of this network is to improve knowledge about factors influencing soil N mineralization and to develop a predictive model adapted to this region.

Method

The experiments were performed on 65 silage maize fields (bare soil during winter) managed without any N fertilization during the experiment and located throughout Brittany (France). The fields were chosen to represent a range of soil parent materials under different management systems (crop rotation and manure supply). For each field, three experimental plots, for measurement replicates, were established in 2010 (28 fields) or 2011 (37 fields) and then monitored for 4 or 5 years. Soil properties (pH, Metson cation exchange capacity (CEC), total and exchangeable elements, organic matter, particulate organic matter, bulk density, soil water content at field capacity and wilting point), microbial biomass and soil-chemical N indices to estimate soil N mineralization (N extraction with hot water, hot KCl and phosphate-borate buffer) were determined. Soil N mineralization was calculated by mineral N mass-balance: amount of mineral N in soil in spring (March) and in autumn (October), maize N uptake, and nitrate leaching (predicted with the STICS model [2]).

The daily effect of soil water content and soil temperature was normalized using functions allowing the conversion of calendar days in normalized days, Jn, [3]. Soil water content and temperature were predicted with STICS [2] from field weather. The normalized N mass balance (BN) was the N mass balance divided by Jn.

One indicator (I_Sys) was calculated to evaluate the effect of field management (crop rotation and manure application) on N mineralization. This indicator was calculated by summing the average nitrogen mass balance of crops and the effect of manure application (estimated with DSM model [4]) for the 15 years before the beginning of the experiment.

All statistical analyses were performed with R, v. 3.2.1. Pearson correlations were used to assess relations between variables. Generalized Additive Models (GAMs) were used to develop a predictive model of the potential of soils to mineralize N [5]. Variables were chosen to obtain models with the smallest Mean Square Error of Prediction (MSEP). This criterion was calculated by applying a “leave-one-out” strategy, which represented an internal validation approach of the model and avoided over-fitting the model to data.

Results

Normalized N mineral mass balance (BN) varied from 0.28-2.53 kgN.ha-1.Jn-1, illustrating the variability in soil potential to mineralize N. Mean BN was higher in 2012 and 2013 than in 2014. These differences in BN between years showed that additional yearly processes besides climate normalization should be considered to properly understand and estimate soil N mineralization.

In laboratory studies, some authors observed a flush of mineralization due to cycles of dry/wet soil water content [6, 7] Moreover, Lado-Monserrat, et al. [8] showed an impact of pre-wetting soil moisture on N mineralization flush.

In the field, dry/wet soil-moisture cycles are not as well defined as in the lab and depend on rainfall and soil properties, such as texture and water content at field capacity and wilting point. Alternation, intensity and duration of soil water content cycles can increase N mineralization, which can be difficult to estimate, especially since other environmental factors can impact it. Weather conditions in 2012 and 2013 were characterized by drought during summer. Therefore, we consider that soil N mineralization is the combination of a basal component and an extra-mineralization (Em) component. The basal component is composed of the potential N mineralization rate (Vp) multiplied by Jn. We determined years in which Em occurred by performing t-tests between the BN of the years, which allowed us to calculate the basal component and Em.

Em can partly be explained by climate variables and soil properties. Em occurred mainly in 2012 and 2013 in fields where we observed summer water deficit followed by a long rewetting time. In these cases, Em can be considered as an autumnal flush and is usually associated with a high amount of mineral N in soil in autumn. Because Em occurred occasionally and cannot be predicted, we developed a model to predict the basal component of soil N mineralization: Vp × Jn.

Vp was significantly correlated with I_Sys, representing the field-management effect ($r = 0.43$, $P < 0.01$), with different soil properties (texture, N stock, C stock), with microbial biomass ($P<0.01$) and with the soil-chemical N indices ($P < 0.01$). However, no correlation was sufficient to predict Vp accurately, and the model to predict Vp combined multiple variables: I_Sys, soil properties (texture, CEC, particulate organic matter), microbial biomass and the N mineral extracted by phosphate-borate buffer. Given the number of variables influencing soil N mineralization and Vp, this model predicts Vp well ($R^2 = 0.67$).

Conclusions

In this study, we measured a network of fields in Brittany to create a reference dataset of soil N mineralization for this region and improve our understanding of environmental factors influencing it. We showed that soil N mineralization is the combination of a basal component and an extra-mineralization (Em) component. Em occurred occasionally; is influenced by weather conditions, soil moisture and soil properties; and cannot be predicted. We developed a model to predict the basal component (Vp × Jn) of soil N mineralization. This model predicts soil N mineralization well from three factors known to influence it: soil properties, crop management and climate (via Jn).

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References

[1] Comifer. 2013. Groupe Azote Comifer, 159.
[2] N. Brisson, M. Launay, B. Mary and N. Beaudoin. 2008. INRA, Rd 10, 78026 Versailles Cedex, France, Editions Quae.
[3] A. Rodrigo, S. Recous, C. Neel and B. Mary. 1997. Ecological Modelling 102(2-3), 325-339.
[4] R. Trochard, A. Bouthier, T. Morvan and J. Grall. 2012. Innovations Agronomiques 25, 55-69.
[5] S. N. Wood. 2006. Boca Raton, Florida, U. S. A., Chapman Hall/CRC.
[6] H. F. Birch. 1958. Plant and Soil 10(1), 9-31.
[7] W. Borken and E. Matzner. 2009. Global Change Biology 15(4), 808-824.
[8] L. Lado-Monserrat, C. Lull, I. Bautista, A. Lidon and R. Herrera. 2014. Plant and Soil 379(1-2), 21-34.

SOIL NITROGEN MINERALIZATION: RELIABILITY OF A MULTI-COMPONENT APPROACH

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Objectives

Accurately estimating mineralizable nitrogen (N) in soil organic matter (OM) is essential to improve fertilizer management and reduce nitrogen leaching in cultivated soils. Many soil-chemical N indices were developed before the 1980s to improve predictions of soil N mineralization [1]. A meta-analysis by Ros, et al. [2] confirmed the utility of some of these tests (5 of the 18 evaluated) but concluded that (i) one single indicator cannot sufficiently predict mineralization and (ii) it is necessary to adapt a multi-component approach based on simultaneously considering several indicators, soil properties, and land use. The objective of this study is to examine this conclusion by studying relations among soil N mineralization, three soil tests, soil microbial biomass, soil physical and chemical properties, and land use.

Method

Soil sampling and analysis

Soil samples were collected in March 2013 from a network of 130 fields in Brittany (France) chosen to represent a range of parent materials under different management systems (annual crops, prairie/crop rotations). We used a 7-day anaerobic incubation to measure soil N mineralization (Ana_Nmin), using a procedure adapted from Keeney and Bremner [3]. Soil microbial biomass was determined by the chloroform fumigation extraction method (AFNOR NF FD ISO 14.240-2, 1997).

Three soil tests, providing five chemical indices, were determined for dried soils sieved at 2 mm: (i) hot-water extractable C (HW_C) and N (HW_N), according a modified method by Leinweber, et al. [4]; (ii) hot extractable NH4-N (Hot_KClNH4) and hydrolysable NH4 (Hyd_KClNH4), the latter obtained by subtracting the NH4 content of the cold KCl extract from the Hot_KClNH4, were determined following the procedure of Gianello and Bremner [1]; and (iii) phosphate-borate distillable nitrogen (PBD_N), analyzed according to Gianello and Bremner [5].

Routine soil analyses (i.e., pH, Metson cation exchange capacity (CEC), total and exchangeable elements) were performed according to AFNOR procedures. Total C and N were analyzed by dry combustion. OM was physically fractionated into OM associated with sand (50-2000 µ), corresponding to particulate OM (POM_C and POM_N), and with silt and clay particles (0-50 µ), following the procedure of Balesdent, et al. [6]. One indicator (I_Sys) was calculated to include the effect of crop rotation and manure application on N mineralization.

Statistical analyses

All statistical analyses were performed with R, v. 3.2.1. Pearson correlations were used to assess relations between variables. Generalized Additive Models (GAMs) [7] were used to determine the best combination of variables for predicting 7-d anaerobic soil mineralization. Variables were chosen to obtain models with the smallest Mean Square Error of Prediction (MSEP). This criterion was calculated by applying a "leave-one-out" strategy, which represented an internal validation approach of the model and avoided over-fitting the model to data.

Results

Ranges of soil characteristics, N mineralization and chemical indices

Soil physical and chemical properties were representative of soils in Brittany. Most of the soils were loams: clay loam, sandy loam and sandy clay loam. Soils had pH from 4.8-7.9 (mean = 6.1) and low CEC (mean = 9.8 meq/100 g). Total N varied widely (0.87- 3.10 g N kg-1 dried soil (d.s.)), as did total C (8.8-37.9 g C kg-1 d.s.), corresponding to high OM content in most of the 130 cultivated soils, except the loamy soils. Mean soil microbial biomass (Biom) was relatively low (179 mg C kg-1 d.s.) given the C content of the soils. The Biom/Total C ratio differed significantly among parent materials ($P<0.001$). The highest percentage of biomass C was observed in loamy soils (mean = 1.10%), while the lowest was observed in micaschist soils (mean = 0.63%).

Chemical extractable N indices also varied widely. Mean values for HW_C, HW_N, Hot_KClNH4, Hyd_KClNH4 and PBD_N were 752.3 mg C kg-1 d.s and 73.5, 22.4, 14.9, 26.3 mg N kg-1 d.s., respectively. The hot-water extraction method was the strongest, extracting a mean of 4.5 times as much C as those based on microbial biomass and 2.8-4.9 times as much N as the other soil-chemical N indices.

Ana_Nmin varied from 8.7-39.2 mg N kg-1 d.s. (mean = 21.8 mg N kg-1 d.s.). The range of Ana_Nmin was similar to those of Hot_KClNH4 and PBD_N.

Correlations and N mineralization modeling

Most of the correlation coefficients among Ana_Nmin, chemical N indices, total N, total C, POM_C and POM_N were highly significant ($P<0.001$ or <0.01). However, correlation coefficients >0.7 were observed only between total N and C ($r=0.93$), Hot_KClNH4 and Hyd_KClNH4 ($r = 0.90$), Hot_KClNH4 and Total N ($r = 0.85$), and Hyd_KClNH4 and Total N ($r = 0.84$).

The correlation coefficients between Ana_Nmin and chemical indices ranged from 0.40-0.56 ($P<0.001$), and was similar to those between Ana_Nmin and total N or POM_gN ($r=0.50$ and 0.48 respectively). The strongest correlation was observed between Ana_Nmin and Biom ($r = 0.59$).

The modeling approach based on the use of GAMs led to development of a model that integrated soil properties (pH, clay content, CEC), soil microbial biomass (Biom), two mineralization indicators (HW_N and Hyd_KClNH4) and the land-use indicator (I_Sys). This model correctly predicted Ana_Nmin ($R^2 = 0.63$).

Conclusions

Mineralizable N was positively related to soil microbial biomass, total N, land use and all soil chemical indices. But none of these variables was accurate enough to predict mineralizable N on its own, in agreement with the conclusions of Ros et al (2011). A “multi-component” modeling approach allowed selection of soil properties and soil chemical indices and showed the utility of integrating a land-use indicator.

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References

[1] C. Gianello and J. M. Bremner. 1986. Communications in Soil Science and Plant Analysis 17(2): 195-214.
[2] G. H. Ros, E. J. M. Temminghoff and E. Hoffland. 2011. European Journal of Soil Science 62(1): 162-173.
[3] D. R. Keeney and J. M. Bremner (1966). Nature 211. 5051: 892-893.
[4] P. Leinweber, H. R. Schulten and M. Korschens. 1995. Biology and Fertility of Soils 20(1): 17-23.
[5] C. Gianello and J. M. Bremner. 1988. Communications in Soil Science and Plant Analysis 19(14): 1551-1568.
[6] J. Balesdent, E. Besnard, D. Arrouays and C. Chenu. 1998. Plant and Soil 201(1): 49-57.
[7] S. N. Wood. 2006. Boca Raton, Florida, U. S. A., Chapman Hall/CRC.

CROPPING SEQUENCE AFFECTS NITRATE LEACHING DIFFERENTLY ON SANDY SOILS IN THE NETHERLANDS

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Objectives

Nitrate leaching to groundwater is still a major environmental concern associated with dairy farming on the sandy regions of the Netherlands. Manure application has been restricted throughout the last decades and a national monitoring program is in place to evaluate the on-farm quality of groundwater. It is well known that nitrate leaching from agricultural soils is influenced by naturogenic factors such as precipitation rates and groundwater level. Moreover, farm management such as the crop choice, type and amount of applied manure and the application time are of major importance[1,2]. However, the effects of cropping sequence on nitrate levels are less known. The objective of this study was to assess the effect of different sequences of grass/ maize rotations on nitrate leaching on the sandy soils of the Netherlands by using on-farm measurements of a large-scale national monitoring program.

Method

The Dutch Minerals Policy Monitoring Program[3] consists of around 450 farms of which about 235 are located in the Sand region. All farms are sampled annually between June and September. On each farm 16 sub samples are taken of the upper groundwater. The nitrate concentration is measured in the field using a Nitrachek reflectometer. Furthermore, the groundwater depth is recorded at the moment of sampling. A groundwater table score is allocated based on the Dutch national groundwater classification system using overlay maps. The wetness index, a measure of the precipitation surplus, is calculated using daily weather data[4].

At farm level, detailed management data is gathered through the national Farm Information Network[5]. Livestock numbers, crop information and nitrogen flows are recorded on an annual basis. Manure application rates are recorded at crop level distinguishing grassland and arable land.

In this study we selected data points based on the following criteria: soil type (sand), crop type (grass or maize) for a period of two and three consecutive years prior to the year of sampling. This resulted in a total number of 5912 and 3632 data points, respectively. Those points were located on 103 farms, which were sampled between 2006 and 2013. Farms were selected based on the criteria: crop (only grass/ maize). Furthermore, the amount and type of fertilization were reported on a crop scale. It was not possible to combine information on the cropping sequence at point level with the data on agricultural practices. However, nitrate concentrations at point level could be aggregated to crop level on farms. This resulted in one dataset at point level and one at farm/crop level.

Statistical tests were performed at point level. Analysis of variance was conducted with cropping sequence and wetness index, including their interaction as explanatory variables and nitrate as dependent variable. The 2-year cropping sequences were: grass-grass, grass-maize, maize-grass and maize-maize. Post-hoc tests were conducted according to LSD. All possible combinations of grass and maize for a three-year cropping sequences were also distinguished except for maize-grass-maize, because this group contained only 16 measurement points.

Results

The analysis of variance revealed that wetness index, cropping sequence and their interaction had a highly significant effect ($P<0.000$) on nitrate concentrations. This was observed for both two and three year cropping sequences. For the two year crop sequences, greatest NO_3 concentrations were found for fields under grass with maize as the preceding crop (95 mg NO3 l^{-1}) and no significant differences were found between grass-maize and maize-maize (90 mg NO3 l^{-1}). Lowest NO_3 concentrations were found for two years of grass (44 mg NO_3 l^{-1}). This was also the case for the three year grass cropping sequences where concentrations were on average 39 mg NO3 l^{-1} for a three year period of grass. Greatest NO_3 concentrations were found for maize-maize-grass (109 mg NO_3 l^{-1}) and grass-maize-grass (101 mg NO_3 l^{-1}). A three year period of maize resulted in an intermediate level of nitrate of 78 mg NO_3 l^{-1} .

Discussion

Largest NO_3 concentrations were found for maize-maize-grass and grass-maize-grass. Fertilization levels of grassland are generally greater than on maize[6]. However the root mass of maize is much smaller resulting in a reduced recovery of the applied fertilizers. Moreover, soil organic matter (SOM) levels of maize land are generally lower, leading to a reduced denitrification capacity of the soil. Large NO_3 concentrations observed for maize-maize-grass are possibly the result of both increased decomposition of SOM due to the annual ploughing and a reduced denitrification capacity due to the lower SOM levels.

The fact that the cropping sequence grass-maize showed greater NO_3 concentrations might be a consequence of the timing of manure application. During a large part of the monitoring period, it was common practice that the process of maize harvesting was followed by animal manure application. Grassland was seeded after ploughing the fields and thus incorporating the manure. In spring manure was again applied before the first cut. During the winter and spring period, newly seeded grasslands are however not fully established while manure is already applied. Consequently, a great part of the applied N will directly leach to the groundwater leading to amplified NO_3 concentrations in young grassland soils.

Conclusions

Based on these preliminary results we conclude for the sandy regions of the Netherlands that multiple years of maize do not lead to greater NO_3 losses as compared to grass with maize in rotation. Further research should contemplate integrating data of the Dutch Minerals Policy Monitoring Program with data on fertilization at farm level and data of the Dutch National Registration of Cropping areas[7], an annual registration program of crop type at field level. In this way, the crop rotation at field level can be retrieved for a period of 6 years and linked to measured NO_3 concentrations and farm management.

References

[1] Schröder et al. 2009. Grass and Forage Science, 49-57.

[2] Hooijboer et al. 2015. Nitrate leaching from dairy farms in the sandy regions in the Netherlands: Causes for higher nitrate leaching from maize land than from grassland, LUWQ2015, Vienna, Austria.

[3] Dutch Minerals Policy Monitoring Program. 2016. At: http://www.rivm.nl/Onderwerpen/L/ Landelijk_ Meetnet_effecten_Mestbeleid, Accessed: 30/1/2016.

[4] Fraters et al. 2015. Acta Agriculturae Scandinavica, Section B - Plant & Soil Science, 144-154.

[5] Farm Information Network. 2016. At: http://www.wageningenur.nl/nl/Expertises-Dienstverle ning/ Onderzoeksinstituten/LEI/Data-1/Bedrijveninformatienet.htm, Accessed: 30/1/2016.

[6] Hooijboer et al. 2014. Agricultural practice and water quality at grassland farms registered forderogation in 2012. p 33.

[7] Dutch National Registration of Cropping areas. 2016. At: https://data.overheid.nl/data/dataset/brp-gewaspercelen , Accessed: 3/2/2016

A NOVEL COMBINATION OF UREASE INHIBITORS AND ITS FORMULATION WITH BETTER PERFORMANCE CONCERNING BIOLOGY, HANDLING TRANSPORT AND STORAGE COMPARED TO EXISTING PRODUCTS

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Objectives

The main disadvantage of urea-containing fertilizers, which are the dominant nitrogen fertilizers worldwide, is nitrogen (N) volatilization losses in form of ammonia (NH_3). Depending on weather and on soil conditions the extent of such N losses can be up to 70% of applied N [1]. One approach to reduce these losses is the application of urease inhibitors (UI), which may substantially reduce NH_3-losses by up to 80% [2].

BASF SE developed a novel combination of urease inhibitors (brand name Limus®), which is a mixture of three parts NBPT (N-(n-butyl)thiophosphoric-triamide) and one part NPPT (N-(n-propyl)thiophosphoric-triamide). The new developed formulation of these two active ingredients (AI) is based on polymers.

The objective of several studies was to compare this novel product with the market standard regarding NH_3 emissions, yield impact, handling, transport and storage properties.

Method

Limus® or the corresponding treated urea-containing fertilizers (urea, urea ammonium nitrate solution (UAN)) was compared with the market standard (MS, Agrotain® or Agrotain Ultra®, Koch Agronomic Services LLC) and the treated urea-containing fertilizers, resp.. The active ingredient (AI) of the MS is NBPT (N-(n-butyl)thiophosphoric-triamide) only. AI concentrations of Limus and MS were between 0.04 and 0.09% based on urea fertilizer. UI-treated urea were produced in small concrete mixer, seed treater or tumbler mixer.

Experiments were conducted under fully controlled conditions in the lab and under field conditions in Argentina, Brazil, Denmark, France, Germany, Italy, Spain and United States. Test crops in the small plot and fully randomised field experiments with minimum three replicates were mainly corn, wheat and rice.

NH_3 emissions were measured in the lab (measuring period up to 35 days) using ventilated chambers and under field conditions (measuring period in most cases 10-15 days) with a closed chamber method. Crops were harvested with small plot combine harvesters or by hand.

Parameters to compare handling, transport and storage properties were drying time after treatment, AI abrasion during transport and AI stability in the formulation (AI degradation after 14 days at 54°C) and crystallization at low temperature (down to -10°C without and with crystal seeding) as well as AI stability on urea during storage (at 20°C and storage time up to 6 months). Applied methods were in-house methods based on AI transfer from fresh treated to untreated urea (drying time), AI analysis [3] [4] in abrasion dust after movement in a rotating metal barrel for 3 minutes (AI abrasion), AI analysis and crystallization rating (AI stability in formulation and on urea).

Results

With the same AI concentration Limus reduced NH3 emissions significantly compared to the MS (no UI: 13.1%, MS: 4.8%, Limus: 3.9% NH3-N losses of applied N, basis: 80 experiments (2013-2015), SNK test 5%). To reach the same performance as the MS the AI concentration of Limus could be reduced between 30 and 40%. On average of 74 field experiments between 2012 and 2015 the yield increase by Limus was 2.1% compared to MS (no UI: 7.57 c, MS: 7.72 b, Limus: 7.88 t/ha a, SNK test 5%). Due to this higher N efficiency the N amount of Limus-treated urea can be reduced to reach same yield level of MS. The reason for this higher efficiency of Limus is a synergistic action of the two AI which could be demonstrated by lab experiments. Due to its new formulation, Limus dried faster than on urea than MS (3 hours after treatment of urea 2.4% of MS AI and just 1% of Limus AI could still transfer to untreated urea). The faster drying time of Limus reduces risk of equipment blocking due to fertilizer aggregation. Also abrasion of AI from the surface of urea granules after mechanical stress was lower for Limus (AI concentration in the abrasion dust remaining in the testing equipment after treatment was 0.7% for Limus and was 2.0% for MS). Lower amounts of abrasion result in less AI loss as well as in less build-up in the blender equipment and so reducing cleaning effort and down-time of the blending system.

Positive effects of the new formulation were also found for AI storage stability in the formulation. At high temperatures (54°C for 14 days) AI loss was lower for Limus (0.2% in the Limus formulation and 1.2% in the MS formulation) and at low temperature (-10°C for 14 days) Limus formulation didn't crystalize out in contrast to the MS formulation. In such cases the MS formulation must be heated to redissolve the crystals before treating urea at low temperature e.g. during winter time. This is an additional effort which reduces flexibility of the fertilizer blenders. Biggest difference between Limus and MS is AI stability on urea during fertilizer storage. After 6 months storage time at 20°C and 70% relative humidity in open bags AI loss from MS-treated urea was 72% and for Limus-treated urea only 14%. Such high AI losses from MS-treated urea reduces possible storage time, biological performance and represent an economical loss for the farmer.
To compensate for these AI losses during storage, AI concentration in MS-treated urea must be clearly increased to be able to guarantee the stated biological performance after long-term storage and to stay above minimum AI concentration on urea according to EU/national fertilizer legislations.

Conclusions

Thanks to the synergistic interaction of the two active ingredients NBPT and NPPT and a tailor made polymer-stabilized formulation the novel product Limus® shows better performance concerning reduction of NH_3 emissions, yield, handling, transport and storage in comparison to the NBPT based market standard. Due to the higher efficiency of Limus the performance level of the market standard could be reached with a lower Limus concentration. The new formulation Limus also provides a shorter drying time, lower abrasion and especially longer AI storage stability on urea compared to market standard. These properties represent advantages for the farmer as well as for the fertilizer producer/distributors. This makes Limus an optimal solution to fulfill international and national efforts to reduce NH_3 emissions from urea-containing fertilizers.

[1] Kiss, S., Simihăian, M. 2002. Improving efficiency of urea fertilizers by inhibition of soil urease activity, Kluwer Academic Publishers, Dordrecht, Boston, London.
[2] Trenkel, M. 2010. Slow- and controlled-release and stabilized fertilizers: An option for enhancing nutrient use efficiency in agriculture, 2nd edition, International Fertilizer Industry Association, Paris.
[3] DIN EN 2008. Fertilizers - Determination of urease inhibitor N-(n-butyl)thiophosphoric triamide (NBPT) using high-performance liquid chromatography (HPLC), DIN EN 15668.
[4] DIN EN 2015. Fertilizers - Determination of urease inhibitor N-(n-butyl)thiophosphoric triamide (NBPT) and N-(n-propyl)thiophosphoric triamide using high-performance liquid chromatography (HPLC), DIN EN 16651

COUPLING OF DAYCENT AND HYDRUS FOR STUDING THE WATER AND NITROGEN CYCLES IN SOILS WITH SHALLOW GROUNDWATER – A CASE STUDY IN NORTH ITALY

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Objectives

DAYCENT model was selected as a tool to evaluate the effectiveness of agri-environmental measures in Veneto Region (northern Italy). Because the site is characterized by both free drainage and shallow groundwater conditions, particular attention must be paid to simulate water dynamic. Indeed, DAYCENT adequately represents the water movement in well-drained soil using the tipping bucket method for water infiltration and redistribution. However, the representation of water movement in shallow groundwater conditions is not exhaustive. In this work we replaced the native water sub-model of DAYCENT with the HYDRUS sub-routines which solve the Richard's equation for saturated–unsaturated water flow. A first evaluation of the efficiency of the coupled model to simulate water and nitrogen cycles is following reported.

Method

Incorporation of HYDRUS 1-D water module into DAYCENT to create a coupled model (DAYCENT&HYDRUS).
Part of the code for integration was adapted from Yuan et al. (2011). During simulation a daily communication occurred between DAYCENT and HYDRUS module. DAYCENT calculates 1) the potential water flux from rain after interception of biomass or the amount of melted water, 2) the potential soil evaporation rate, 3) the potential transpiration rate, 4) root depth. The variables from HYDRUS that are returned to DAYCENT are 1) actual evaporation, 2) actual transpiration, 3) drainage (or capillary rise), 4) total net water flux for each node. Actual evapotranspiration (ETa) and soil water content were used from DAYCENT to growth plants and for C e N biogeochemical processes.

Model testing

DAYCENT and DAYCENT&HYDRUS were tested using data measured in a lysimeter experiment in northern Italy. A three-year experiment (2011-2013) on continuous maize (*Zea mays* L.) was conducted in 12 loamy-soil lysimeters (1 x 1 m^2 width x 1.5 m depth). The factorial combination of three water table levels (free drainage – FD, water table at 60 cm – WT60 and water table at 120 cm – WT120 depths) with two N input levels ("Low" and "High") were evaluated. N input was a sum of organic+mineral nitrogen ("Low" =170+80 and "High" =250+118 kg N ha^{-1} y^{-1}).

The experimental design was completely randomised with two replicates. Soil hydraulic parameters of the 120 cm profile were estimated by laboratory methods (e.g. Wind's method). Water balance was monitored considering the precipitation, irrigation, groundwater recharge and upflux and the soil water content. Moreover the nitrogen balance was calculated in terms of N-uptake and N leaching. Lysimeters were also equipped by an automatically chamber system to monitor N_2O emission from the soil.

Results

DAYCENT was sensitive to N input simulating an higher biomass and crop yield according to the N input. In free drainage conditions, simulated yield and N uptake were close to the real ones, 251 vs 264 g C m^{-2} y^{-1} and 10.2 vs 11 g N m^{-2} y^{-1}. Also, actual evapotranspiration (ET_a) and percolation well fitted with the measured data. On the contrary, total biomass and yield were underpredicted when watertable boundary condition were simulated (WT60 and WT120), because the model was not able to describe the capillary rise (e.g. in WT120, simulated grain was 290 g C m^{-2} y^{-1} vs observed 504 g C m-2 y^{-1}). Moreover, DAYCENT could not differentiate WT120 from WT60. In terms of water balance, percolation tended to zero, an obvious underestimate with respect to real values of about 220 mm, while simulated ETa was about the 63% and 61%

of the real ETa in WT120 and WT60, respectively.

DAYCENT &HYDRUS allowed to better represent the higher water availability in correspondence of shallow groundwater conditions. The simulated yield was more realistic than in DAYCENT e.g. in WT120 grain was 290, 600 and 503 g C m^{-2} y^{-1} for DAYCENT, DAYCENT &HYDRUS and lysimeters, respectively. In some cases, the crop production in the coupled model exceeded the real one, due to the transient water flow imposed by HYDRUS sub-routines.

Regarding the N_2O emissions, during crop growing season all nitrogen emitted was due to nitrification pathway in both the models. In FD condition, real emission was of 1.36 kg N-N_2O ha^{-1} y^{-1} vs 2.61 kg N-N_2O ha^{-1} y^{-1} and 1.65 kg N-N_2O ha^{-1} y^{-1} simulated by DAYCENT and coupled model, respectively. In WT120 emissions were 1.23 (real) vs 1.22 kg N-N_2O ha^{-1} y^{-1} and 2.45 kg N-N_2O ha^{-1} y^{-1} simulated by DAYCENT and DAYCENT&HYDRUS. During the winter period N_2O fluxes simulated by the coupled model in the shallow groundwater conditions were on average 8.9 kg N-N_2O ha^{-1} y^{-1}, due to the denitrification pathway triggered by the water saturation in the deeper layers.

Conclusions

The application of the DAYCENT &HYDRUS in free drainage conditions did not improve the results with respect to the original model . On the contrary, the coupled model favored a more dynamic representation of soil water content and in turn actual evapotranspiration, water distribution within the profile, crop productivities and N leaching. A problem persists in simulating the N_2O emissions that are higher than the measured ones. Such differences probably depend on the sensitivity of the denitrification module to the saturated soil water content. Indeed, soil water content influences soil-gas diffusion coefficient, and also the prediction of total denitrification flux (N_2+N_2O) and the repartition of N in N_2 and N_2O. A specific calibration of the algorithm for nitrogen emissions could improve the description of the N gaseous losses in shallow groundwater conditions.

Acknowledgements

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References

[1] Yuan, F., Meixner, T., Fenn, M. E., Simunek, J. (2011). Impact of transient soil water simulation to estimated nitrogen leaching and emission at high- and low-deposition forest sites in Southern California. Journal of Geophysical Research: Biogeosciences, 116, 1–15.

THE APPORTIONING OF N_2O EMISSIONS TO NITRIFICATION OR DENITRIFICATION FROM DIFFERENT NITRATE SOURCES AT DIFFERENT WATER-FILLED-PORESPACES (WFPS)

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Objectives

A series of laboratory incubation experiments suggested the existence of different pools of NO_3^- in soils. For the assessment of the utilisation of applied NO3- vs nitrified NO_3^- from applied NH_4^+, the model developed by Müller et al. [1,2] can be used to calculate the immobilisation of added NO_3^- and NH_4^+, nitrification of added NH_4^+, mineralisation of organic N and subsequent nitrification by the analysis of the ^{15}N in the soil as well as the ^{15}N enrichment of the emitted N_2O.

Using our denitrification incubation system (DENIS, [3]) further developed to include real time measurements of ^{15}N-N_2O, three experiments will be performed, each using twelve re-packed soil cores incubated within the DENIS and amended using the triple labelled N technique ($^{15}NH_4NO_3$, $NH_4{}^{15}NO_3$ and $^{15}NH_4{}^{15}NO_3$) [1,2].
The WFPS will be set at a high, medium and low level to favour nitrification, a mixture of nitrification and denitrification, and denitrification.

Method

Soil samples were taken from a typical grassland soil from SW England. The soil was air dried to ~20% H2O, sieved to <2 mm and stored at 4°C until the start of the experiment. The soil was acclimatised to room temperature (RT) for 1 week before the moisture content was adjusted to correspond to the final WFPS (taking the later addition of 50 ml amendment solution into account). The soil was left loosely covered at RT for another week before soil cores were packed. Experiments were performed at 55% and 70% WFPS (with a further experiment at 85% WFPS to be done), each containing 4 different treatments with three replicates each. $^{15}NH_4NO_3$, $NH_4{}^{15}NO_3$, $^{15}NH_4{}^{15}NO_3$ and a control of KNO_3 serving as a treatment indicating total denitrification potential of the soil. This treatment was adjusted to 85% WFPS just before cores were placed into the incubation chamber. For each experiment 12 soil cores (140 mm diameter x 75 mm height) were packed to a bulk density of 0.8 g cm^{-3}. Cores were left over night and after final moisture adjustment placed into the DENIS, where they were kept at 20°C. To remove native N2 from the soil, cores were flushed from the bottom with a mixture of He/O2 (80:20) at 30 ml min^{-1} for 4 days. Flow rates were then decreased to 12 ml min^{-1} and the flow re-directed to flow over the surface of the soil core. For all treatments N was added at 75 kg N ha^{-1} in 50 ml water via a sealed, He-flushed amendment chamber fixed to each vessel lid. Measurements were taken “continuously” for 15 days with one sample being analysed every 20 minutes resulting in four-hourly values for each vessel. Emissions of N_2O and CO_2 were measured by GC with an electron capture detector and N_2 with a helium ionisation detector, while NO concentrations were determined by chemiluminescence. ^{15}N enrichment of the emitted N_2O was measured by mass spectrometry. All gas concentrations were corrected by the flow rate through the vessel and fluxes were calculated on a kg N or C ha^{-1} basis.

Results

The emitted N_2O was analysed for its ^{15}N enrichment. At 55% WFPS the highest enrichment was found in the dual labelled treatment ($^{15}NH_4{}^{15}NO_3$, increasing to 9 atom% by day 13) indicating that both nitrification (NH_4-oxidation) as well as denitrification (NO_3-reduction) contributed to N_2O production at this moisture level. This was confirmed by the enrichment of N_2O in the two single labelled treatments. No significant difference was found between those two treatments in the ^{15}N-enrichment of the produced N_2O and in both treatments the enrichment increased over the course of the experiment to around 6.5 atom%.
At 70% WFPS the highest enrichment was again found for the dual labelled treatment ($^{15}NH_4{}^{15}NO_3$). At this

higher soil moisture enrichment levels increase more rapidly and to a higher level (16.5 atom% by day 13). In contrast to the lower WFPS, enrichment levels of the single labelled treatments revealed that most of the N_2O derived from NH_4^+. While the ^{15}N-enrichment from the labelled $^{15}NO_3$ increased similarly to the same treatment at 55% WFPS, the enrichment of N_2O from the labelled $^{15}NH_4$ treatment increased more rapidly and to a higher level (13.5 atom%)

The model by Müller allows determination of N_2O emissions from added NO_3^- or from the added NH_4^+ that has been nitrified. In addition, immobilisation of added NO_3^- and NH_4^+, nitrification of added NH_4^+, mineralisation of organic N and subsequent nitrification will be determined by the analysis of the ^{15}N in the soil. We will add the data for nitrification/denitrification from this study.

A KNO_3 treatment was used in each experimental run to determine the denitrification potential of the soil under the given conditions. At 85% WFPS denitrification is promoted. The KNO_3 treatments in both experiments showed the typical appearance of the different gases as has been found in previous experiments [2]

Conclusions

N_2O can be produces during nitrification as well as denitrification. Nitrification and denitrification may occur simultaneously in different microsites of the same soil but there is often uncertainty associated with which process dominates in a particular soil under specific conditions. Low WFPS is thought to promote nitrification, due to better aeration of the soil, while high WFPS is thought to promote denitrification during induced anaerobicity. 55% WFPS was considered to be favourable for nitrification, while WFPS above 80% would promote denitrification. At the chosen WFPS of 70% a combination of nitrification and denitrification is expected. The performed experiments give insight into the origin of the emitted N_2O and the major processes contributing to its emission and not only show the influence of the immediate WFPS on GHG emissions and the processes leading to them, but also highlight the effect of previous moisture conditions on GHG emissions and the denitrification potential of the soil under the given conditions.

Acknowledgement

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References

[1] Müller, C., Rütting, T.,Kattge, J., Laughlin, R. J., Stevens, R. J. 2007. Soil Biology & Biochemistry 39, 715-726
[2] Müller, C., Stevens, R. J., Laughlin, R. J. 2004. Soil Biology & Biochemistry 36, 619-632
[3] Cárdenas, L.M., Hawkins, J.M.B., Chadwick, D., Scholefield, D. 2003. Soil Biology & Biochemistry 35, 867-870
[4] Loick, N., Dixon, E.R., Abalos, D., Vallejo, A., Matthews, G.P., McGeough, K.L., Well, R., Watson, C.J., Laughlin, R.J., Cárdenas, L.M. 2016. Soil Biology & Biochemistry 95, 1-7

FOCUS ON NUTRIENTS - A SWEDISH EXTENSION SERVICES PROGRAM

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Objectives

Focus on Nutrients (Greppa Näringen in Swedish) offers advice that benefits both the environment and the farm finances free of charge for the farmer. Focus on Nutrients started in 2001 and is a joint venture between The Swedish Board of Agriculture, The County Administration Boards and the Federation of Swedish Farmers. Focus on nutrients is funded by the EU Rural Development Program for Sweden.

The purpose of the project is to:

- reduce losses of greenhouse gases from agriculture; nitrous oxide, methane and carbon dioxide
- reduce losses of nitrate and phosphorus from farmland
- reduce ammonia emissions from animal production and manure handling
- avoid or reduce losses of pesticides into surface and groundwater
- increase energy efficiency on farms.

Method

In order to fulfil the objectives the project focuses on increasing nutrient management efficiency by increasing the farmer's awareness and knowledge. The farmer is in focus and therefore the core of the project is education and individual on-farm advisory visits. Generally, a farmer needs to farm more than 50 hectares of arable land and/or have more than 25 livestock units in order to qualify for the individual counselling visits. When a farmer signs up to become a member the first step is a start-up visit, which includes calculating the farm's nutrient balance. A plan for future advisory visits is also made during the start-up visit. The advisory plan is based on the specific challenges that each farmer faces, which in turn vary depending on the type of production and environmental impact that the farm has. There are over 30 different types of advisory visits (consulting modules) to choose from. After approximately 3 years or 4-6 visits there is a follow-up visit where the farmer and advisor go through the changes made on the farm and which environmental and economic benefits these changes have resulted in. Farm nutrient balances, nitrogen leaching, ammonia and greenhouse gas emissions from the farm are calculated by the advisory tool VERA (VERA, 2016). VERA can also be used to make up fertilisation plans and calculate the nutrient content and amounts of manure produced. VERA was released in August 2015 and replaced an earlier tool, STANK in MIND.

Results

Focus on Nutrients has a systematic approach to ensure the quality of the advice given by the extension services as well as to ensure the environmental benefits of the program. About 50 000 farm visits have been carried out since the beginning of the project. The on-farm visits are carried out by almost 300 advisors who employed by 70 different consultancy companies across Sweden. In 2011, Focus on Nutrients introduced advisory services on climate and energy efficiency, as well as advisory services aimed at meeting the objectives in the EU water framework directive.

Farm surpluses of nitrogen and phosphorus have decreased significantly since the start of the program mainly due to more efficient production on the farms (Nilsson & Olofsson, 2015). To achieve any long-term changes on the farm it is important to make repeated visits. The results from the program are regularly evaluated and the farmers and advisors have been very satisfied throughout the years (Focus on Nutrients, 2011).

Conclusions

Farm surpluses in nutrient balances were decreased by a program offering advices free of charge. Long-term changes in farm nutrient efficiency was improved by repeated visits by advisors at the farms.

DIFFERENT NITROGEN SEASONAL DYNAMIC UNDER CONVENTIONAL AND CONSERVATION TILLAGE

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Objectives

Interest on conservation tillage practices is growing because of its beneficial effects on soil quality and positive environmental impact. Conservation tillage, in comparison to conventional moldboard ploughing, minimizes soil disturbance and augment crop residue near the soil surfaces, which results in accumulation of soil organic carbon in the top soil and may also affect N transformation processes leading to changes in N dynamic and distribution in the soil profile. However these tillage effects are environmentally dependent and related to different types of soil and climate [1; 2]. The objectives of this study were (i) to determine influences of two different tillage intensities on temporal soil nitrogen dynamic and its distribution in soil profile of a shallow Cambisol in NE Slovenia and (ii) to potentially adapt fertilizer requirements regarding to the changes in plant available nitrogen contents.

Method

Field experiment was carried out on a long term field trial in Moškanjci in Sub-Pannonia basin, Slovenia (46º 3`, 15º 4`; 225 m a.s.l.) where two different soil cultivation systems including convectional tillage (CT) by moldboard plough (20 - 25 cm deep) and minimum tillage (MT) by vario-disc harrow (10 cm deep) have been compared side by side since 1999. Location is characterized by a continental climate (annual mean temperature 10.6°C and mean precipitation 913 mm), with shallow soil (40-60 cm) classified as a Cambisol formed over sand and gravel (loamy texture: 30-40 % sand, 42-48 % silt, 17-26 % clay) and pH of 6.0-6.5. During the period of investigation (April to October 2012) main crop, sunflower, was fertilized on 6th June by 40 kg N/ha (as CAN). Soil samples were taken from four randomly chosen plots sized 12 x 8 m each. The soil in both tillage treatments was sampled four times: after maize harvest in November 2011, 10 days after tillage in April 2012, during the vegetative growth of sunflower in July 2012, and after tillage and seeding of rye in October 2012. The soil samples were taken at depths of 0-10, 10-20 and 20-30 cm. Samples were dried at 40º C, ground to pass a 2 mm sieve and extracted by 0.01 M CaCl2 [3]. Ntot and Nmin (NO3-N and NH4-N) in the extracts were measured with autoanalyser (Bran Luebbe-Technicon), dissolved organic nitrogen (DON) was calculated from the difference between Ntot and Nmin.

Results

13 years of continuous minimum tillage (MT) changed several chemical and physical soil properties in the upper 10 cm: higher OM content, water-stable 2-4 mm sized aggregates, and water-holding capacity [4]. The variations of the Nmin content in the 0-30 cm depth were higher in CT than in MT. Nmin was quite stabile under MT during the year. CT resulted in significantly higher Nmin in April 2012, indicating the increased mineralization. The opposite situation was in hot and dry period of mid-July: Nmin was almost twice higher by MT in the upper soil layer. Year later at the same experimental site Kaurin et al. [4] reported about significantly higher microbial biomass in 0-10 cm depth by MT, which seems to provide better living conditions for the microbes and better resilience of microbial population to drought stress. The yield of sunflower was nearly the same (1.6 t dry seeds/ha) for the both tillage treatments, which indicates onset of increased mineralization in the spring by CT was not beneficial for the yield. In October 2012 after sunflower harvest and subsequent tillage and rye seeding CT again led to significant increase in Nmin content compared to MT, which could lead the NO3-N leaching during winter. Contents of Nmin progressively increased with depth (0-30 cm) by CT (leaching), whereas by MT there were no significant Nmin differences between the soil depths.

Temporal distribution of DON was more homogenous, differences between the tillage treatments were significant only in the summer with the highest contents of DON by MT. Soil profile distribution of DON showed the same trend as Nmin distribution in the same time. Significantly higher contents of DON in top (0-10 cm) of MT soil were also reported by Kaurin et al. [4].

Conclusions

13 years of practicing different tillage treatment resulted in changed dynamic of Nmin. By CT temporal dynamic is more intensive and related to greater disturbance of soil profile. Higher Nmin contents in summer by MT may indicate on better soil condition for microbial activity even in more dry conditions. In autumn advantage of minimal soil disturbance regarding to plowing has been shown in decreased mineralization of soil nitrogen and reduced potential for nitrate leaching during the winter. Delayed beginning of mineralization processes in spring time may cause nitrogen deficiency for winter crops in early season, but not very likely for the summer crops in conditions of gravelly Cambisol in NE Slovenia.

[1] Gomez-Rey M. X., Couto-Vazquez A., Gonzalez-Prieto S. J. 2012. Nitrogen transformation rates and nutrient availability under conventional plough and conservation tillage. Soil & Tillage Research, 124: 144-152
[2] Wright L. A., Hons M. F., Lemon G. R., McFarland L. M., Nichols L. R. 2007. Stratification of nutrients in soil for different tillage regimes and cotton rotations. Soil & Tillage Research, 96: 19-27
[3] Houba V. J. G., Temminghoff E. J. M., Gaikhorst G. A., van Wark W. 1999. Soil analysis procedures, extractions with 0.01 M CaCl2. Wageningen, Agricutural University: 95 p.
[4] Kaurin A., Mihelič R., Kastelec D., Schloter M., Suhadolc M., Grčman H. 2015. Consequences of minimum soil tillage on abiotic soil properties and composition of microbial communities in a shallow Cambisol originated from fluvioglacial deposits. Biology and fertility of soils 2015 v.51 no.8 pp. 923-933.

TOP DRESSING NITROGEN RECOMMENDATION IN WHEAT AFTER APPLYING ORGANIC MANURES. USE OF FIELD DIAGNOSTIC TOOLS

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Objectives

Evaluate the usefulness of the proxy tools N-tester and RapidScan for diagnosis of nitrogen nutritional status in the field when farmyard manures are applied.

Method

A field trial was established in Arkaute (Basque Country, Spain) in the 2014-2015 winter wheat growing season and 16 N fertilization treatments tested. Three kinds of initial fertilization were applied: dairy slurry (40 t/ha), sheep farmyard manure (40 t/ha) and conventional (not organic fertilizer on basal dressing and 40 kg N/ha at tillering). These three types of fertilization were combined with five N dose at top dressing applied at stem elongation (0, 40, 80, 120 and 160 kg N/ha). The experimental design was a factorial randomized block with four replicates. Dairy slurry dry matter (DM) content was 8.99 %; N-NH_4^+ (2.6 %); total N (4.8 kg/t); P_2O_5 (1.8 kg/t); and K_2O (3.4 kg/t); and sheep manure DM was 38.02 %; total N (8.4 kg/t); P_2O_5 (6.2 kg/t); and K_2O (15.3 kg/t). Soil texture was sandy clay loam, soil P and K content were high and pH was 8.55. The proxy tools for the diagnosis of the N nutritional status tested (©Hydro-N-tester of Yara and RapidScan CS-45 (Holland Scientific)) were used at stem elongation. ©Hydro-N-tester measures the light transmittance in red and near infrared and calculates a numeric value that estimates chlorophyll content. RapidScan CS-45 measures the reflectance of crop canopy, provides the NDVI Index and estimates the photosynthetically active biomass. Normalized values were calculated to avoid the noise encountered by variables other than N fertilization and were calculated as a percentage by assigning the 100% value to an overfertilized control plot, which received 280 kg N/ha. Three rows of wheat one meter long were cut before applying the top dressing at stem elongation. Biomass was estimated and N concentration determined from these samples in order to calculate 'Nitrogen nutrition index (NNI)' [1]. Grain and straw yield, and yield components of each treatment were measured at harvest.

Results

There were not significant differences among NNI values before applying N at stem elongation for the three initial fertilization treatments, ranging from 0.29 for sheep manure and 0.37 for dairy slurry. This values were low (NNI<1), so N was limiting for wheat [1], even at the conventional treatment, where 40 kg N/ha had been applied at tillering. Accordingly, at tillering, just before the first N application, soil mineral N at 0-60 cm depth was lower than 30 kg N/ha in all treatments. ©Hydro-N-tester and RapidScan CS-45 gave the same results and showed higher values at the conventional treatment without manure application and 40 kg N/ha at tillering (87 %), than dairy slurry and sheep manure treatments (65 %). Crop yield response was adjusted to a Quadratic-Plateau Model, being the N optimum rate at stem elongation 98 kg N/ha at conventional treatment (total dose 138 kg N mineral/ha) and 118 kg N mineral/ha at dairy slurry and sheep manure treatments. Maximum yields were about 8.500 kg/ha. The number of spikes/m^2 when N was not applied at stem elongation was greater for the conventional treatment, due to the effect of the 40 kg N/ha applied at tillering. However, when N was provided at stem elongation these differences in the number of spikes/m^2 disappeared. These results confirm findings of other authors [2] who observed that even suffering early N stress it is possible to achieve maximum yields when N is applied later. To obtain the maximum protein value in grain (around 11%) the highest dose of N, 160 kg N/ha, was necessary at stem elongation for any of the initial fertilizations tested. Differences obtained in the optimum dose of N applied at stem elongation, evidenced that the proxy tools correctly diagnosed different nutritional situations that NNI was not able to predict. Thus, treatments with organic basal dressing needed 20 kg N mineral/ha less than the conventional treatment. Tools tested are not invasive and measurements can be repeated several times along the growth period, so information obtained on crop N status dynamics can be used for decision making in N fertilizer management [3].

Conclusions

These preliminary results look promising in order to modulate N application rate at stem elongation, but more studies are needed to further evaluate these field devices under different conditions and make specific N recommendations.

Acknowledgments

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References

[1] Justes, E., Mary, B., Meynard, J.M., Machet J.M. & Thelier-Huche L. 1994. Annals of Botany 74, 397-407.
[2] Morris, K.B., K.L. Martin, K.W. Freeman, R.K. Teal, K. Girma, D.B. Arnall, P.J. Hodgen, J. Mosali, W.R. Raun & J.B. Solie. 2006. J. Plant Nutr. 29, 727–745.
[3] Lemaire, G., Jeuffroy, M.H. & Gastal, F. 2008. European Journal of Agronomy 28, 614-624.

CROPPING SYSTEMS FOR TRANSFER OF SOIL MINERAL N IN ORGANIC GREEN MANURE LEYS TO SUBSEQUENT SPRING WHEAT

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Objectives

There is a shortage of organic quality spring wheat with protein content greater than 12 % demanded by the milling industry in Sweden. The organic fertilizers commonly used in stockless organic wheat production are generally not sufficient to achieve high enough nitrogen availability during the growing season of wheat. Therefore, the protein concentration in organically produced spring wheat grains is often too low to qualify for premium price. Rotational grass/clover leys are sometimes used as green manure crops in organic farming, but the transfer of N from the green manure to subsequent spring wheat are generally not efficient due to losses [1].

The objective of this study was to quantify the nitrogen effect of using annual crops established after incorporation of grass/clover to carry nitrogen to subsequent spring wheat.

Method

The investigations were carried out 1997-2001 in twenty field experiments located at ten farms in organic production in central Sweden. The ley was established in spring cereals and allowed to grow during two seasons. The experiment starts with the incorporation of the grass/clover during the third autumn after sowing. The grass/clover ley consisted of red clover (*Trifolium pratense*) with timothy (*Phleum pratense*) and meadow fescue (*Festuca pratense*) as companion grasses. The tillage was performed with a mouldboard plough. The treatments were, a) Incorporation (IC) of ley in early August, catch crop: frost sensitive winter oilseed rape (*Brassice napus* L,) (IC Aug + WOSR), b) Incorporation of ley in early August, catch crop: 1997-1998 spring turnip rape (*B. campestris* L), 1999-2000 white mustard (*Sinapsis alba* L) (IC Aug + SOTR or WM), c) Incorporation of ley in early October, no catch crop (IC Oct), d) Incorporation of ley in early November, no catch crop (IC Nov), e) Incorporation of ley in April before sowing (IC April). The duration of catch crops lasted until the following spring, and was incorporated with a harrow into the soil right before seedbed preparation. The catch crop in treatment b (IC Aug + SOTR or WM) was changed from spring turnip rape to white mustard in 1999, since the growth potential of SOTR was low. The treatment (IC April) was added to the experiments in 1998 as a control treatment to demonstrate the effects of a late onset of mineralization. Spring wheat, were sown in all field trials. Grain yield was determined at harvest. Dry matter (DM) and Kjeldahl N content of grain was analyzed. Soil samples were collected on two occasions; at sowing and after harvest at 0-30 cm, 30-60 and 60- 90 cm and were analysed for soil mineral N (SMN) (NH_4-N and NO_{3-}N). The systems were evaluated on the variables time point of incorporating the ley and on the choice of catch crop.

Results

The investigations were carried out 1997-2001 in twenty field experiments located at ten farms in organic production in central Sweden. The ley was established in spring cereals and allowed to grow during two seasons. The experiment starts with the incorporation of the grass/clover during the third autumn after sowing. The grass/clover ley consisted of red clover (*Trifolium pratense*) with timothy (*Phleum pratense*) and meadow fescue (*Festuca pratense*) as companion grasses. The tillage was performed with a mouldboard plough. The treatments were, a) Incorporation (IC) of ley in early August, catch crop: frost sensitive winter oilseed rape (*Brassice napus* L,) (IC Aug + WOSR), b) Incorporation of ley in early August, catch crop: 1997-1998 spring turnip rape (*B. campestris* L), 1999-2000 white mustard (*Sinapsis alba* L) (IC Aug + SOTR or WM), c) Incorporation of ley in early October, no catch crop (IC Oct), d) Incorporation of ley in early November, no catch crop (IC Nov), e) Incorporation of ley in April before sowing (IC April). The duration of catch crops lasted until the following spring, and was incorporated with a harrow into the soil right before seedbed preparation. The catch crop in treatment b (IC Aug + SOTR or WM) was changed from spring turnip rape

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Conclusions

In conclusion, an early turn under of ley followed by an easily decomposed catch crop, e.g. white mustard, compared with a later turn under of ley, will result in a higher yield of spring wheat and a in protein content >12 % of the grain. Our results show that production of organic spring wheat with baking quality is possible with an N source relying on a green manure ley in combination with a catch crop.

Our results show that the content of soil mineral N is detrimental for organic spring wheat production of premium quality. Green manure crops incorporated in early August, followed by an easily decomposed catch drop e.g. white mustard provide a transfer of soil mineral N superior to incorporating the ley in early October, early November or in April the following year.

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References

[1] Thorup-Kristensen, K., Magid, J., Stoumann Jensen, L. 2003. Catch crops and green manures as biological tools in nitrogen management in temperate zones. Advances in Agronomy,79, 227-302.
[2] Andersen, M.K., Jensen, L.S. 2001. Low soil temperatures on short- term gross N mineralisaitio0n- immobilization turnover after incorporating a green manure. Soil Biology & Biochemistry, 33, 511-521.

EFFECT OF VARYING DOSES OF SOIL APPLIED UREA ON GROWTH AND PRODUCTION POTENTIAL OF QUINOA (Chenopodium quinoa Willd.)

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Objectives

Quinoa (Chenopodium quinoa Willd.), a lesser-known food and feed crop is gaining acceptance in Pakistan. It is being cultivated to develop its production technology under local conditions. A balanced fertilization ensures the maximum economic return. Therefore, a field experiment was proposed to optimize the dose of nitrogenous fertilizer on the phenology and production potential of quinoa.

Method

Quinoa seeds of three accessions collected from the department of Crop Physiology, University of Agriculture Faisalabad Pakistan were sown on sandy loam soil of pH 7.9 and EC of 1.74 dS m^{-1} at Agronomy students' farm during 2nd week of November 2012 with 15 cm and 75 cm as distances between plants and rows, respectively. Study was performed in randomized complete block design (RCBD) with split plot arrangement in three replications. Three genotype viz. HBM-3, HMB-4, HMB-5 were assigned in main plot and four nitrogen levels (80, 100, 120 and 140 kg ha-1) were kept in subplots. All the other Agronomic practices were carried out using standard procedure for quinoa crop. Growth and yield data were recorded by adopting standard procedure and quality analysis were made from the samples.
Leaf area index, leaf area duration, crop growth rate and net assimilation rate were derived adopting formulae as described by Hunt (1978) at various crop stages. Data was analyzed using MSTAT C Program (MSTAT Development Team, 1989). Least Significant difference (LSD) test at 5% level of probability was used to compute the mean values (Steel et al., 1997).

Results

Results revealed that all the growth and yield related traits such as leaf area index, leaf area duration, crop growth rate, net assimilation rate, plant height, stem diameter, number of panicles per plant, main panicle length, and thousand grain weight were maximum for genotype HMB4 and minimum for genotype HMB5 among three genotypes. While in case of nitrogen levels an increasing trend, in growth and yield components was recorded with in nitrogen levels from 80 to 140 kg N ha^{-1} except thousand grain weight which were maximum at 100 kg N ha^{-1}. However interaction was non-significant except biological yield, economic yield and harvest index which were maximum for genotype HMB-4 at nitrogen level of 100 kg ha^{-1}. Nitrogen application also increased leaf chlorophyll content (40.124 mg g^{-1}Fresh wt.) and total phenolics (9.2976 mg g^{-1}fresh wt.) when soil was fertilized with 140 kg N ha^{-1} and 80 kg N ha^{-1} respectively.

Discussion

Nitrogen is most important determinant of growth and yield of crops among all major plant nutrients. Deficiency of nitrogen in crops plants causes stunted growth and chlorosis (yellowing) of leaves due to decreased level of chlorophyll content. Nitrogen fertilization significantly increased the growth related traits like leaf area, leaf area index, leaf area duration, crop growth rate, net assimilation rate and total dry matter up to maximum nitrogen level i.e. 140 kg ha^{-1}. Increase in chlorophyll content not only increase the leaf area but also the nitrogen assimilation resulting in better growth and development of crop. Nitrogen supply also increases rates of cell division and expansion, photosynthesis and leaf production. The source sink relationship is due to the development and maintenance of leaf area which is influenced by nitrogen as a result photosynthetic efficiency as well as dry matter partitioning to reproductive organs improved under optimum nitrogen availability and translocation of photo assimilates from source (leaves) to sink (grain) during grain development. Significant increase in yield contributing traits by soil supplementation with nitrogen (100 kg ha^{-1}) resulted in substantial increase in grain yield. Increase in biological yield by nitrogen application might be due to improved leaf area development and photosynthetic efficiency due to fact that N is a part of Rubisco which resulted in improved plant height, leaf area index and crop growth rate which increased the biological yield. Varying levels of nitrogen fertilization resulted in increased harvest index of quinoa genotypes. Higher the harvest index, greater will be the physiological potential for converting dry matter into economic part. It might also be due to nitrogen ability to enhance the translocation of photo assimilates from vegetative to reproductive parts, which may increase the grain yield and consequently the harvest index in quinoa.

Conclusions

Nitrogen application increased all growth related traits like leaf area index, leaf area duration and crop growth rate, net assimilation rate with increasing nitrogen rates. Nitrogen dose of 100 kg ha^{-1} contributing to substantial increase in economic yield, biomass production and harvest index in quinoa genotypes under semi-arid conditions.

References

[1] FAO. 2003. The State of Food Insecurity in the World. Published by the Food and Agriculture Organization of the United Nations Viale delle Terme di Caracalla, 00100 Rome, Italy.
[2] Jacobsen, S.E., A. Mujica and R. Ortiz. 2003. The global potential for quinoa and other Andean crops. Food Rev. Inter., 19: 139-148.
[3] Ogungbenle, H.N. 2003. Nutritional evaluation and functional properties of quinoa (*Chenopodium quinoa* Willd.) flour. International Journal of Food Sciences and Nutrition 54: 153 -158.
[4] Repo-Carrasco R, C. Espinoza and S.E. Jacobsen. 2003. Nutritional value and use of the Andean crops quinoa (*Chenopodium quinoa*) and ka˜niwa (*Chenopodium pallidicaule*). Food Rev. Int., 19:179-189.
[5] Shams, A.S. 2010. Combat degradation in rainfed areas by introducing new drought tolerant crops in Egypt. 4thInternational Conference on Water Resources and Arid Environments, Riyadh, Saudi Arabia, 5- 8 December, 575-582.
[6] Shams, A.S. 2012.Response of quinoa to nitrogen fertilizer rates under sandy soil conditions. 13th international Conf. Agron faculty of Agric., Benha Univ., Egypt, 9-10 September, 195-205.
[7] Vega-Gálvez, A., M. Miranda, J. Vergara, E. Uribe, L. Puente and E.A. Martínez. 2010. Nutrition facts and functional potential of quinoa (*Chenopodium quinoa* Willd.), an ancient Andean grain: a review. J. Sci. Food Agric. 90: 2541-2547.

NITROGEN LEACHING RISK FROM PREFERENTIAL FLOW IN A STONY SOIL IRRIGATED BY CENTRE PIVOT

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Objectives

The area of irrigated land in New Zealand is increasing and it is expanding fast in the South Island on areas with stony soils. Such soils are considered vulnerable to nutrient leaching losses and likely to exhibit preferential flow. Nitrogen (N) losses from irrigated dairy farms are a major concern in many regions. This study aimed to investigate whether irrigation intensity has an effect on preferential solute transport in a typical New Zealand stony soil. Data was gathered from an experiment performed in large lysimeters under different irrigation regimes where a non-reactive tracer was applied on the soil surface. The Burns' equation was fitted to the measured data to infer the fraction of soil water that takes part in the solute transport. An exponential function was proposed to extrapolate these results. This approach was then used to describe the potential risk of nitrogen leaching under a centre-pivot irrigation system.

Method

The experiment was conducted under rain shelter in December 2014 at the lysimeter facility of Plant and Food Research at Lincoln, NZ. 12 lysimeters, with 500 mm diameter and 700 mm length, were collected from a dairy farm following the procedure described by Cameron et al. [1]. The soil was a Lismore Stony Silt Loam (Typic Dystrustept), with total porosity of 57% (fine earth fraction) and stone content varying between 17% in the surface to 64% at the base of the lysimeters. Two irrigation treatments were used, with application intensities of 5 mm/h and 20 mm/h, kept constant during the experiment. The irrigation lasted until the equivalent of approximately three pore volumes of leachate were collected. All lysimeters received an application of chloride (as KCl, at a rate equivalent to 400 kg/ha) after approximately one pore volume had been leached. The leachate was collected at regular intervals, stored at 4°C, and subsequently analysed using ion exchange chromatography. The Burns' equation, following the approach presented by Scotter et al. [1], was used to describe the leaching series of the non-reactive tracer in each irrigation treatment. In this approach, the proportion, X, of a solute leached below a given depth, z (mm), is a function of cumulative drainage, I (mm):

$$X = \exp(-z\theta_{FC}f_t/I)$$

where θ_{FC} (m^3/m^3) is the soil water content at field capacity, and f_t represents the fraction of water that effectively takes part in the solute transport. An exponential function was then used to describe the relationship between f_t and the irrigation intensity, J (mm/h):

$$f_t = 1 + m[\exp(-bJ) - 1]$$

where m and b are fitting parameters. It was assumed that f_t should be equal to one when irrigation intensity approaches zero, that is, the whole soil water takes part in the solute transport. The two functions above were then used to infer the value of f_t as function of the irrigation intensity, as it varies across the length of a centre-pivot, and subsequently to estimate the potential risk of nitrogen leaching losses as function of the length of this irrigation system. The leaching risk was defined as the proportion of solute leached below the depth of 0.5m after 100mm of drainage.

Results

The results from chloride leaching provided strong evidence of preferential solute transport in the Lismore stony soil, and corroborated other studies with stony soils in New Zealand [2, 3]. The Burns' equation was able to describe the experimental data well and thus, following the interpretation of Scotter et al. [1], it was used to characterise the extent of preferential flow in this soil. This approach is simpler than most standard models, it requires only basic soil properties and has only one fitting parameter (f_t). Based on the estimated values of f_t, irrigation intensity was found to have a significant effect on preferential solute transport. The mean value of f_t was reduced from 0.85 for 5 mm/h to 0.58 for 20 mm/h. Such values are in general agreement with estimates for other similarly stony New Zealand soils [2, 3]. A smaller value of f_t means faster movement of solute and therefore a higher risk of leaching losses, as it can be inferred from Burn›s equation.

With the assumption that the fraction of soil water that takes part on solute transport is equal to one as intensity approaches zero, an exponential function was found reasonable to describe the relationship between irrigation intensity and f_t. This function suggests that f_t decreases as the irrigation intensity increases, and it reaches a plateau as irrigation increases beyond approximately 50 mm/h, with asymptote value of 0.35. This relationship can then be employed to estimate the likely values of f_t for varying irrigation intensities.

Centre pivots have variable application intensities along their length in order to compensate for the faster speed of nozzles away from the centre. Considering the results of our study, lower values of f_t can be expected along the length of the pivot and thus higher risk of leaching losses. Moreover, the area irrigated by each nozzle is much larger away from the centre. The potential risk for N leaching, i.e. the fraction of solute leached below a given depth, as function of centre pivot length can thus be estimated by combining the results from Burn›s equation and the area irrigated. It can be shown that, for a soil exhibiting preferential flow, the risk of leaching is considerably higher under the variable intensity of a centre pivot than it would be expected if the intensity was constant. This results should be tested further for different soils, but raise concerns over the estimation of the impact of irrigation systems on the environment. The increase in irrigation systems in New Zealand is linked to the expansion of dairy farming, such intensive land use has been linked to N leaching from effluent and especially urine depositions. The design and management of irrigated systems should thus take in consideration the potential leaching risk due to high intensity irrigation.

Conclusions

The experimental data was successfully described using the Burns' equation, which was used to quantify the fraction of the soil pore space ( ) involved in solute transport. The results were sufficient to confirm a significant effect of irrigation intensity on preferential solute flow in the stony soil of this study. The presence of preferential flow is a concern as it suggests that the risk of leaching losses should increase as irrigation intensity increases. An exponential function was used to relate the values of and irrigation intensity and employed to assess the risk of N leaching under irrigation by a centre pivot. More studies are needed to better understand this relationship. This approach can then be used to aid on the design and management of irrigation systems.

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References

[1] Scotter, D.R.; White, R.E.; & Dyson, J.S. 1993. The Burns leaching equation. *Journal of Soil Science*, 44(1):25-33.
[2] Pang, L.; McLeod, M.; Aislabie, J.; Šimůnek, J.; Close, M.; & Hector, R. 2008. Modeling transport of microbes in ten undisturbed soils under effluent irrigation. *Vadose Zone Journal*, 7(1):97-111.
[3] Carrick, S.; Cavanagh, J.; Scott, J.; & McLeod, M. 2014. Understanding phosphorus, nitrogen, and cadmium transfer through a young stony soil. *Nutrient management for the farm, catchment and community*. Palmerston North, New Zealand: Fertiliser and Lime Research Centre. pp. 1-11.

REYGRASS OVERSOWING IN SOYBEAN AS AN ALTERNATIVE TO REDUCE NITROUS OXIDE EMISSIONS IN INTEGRATED CROP-LIVESTOCK SYSTEM

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Objectives

Integrated crop-livestock system (ICLS) is defined as a rotation of annual summer crops with winter pastures, which helps in practicing agricultural and livestock activities within the same area. In southern Brazil, ICLS is mainly characterized by the use of soybeans for grain production in the summer and ryegrass for forage production in winter. The most common strategy of ryegrass use is its sowing after soybean harvest. However, sowing of ryegrass when soybean is in R6-R7 stage i.e. at the time of senescence of leaves, appeared as a strategy to anticipate the supply of forage to animals. The aim of this study was i) to compare two options of ryegrass sowing, i.e. oversowing of ryegrass or sowing after the soybean harvest, on N_2O emissions and ii) to compare the N_2O emissions of between ICLS and systems exclusively devoted for grains production.

Method

The experiment was conducted from November 2011 to October 2013 on a Typic Hapludalf (60% sand, 30% silt, 10% clay, total C 7.5 g kg^{-1}) at the Department of Soil, Federal University of Santa Maria (29°41’S, 53°48’W), Brazil. The treatments were three crop rotations (summer/winter): CR1- soybean/ryegrass (*Lolium multiflorum*) in post harvest (late sowing); CR2- soybean (*Glycine max*)/ryegrass in oversowing; and CR3- soybean/oilseed rape (*Brassica napus*) in 2011/12 and soybean/wheat (*Triticum aestivum*) in 2012/13. CR1 and CR2 are characteristic of ICLS and CR3 of grain production systems. All crop rotations have been managed under no-till. During the two years and in all rotations, soybean was sown in November, while ryegrass in the CR1 and CR2 was sown 15 days after soybean harvest (May) and 30 days before soybean harvest at the stage R6-R7 of soybean (March), respectively. The oversowing of ryegrass in CR2 was held manually. In CR3, oilseed and wheat were sown on 30 (May 2012) and 45 (June 2013) days after soybean harvest, respectively. The treatments were organized in a randomized complete block design with four replications. The size of the plot was $25m^2$. Phosphorus and potassium were applied to soybean, wheat and oilseed rape before sowing. However, urea-N (60 kg ha^{-1}) was applied only in wheat and oilseed rape. Soil N_2O fluxes were measured periodically by the closed static chamber technique. The N2O concentrations in the samples were analyzed by gas chromatography (Shimadzu GC-2014 Greenhouse). Daily N_2O fluxes (µg N m^{-2} h^{-1}) were calculated by linear interpolation and the cumulative fluxes (g N ha-1) were calculated by the integration of the daily N_2O emissions. Gravimetric soil moisture (105°C for 24 h), soil inorganic N (NH_4 and NO_3) and water-filled pore space (WFPS) were determined in the 0-10 cm soil layer on each gas sampling date.

Results

The N_2O-N fluxes ranged from -22.9 to 173.6 µg m^{-2} h^{-1} in the first year and from -5.0 to 252.2 µg m^{-2} h^{-1} during the second year of the study. In both years, the largest fluxes of N_2O-N occurred in the period between the start of senescence of soybean leaves (74 days after sowing) and two weeks after soybean harvest (157 days after sowing). Likely, this has occurred due to increased availability of C and N in the soil, mainly by the decomposition of soybean senescing leaves. This condition, combined with periods of low O_2 availability in the soil, increased N_2O production by denitrification process. During this period, oversowing of ryegrass (CR2) reduced the mean N_2O-N flux by 11% in the first year compared to CR1 and CR3 and by 16% and 24% in the second year in relation to CR1 and CR3, respectively. Two weeks after soybean harvest

N2O-N fluxes were reduced in all rotations with CR2 presenting the lowest flows.
Annual N_2O-N emissions did not vary greatly between two years (938 and 1,064 g ha^{-1}), being higher in CR3 (1,176 g ha^{-1}) than in CR1 (1,006 g ha^{-1}) and CR2 (821 g ha^{-1}). The largest emissions of N_2O-N in CR3 were due to the use of N fertilizer (60 kg N ha^{-1}) in grain crops (oilseed and wheat) after soybean. The oversowing of ryegrass in CR2 reduced cumulative emissions of N_2O-N by 30% and 18% in comparison to the late sowing of ryegrass in CR1 and grain crops in CR3, respectively. Although the oversowing of ryegrass has reduced N_2O emissions from its sowing to soybean harvest, the main effect of this practice was seen from soybean harvest and by the end of ryegrass, oilseed and wheat cultivation. On an average of two years, the cumulative emission of N_2O-N in this period decreased in the following order CR3 (340 g ha^{-1})> CR1 (186 g ha^{-1})> CR2 (83 g ha^{-1}). The oversowing of ryegrass anticipated the establishment of grass that used the N mineralized from senescent leaves and crop residues of soybean, thereby reducing mineral N content in the soil and consequently its possible loss in the form of N_2O, with agronomic and environmental benefits.

Conclusions

The results of this study indicate that the ICLS with soybean in summer and ryegrass in winter (soybean/reygrass) have lower N_2O emissions compared to grain production systems (soybean/oilseed and soybean/wheat). The oversowing of ryegrass reduced N_2O emissions in relation to its sowing after soybean harvest and therefore can be considered as a mitigating practice of N_2O emissions in the ICLS under no-till conditions.

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EFFECT OF N SOURCE ON GROWTH, YIELD, YIELD COMPONENTS AND YIELD OF BUCKWHEAT IN THE FENUGREEK/BUCKWHEAT INTERCROPPING

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Objectives

To meet the requirements of sustainable development for feeding the increasing population in the world, farmers and scientists have developed many valuable eco-agricultural techniques. These include integrate systems and applying organic fertilizers [1, 2]. Also improving productivity and soil fertility is important to increasing production on medicinal plant .The present study investigated effect of fertilizer sources on growth, yield and yield components of buckwheat in intercropped with fenugreek.

Method

A field factorial experiment was conducted in randomized complete block design at research farm of Shahrekord University, Iran in 2014. Sole cropping of fenugreek (F), sole cropping of buckwheat (B) and three intercropping ratios (F:B; 2:1 (two rows of fenugreek + one row of buckwheat), 1:1 (one row of fenugreek + one row of buckwheat) and 1:2 (one row of fenugreek + two rows of buckwheat)), were evaluated as the first factor and three sources of fertilizer consist of chemical fertilizer (CF), broiler litter (BL) and integrated fertilizer (IF); (50% CF+ 50% BL) and as the second factor. The measured traits were plant height, No. branch plant^{-1}, No. nod plant^{-1}, 1000-seed weight, seed yield, biological yield and harvest index for buckwheat and fenugreek, No. spike plant^{-1}, No. seed spike^{-1} for buckwheat and also No. pod plant^{-1} and No. seed pod^{-1} for fenugreek. Analysis of variance (ANOVA) was performed by SAS software and fisher's least significant difference (LSD) was used for comparison of means

Results

The results showed that N source, intercropping ratio and interaction of N source and intercropping ratio had a significant effect ($p < 0.01$) on the most of studied characters of buckwheat and fenugreek.
The results indicated that intercropping ratios significantly increased the most of studied characters in compared with sole crop. The F:B (2:1) increased No. spike plant^{-1} (41.53 %) and 1000-seed weight (18.32 %) of buckwheat over sole crop. No. spike plant^{-1} and 1000-seed weight of buckwheat were higher in the integrated fertilizer than CF and BL. The highest No. seed spike^{-1} of buckwheat was recorded for F:B (2:1), also in this treatment the lowest No. seed spike^{-1} of 6.09 and the highest of 8.69 were achieved for CF and BL, respectively, but there was no significant difference between CF and IF.
In sole buckwheat, the lowest seed yield, biological yield and harvest index of 3125, 7764 kg ha^{-1} and 40.39 % were recorded for the chemical fertilizer, respectively. Also the highest seed yield, biological yield, harvest index of 4758, 10455 kg ha^{-1} and 49.1 % for buckwheat were observed for integrated fertilizer treatment, respectively. Buckwheat yield (3050 kg ha^{-1}) and biological yield (7535 kg ha^{-1}) was highest in F:B (2:1), but harvest index of 44.28 % was highest in the F:B (1:2) treatments. The highest and the lowest buckwheat yield were observed for IF and CF in the F:B (2:1) intercropped.
The results showed seed yield (2329 kg ha^{-1}) and biological yield (7234 kg ha^{-1}) of fenugreek were recorded for IF in the F:B (2:1) and harvest index of 32.49 % was highest for BL in the F:B (1:2). The application integrated fertilizer and broiler litter has been shown to influence nutrient cycling [3] and increasing yield of intercropping [4]. Similar results in other studies were found for higher yield in intercropping than sole crop [5,6]). In general it can be concluded that use of intercropping under integrated fertilizer conditions by the potential availability of nutrients in the soil cause to increase the yield of buckwheat.

Conclusions

In overall, the most of studied characters were higher in intercropping and organic manure compared with sole crop and inorganic manure respectively. So that this increasing was higher in intercropping (specially

F:B (2;1)) than sole crop and organic manure (specially, integrated fertilizer) than inorganic manure. So, seed yield and other characters studied of both plant was increased in the F:B (2:1) under fertilization (IF and BL) and this system can be efficient for manufactures of medicinal plants.

Acknowledgements

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References

[1] Gomiero, T., Pimentel, D., Paoletti, M.G. 2011. Is there a need for a more sustainable agriculture? Crit. Rev. Plant. Sci. 30, 6-23.

[2] Branca, G., Lipper, L., McCarthy, N., Jolejole, M.C. 2013. Food security, climate change,and sustainable land management. A review. Agron. Sustain. Dev. 27, 1-16.

[3] Bastida, F., Moreno, J.L., Hernandez, T., Garcıa, C. 2006. Microbiological degradation index of soils in a semiarid climate. Soil Biol. Biochem. 38, 3463-3473.

[4] Rostaei, M., Fallah, S., Abbasi Sorki, A. 2014. Effect of fertilizer sources on growth, yield and yield components of fenugreek intercropped with black cumin. Crop production. 7 (4): 197-222

[5] Saban, Y., Mehmt, A., Mustafa, E. 2007. Identification of advantage of maize-legume intercropping over solitary cropping through competition indices in the East Mediterean region. Turk J. Agric., 32: 111-119

[6] Sheri, M., Strydhorst, J., King, R., Lopetinsky, K.J., Neil Harker, K. 2008. Froge potential of intercopping barly with faba bean, lupin, or field pea. Agron. J., 100: 182-190.

CONSIDERING THE FINE SCALE OF VARIATION FOR NITROGEN MANAGEMENT

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Objectives

The world population diet relies largely on the cereal crop production, which in turn demands significant quantities of N (nitrogen) to grow, particularly under the current climatic change scenario and the improved new plant varieties. However, the N supply through the mineralization process seems to be a site-specific soil property, as it has been shown to be spatially variable and scale dependent, limiting the precision of the N application to match the crop demand at all scales, and raising environmental uncertainties. Geostatistics resolves the analysis of the soil spatial variability, but an a-priori figure of the spatial dependence of a soil property is recommended to make the analysis straightforward. Therefore, the focus of this research is to assess the spatial dependence of the N supply in a volcanic soil under cereal crop production in order to better understand and further model the spatial N application, using an appropriated sampling scheme.

Method

The study was carried out over a 6-ha field of an Andisol under wheat crop, at the beginning of the Autumn season. The site is located in the Andes pre-mountains in the South of Chile (36° 59' S, 71° 55' W, 937 m.a.s.l.) and the crop rotation is based on oat-wheat.

The spatial dependence of N supply was assessed by applying an optimized hierarchical nested design [1, 2], where main stations (n=6) were separated 121.5m away forming an equilateral triangle from where groups of interval distances of 40.5m, 13.5m, 4.5m, and 1.5m, were randomly allocated, respectively. Thus, 96 soil samples were obtained at 23 cm depth, air dried for 48 hours and sieved at 2mm to measure an index of N supply.

The potentially available N represents the amount of N mineralized during a crop season, and it is measured as the ammonium content released after 7 days of anaerobic soil incubation at 40°C. The ammonium concentration was measured at the beginning and at the end of the incubation on soil extracts of 2M KCl (ratio 1:5) shaked for 60 min, settle for 30 min, then centrifuged for 8 min at 6000 rpm and filtered. Nessler and NaOH (3M) solutions were added to 2 mL of the extracts from the soil samples as well as to 2mL of the standard ammonium concentration solutions. Samples were left to stand for 20 min for colour development and the absorption (490 nm) of the samples was measured by molecular absorption spectroscopy. A regression model between the standard ammonium concentrations and the absorbance was used to interpolate the ammonium content in the soil extracts.

Summary statistics were computed for all data set, and components of variance were calculated by residual maximum likelihood (REML) for each stage and accumulated from the smallest spacing of 1.5m up to the largest 121.5m. The difference between the stages are equivalent to the range of distances to the semivariances of the regionalized variable theory, from where the spatial dependence of the N supply index can be estimated.

Results

The N supply measured as the potentially N mineralized under controlled conditions was between 1.2 and 188.2 mg NH_4^+ kg suelo^{-1}, with a mean value of 80 mg NH_4^+ kg suelo^{-1} (standard deviation of 47.92), which is large compared to other type of soils. A large initial ammonium content was also observed in soil samples before incubation. However, this might be explained by the large soil organic matter measured in the field (11%), and the effect of residual N application. This wide range of values shows the spatial variability of nitrogen under traditional agronomic management at the field scale.

The estimated components of variance calculated by REML were constrained to positive values, as negative components were found at the stages 40.5m and 13.5m, respectively. Negative components are associated to a repetition of the values, which might signify, for example, a repetitive pattern from the stage 13.5m, thought to represent the width of machinary used for fertilizer/pesticides applications in the field. After the positive constraint, the main contribution to the total variance was observed from the stages 1.5m, 4.5m, and 121.5m, respectively. Nevertheless, up to 60% of the variance was found at the short interval distance of 4.5m, showing the fine spatial variation of the N. This is similar to other unpublished result in a natural forest on a volcanic soil, where 80% of the total variance of available NO_3^- was accounted for at 5m interval. Under the light of these results, it seems that the biological process of mineralization and/or its physico-chemical conditions might be defining the fine spatial dependence of the N supply at the field scale. Although other authors have previously discussed the influence of the scale of variation, there are not many studies reporting this information, which can lead not only to a more effcient spatial analysis concerning N management, but can also provide a guide to design the plot size under specific conditions in experimental studies of N transformation.

Conclusions

The N supply measured as potentially available N showed to be different according the interval distance of sampling, and although this variability has been described before, it is not usually reported for cereal crops growing on volcanic soils.
Under the conditions of this study, the shortest interval distances showed to have a larger influence in the total variance than the stages 13.5m, 40.5m explored, making it relevant to consider 4.5m as an optimum sampling interval to analyze the spatial structure of N variability.

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References

[1] Lark, R.M., 2011.Spatially nested sampling schemes for spatial variance components: scope for their optimization. Computers and Geosciences, 37: 1633-1641.

[2] Webster R., Lark, M., 2013. Field sampling for environmental science and management. Routledge Eds.. Milton Park, Abingdon, Oxon. United Kingdom.

QUANTIFICATION OF LABILE NITROGEN IN SOIL UNDER DIFFERENT FERTILIZATION REGIMES

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Objectives

More than half a century ago Jansson [1] developed a theory of the internal cycle of nitrogen in soil and defined active and passive N phases (pools). This approach is still popular and two-pool models of soil organic matter are widely used. However, there is always one big problem - how to quantify labile soil organic matter and in particular labile N. Stevenson [2] considered it to be formed from many substances of different origin and composition, but similar biokinetic properties. Jansson [1] concluded that only 10-15 % of total nitrogen (TN) content can be defined as active or labile. Kudeyarov [3] found this pool to be much bigger - 26-65 % of TN. Commonly these values vary in wide ranges (10-70%) [4]. The purpose of our research was to “shrink” this range and to develop a new method to evaluate the content of really labile N in arable soil.

Method

The experiments were carried out on the long-term agricultural research sites in Obroshyno (Ukraine). They were established in 1965 and then in 1975 conversed into intensively managed hayfields with 5 cuttings per vegetation period (imitation of grazing). Soils of the research sites were *Gleyic Phaeozems*. Basic soil agrochemical properties of the topsoil (0-20 cm) were studied before conversion in 1974. TOC content was 20.7 mg g^{-1}, TN - 3.31 mg g^{-1}, available P (0.2 M HCl) - 37.2 mg kg^{-1}, labile K (1 M CH_3COONH_4) - 45.1 mg kg^{-1}, pH_{KCl} - 5.42, cation-exchange capacity - 35.2 $cmol^+/kg$, exchangeable acidity (in CH_3COONa) - 6.7 $cmol^+/kg$. Content of clay was 12.0 %, silt - 71.5 % and sand - 16.5 %.

We studied soil under four fertilization regimes (in 3 replicates): control (no fertilization); $P_{90}K_{120}$; $P_{90}K_{120}N_{240\,(60+60+60+60)}$ and $P_{90}K_{120}N_{240\,(0+30+90+120)}$. Granulated superphosphate, potash and ammonium nitrate were used in this study. Soil samples were taken from 0-20 cm depth in 3 replicates 4 times during vegetation period: 04.01, 05.13, 06.30 and 09.17.

For the evaluation of labile N pool the method of Cornfield [5] in modification of Shcherbakov and Kislykh [6] was used. We further developed this method of multistep alkali hydrolysis. After preliminary studies on the effect of different alkali concentrations (0.25 - 17 M) and exposure times (6 - 192 hours) it was found that the most informative fractions can be extracted in the range: 0.25 - 8 M NaOH and 6 - 144 hours [4]. For this purpose 11 different concentrations of NaOH (0.25, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0 M) and 12 different exposure times (6, 12, 18, 24, 30, 36, 42, 48, 54, 90, 120 i 144 hours) were used. This fractionating scheme provides 132 fractions of labile nitrogen. For visual interpretation of the results we used a 3D (XYZ) model (N content; alkali concentration, exposure time). Content of labile nitrogen in the obtained extracts was determined by Cornfield method [5]. Total nitrogen was determined in soil samples by Kjeldahl method.

Results

We found that a traditional method of Cornfield [5] (1 M NaOH, 40-42 hours), which is widely used as an indicator of labile nitrogen content in soil, was not informative enough. Content of this fraction changed insignificantly during the period of vegetation and did not respond to nitrogen fertilizer application. It was found that alkali hydrolyses with 8 M NaOH during 144 hours was the most informative. Content of this fraction changed dramatically during vegetation period and was a reliable indicator of N-mineralization and N-immobilization processes in soil. In this study we define content of this fraction as hardly hydrolyzable labile nitrogen (HHLN).

Control (no fertilization). Long exposure time (144 hours) caused a significant increase of labile N content in comparison to traditional (42 hours) method, especially when high concentrations of NaOH (4-8 M) were used. It was found that in spring content of HHLN was 920 mg kg^{-1} (18% of TN). During the vegetation period content of HHLN decreased and reached 402 mg kg^{-1} (14% of TN). Multistep hydrolysis gives one more important opportunity. With this method it is possible to evaluate the homogeneity of labile N pool. In control, this pool was formed by three main fractions with ratio 230:200:490 mg kg^{-1} in spring and 270:70:60 mg kg^{-1} in autumn. Hence, homogeneity of labile N pool in soil increased during the vegetation process. Content of the most hardly hydrolyzable fraction was the most informative one and decreased in 8.2 times.

$P_{90}K_{120}$. Application of P and K fertilizers slightly changed the content of HHLN in soil. As in control, its highest content was observed in spring (04.01) - 850 mg kg^{-1}. During the vegetation period content of this fraction gradually decreased down to 440-460 mg kg^{-1} in summer (06.30) and autumn (09.17).

$P_{90}K_{120}N_{240(60+60+60+60)}$. Application of N fertilizers in spring (04.01) caused a significant accumulation of labile N in soil. 40 days after fertilization content of HHLN increased by 150 mg kg^{-1}. In summer (06.30) the lowest content of HHLN (445 mg kg^{-1}) was observed. This fact was caused by mineralization of soil organic matter and was followed by intensive nitrification and ammonification. Application of N fertilizers significantly changed lability and probably availability of nitrogen in soil during vegetation period (04.01, 05.13, 06.30 and 09.17). Percentage of HHLN (% of TN) was 18.0:19.5:15.4:14.0 in control and 17.3:22.7:14.1:29.2 when $P_{90}K_{120}N_{240(60+60+60+60)}$ applied.

$P_{90}K_{120}N_{240\ (0+30+90+120)}$. Gradual increase of N doses during vegetation period caused a significant decrease of HHLN content in soil - at least by 50-60 mg kg^{-1} in comparison to the previous fertilization regime. These results further support the idea of Kudeyarov [3], who assumed that application of nitrogen fertilizers may increase total but significantly decrease labile N contents.

Conclusions

This study has shown that multistep alkali hydrolyses is a reliable and informative method for SOM evaluation and quantification of labile nitrogen in soil. In our 4-year field experiments we found that content of hardly hydrolyzable labile nitrogen (HHLN) was between 18 and 32 % of total nitrogen.

This method is suitable not only for quantification of different N fractions in soil, but also shows the heterogeneity of labile N pool. Such approach is suitable for the differential evaluation of mineralization and immobilization processes in soil, especially when N fertilizers applied.

It was found that alkali hydrolyses with 8 M NaOH during 144 hours was the most sensitive in comparison to other concentrations and exposure times. The described method is an informative and cheap alternative to expensive stable isotope techniques in quantifying labile nitrogen in soil and priming effect evaluation.

References

[1] Jansson, S.L. 1958. Tracer studies on nitrogen transformations in soil with special attention to mineralization-immobilization relationships. Lantbrukhogsk. Ann. 24, 101-361.
[2] Stevenson, F. J., Cole M. A. Cycles of Soils: Carbon, Nitrogen, Phosphorus, Sulfur, Micronutrients, 2nd ed. 448 p.
[3] Kudeyarov, V.N. 1989. Nitrogen cycle in soil and effectiveness of fertilizers. Moscow. 216 p.
[4] Hamkalo Z. 2009. Soil ecological quality, Lviv, 412 p.
[5] Cornfield, A.H. 1960. Ammonia released on treating soils with N sodium hydroxide as a possible means of predicting the nitrogen-supplying power of soils. Nature 187, 260-261.
[5] Shcherbakov, A.P., Kislykh Y.Y. 1990. Effective Soil Fertility: Methodological Aspects, Moscow, 70 p.

NITROGEN FERTILIZATION REDUCTION OF CORN IN A NITRATE VULNERABLE ZONE

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Objectives

The aim of this work is to study the response of different corn hybrids to nitrogen fertilization reduction in a nitrate vulnerable zone in central Spain. Yield, yield components and radiation use efficiency were analyzed and crop gross margin was evaluated.

Method

In 2013, a trial was carried out in Jadraque that is included in the "Alcarria-Guadalajara" Nitrate Vulnerable zone in Castilla-La Mancha region in Spain. This is a semiarid zone, where maize is commonly cultivated with irrigation during summer months. Two nitrogen fertilization rates were studied: farmers rate (FR: 372 kg N/ha) and the maximum rate established in the Action Programme of that Vulnerable zone (APMR: 211 kg N/ha). Three corn hybrids (one FAO 500 cycle and two FAO 600 cycle) were sown in each N level on 5th of May, with a final plant density of 96,000 plants/ha. Four replications were done, so 24 elemental plots were defined of 162 m^2 per plot (12 rows x 18 m). The experimental area was surrounded by a commercial corn crop, so border effects were avoided. 165 kg N/ha were applied before sowing in all the plots and other 207 kg N/ha were applied on 15th June in top dressing FR fertilization, but only 46 kg N/ha in APMR level. Crop was irrigated from June to September with 570 mm of water. The other crop practices were the usual done in that farming area. Harvest was done on 5th December with a commercial harvester. Grain of each elemental plot was weighted in a portable bascule and grain moisture content was measured with an automatic device. Prior to harvest, the number of plants and number of cobs were measured in two crop rows of each plot. Later, the number of rows per cob and number of grains per row were counted in six cobs of each plot at the laboratory. The weight of 100 grains was also measured. So, crop yield and yield components were estimated. During crop growth cycle, leaf chlorophyll content was measured with an SPAD device and Photosynthetically Active Radiation (PAR) was measured with a quantum sensor. Intercepted PAR was assessed as incident solar PAR in the top of the crop canopy minus incident PAR at the ground level below crop canopy. Crop economic gross margin was calculated with crop yield and corn price and nitrogen and seed prices and rates.

Results

Leaf chlorophyll content was affected by N fertilization, but this effect was strongest in one hybrid, where decline in SPAD values began in July. These SPAD values were correlated with final corn yield, but the parabolic relationship between those variables indicates that there is a threshold level of chlorophyll (42-43 SPAD values in mid-June and 49-53 in mid-July) beyond that yield does not increase.
Nitrogen fertilization reduction did not affect PAR radiation interception except in one hybrid, but it had a clear effect on radiation use efficiency (mass of grain per MJ of intercepted PAR) in the three hybrids, and this variable was highly correlated with corn yield. So, nitrogen reduction in this trial should affect some physiological plant processes other than leaf growth and radiation interception.

Nitrogen reduction also affected the weight of grain per cob, which was the component that showed the best correlation with final corn yield. The second component was the number of cobs per ha.

Nitrogen fertilization reduction significantly decreased corn yield in two hybrids but not in the third, so interaction arose between the two studied factors (N rate and corn hybrid). Choosing the latter hybrid in the Vulnerable zone may thus prevent yield reductions due to reduced N fertilizer application. With this hybrid the maximum economic gross margin was also achieved.

Conclusions

Nitrogen fertilization reduction in corn cultivated in a Nitrate Vulnerable zone reduced leaf chlorophyll content and radiation use efficiency of the crop. The effect of N rate on yield depended on the sown hybrid, so, choosing the adequate one, yield should not be reduced using less N fertilizer; neither gross economic margin should be reduced, compared with other highly fertilized hybrids commonly sown in that zone. However, the high yielding hybrid showed the highest yield and profit using an N rate higher than the maximum rate established in the Action Programme of the Nitrate Vulnerable zone.

OPTIMIZATION TESTING AND SPLITTING OF THE CONTRIBUTION PERIOD OF NITROGEN FOR GROWING DURUM WHEAT IN IRRIGATED SEMI-ARID ZONE

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Objectives

When one is interested in growing techniques, we should mention the key element for developing wheat yields, such as nitrogen fertilization who requires strict management, based on the strategy to adapt the inputs crop requirements during its various stages of development (Fair, 1993).

In this context, we seek to compare several nitrogen fractionation procedures. The Selected fertilization methods allow to know the response of a variety of durum wheat (Chen's), widespread in our region (Ain Temouchent, Northwest Algeria) to the action of unfractionated nitrogen fertilization, on one hand, and the effect of requirements divided into two and three equal or unequal fractions, other hand. The effectiveness of different modalities is aprecied at the level of yields support, that is the biomass and yield components, without neglecting a very important element that is the nitrogen content of the biomass formed, and therefore the protein content of the grain produced.

Method

The parameters measured during this study are :

1/ Air dry biomass : The production of dry matter produced by a plot of 0.6 m² at heading stage is evaluated after passage of the sample in an oven set at 80 ° C for 48 hours (ICARDA 1996).

2/ The nitrogen content : the Nitrogen levels in aboveground biomass and grain are measured by the Kjeldahl method.

3/ The grain protein content : The protein content of the harvested grain is calculated by the formula: Protein (%) = N content of grain x5,7 (JEUFFROY 2001).

4/ Other parameters are taken into account in particular :
- Number of ears / m² per plant;
- Number of grains / m² per spike;
- 1000 kernel weight;
- Grain yield and straw / m².

Results

The study broadly confirms the equivalent nitrogen needs of the crop improves grain yield components, including the ear fertility. To be most effective, nitrogen fertilization should be divided into several fractions. Moreover, a good combination between fractions and fertilizer contributed stages adds value more nitrogen fertilizer.

Under our experimental conditions, the best results were obtained with the modality in 3 fractions in general and its G2 and G3 variants in particular. The advantage of this method lies in the fact that its application covers 3 vegetative stages criticism of wheat with a view to the nitrogen.

The number of grains is the second component that reflects the nitrogen nutrition (Jeuffroy and Bouchard, 1999). In this study, this component responds positively to nitrogen fertilization. The plot driving with a nitrogen supply produces a grain significantly heavier. By cons, splitting fertilization overall still no significant effect on this component.

Moreover, as for the production parameters, the grain protein content and nitrogen content of its support heavily dependent on user input of nitrogen fertilizer needs. It improves if more nitrogen fertilizer is distributed between the different stages. The fractionation related increase is on average 55.75% for the nitrogen content of the biomass heading and 13.68% for the rate of grain protein.

Better yet, the division in 3 contributions from all variants is more rewarding than 2 fractions. Its grain and its biomass heading contain respectively 40.30 and 86.14 % more than the control, and 47.65% against 6.31 for option 2 contributions; In other words, the effectiveness of the fumure fractions is 6.4 to 3 times that of the mode 2 inputs to the grain protein, and 1.8 times for the nitrogen content of the heading biomass.

Conclusions

The study focuses on the optimization of the fractionation and the contribution period of the nitrogen requirements of the winter cereals. The test was conducted on a local variety (Chen's) driving in the field of semi-arid zone. A total of 22 combinations of intake of 115 units of ammonium nitrate 33.5% / ha was tested. The airline biomass, straw, grain yield and its components, as well as the nitrogen content in certain organs proteins were determined.

The results obtained showed that the nitrogen fertilization encourages all the parameters considered, but its effectiveness varies greatly with the input modality. The number of fractions, the proportion of the contributions and the stage of fertilized culture are very influential.

The results confirm that nitrogen fertilizer applied in a single intake is less efficient than fractionated. the Splitting improves straw yield of 20.6%, 24% in grain and grain protein content of 11%.

The most effective of the 19 fractionated modalities studied is that fractioned in 3 inputs, divided between early tillering, ear in 1cm 2 knots. The best results were obtained with the contributions of 25% of needs in early tillering, 50% to the ear 1cm and 25% in stage 2 knots. This allocation improves the yield of 86.7% of grains by 112.1% straw and rich in grain protein by 59% (+ 6%).

NITROGEN BALANCES AND FLOWS IN CENTRAL SPAIN DAIRY FARMS

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Objectives

The aim of this work is to study the nitrogen use efficiency and eco-efficiency in dairy farms of Castilla y Leon region in Spain, considering different farm size, livestock density, milk production, feeding type, agricultural land and fodder production. This region has important differences with typical dairy zones in the North and the Northwest of Spain, because farms in Castilla have more agricultural land for cultivating fodder (silage of rye or corn; hay of wheat or vetch with oats) and feeding crops (barley and wheat). Nitrogen flows and balances were estimated at different levels: cow, dairy and farm.

Method

Six dairy farms from Ambles Valley (Avila, Spain) were studied. In 2013, data about livestock (milking cows, dry cows and calves), feeding, milk production (quantity and composition) and agricultural land (fodder, cereal, pastures, etc.) were recorded in each farm.

The amount and types of feeds and fodders used in livestock feeding were also consigned and a sample of each raw material was taken. Oven dry matter and nitrogen (Kjeldahl method) content of each feeding product were analyzed in the laboratory. Milk production and protein content were also consigned. N excreted by each animal was estimated as the difference between N intake and N in milk (only in milking cows) minus N retention in body mass. N dietary intake was estimated for each group of animals with the data of feeding intake, dry matter content and protein content. N in milk was estimated with the data of milk production and protein content of the milk. N retention in body mass was taken from literature: 15% of N intake in cows and 11% in calves. Nitrogen use efficiency of milking cows was calculated as the ratio of N in milk and N intake. Nitrogen use efficiency of dairies was calculated as the ratio of N in milk and N intake of all types of animals.

A nitrogen balance was carried out at farm scale considering farm gate inputs and outputs. N inputs were: fertilizers (quantity and N content were consigned), fodder and feeds (quantity and N content were consigned). N outputs were: milk (quantity and N content were consigned), cereals not used in the farm (quantity sold and N content were consigned) and live animals (old cows, male calves and part of female calves: number and average weight of animals were consigned and 2.2% N was considered from literature).

Some indicators were computed as follows: Nitrogen surplus as the difference of N inputs and outputs, N efficiency as the ratio of N outputs and inputs; eco-efficiency as the ratio of N surplus and N outputs.

Results

Studied farms had between 20 and 100 milking cows, with a milk quota of 150-1,200 L, 20-34 kg FCM per cow and day (fat corrected milk) and 40-200 ha of agricultural land. The livestock density was between 0.3 and 1.6 LU/ha, less than the maximum required of 2.5 LU/ha.

N excretion of milking cows was between 90 and 143 kg N/cow year, according to literature values. Thus, animals excreted between 48-65% of N dietary intake, so nitrogen use efficiency was between 20-37%. Four farms showed an average N efficiency of milking cows (25-30%), one showed an excellent one (37%) and the last should improved its efficiency (20%). The N efficiency of the dairy (considering all N intakes of all types of cows) decreased to 20-25%, although in the worst farm this value was only 17%, but the best recovered 31% of N intake in the milk. In this farm, 16 kg N were used to produce 1 ton of FCM, but more than 20 kg N were needed in the other less efficient farms. Dairy cows accounted for 86% of N dietary intake in the farm, but only for 80% of N excretion.

N excretion per ha in all studied farms was lower than 170 kg N/ha, the limit of Nitrates Directive, because none of them had a high livestock density and the amount of agricultural land was appreciable.

The most important nitrogen flows in the farms were those related to feeding and excretion. In four farms all N flows were lower than 100 kg N/ha, but in the two other there were nitrogen flows higher than 100 kg N/ha.

Nitrogen inputs in the farms depended on N in purchased concentrates, but total N inputs per ha were lower in this zone than in farms from the North of Spain. The proportion of purchased N to total N in feeds increased with livestock density in the studied farms. N in milk was the main nitrogen output. Farm N surplus varied between 42 and 187 kg N/ha, and it was lower than data showed in the literature about farms in the North of Spain. This farm surplus was correlated with N excretion per ha, so when livestock density increased, the nitrogen surplus to the environment was higher.

N use efficiency in dairy farms varied between 22 and 36%, and the most efficient ones were also the most eco-efficient, because they lost less nitrogen to the environment. Thus, the two most efficient farms lost less than 2 kg N per kg N that went out the farm gate in form of milk, crop products or animals, but the less efficient farms lost more than 3 kg N to the environment.

Conclusions

The purchased N in concentrates was higher in farms with more livestock density, and internal production of fodders and cereals was lower. Nitrogen excretion and surplus to the environment were also higher in farms with more animals per ha, so they were less efficient and eco-efficient. Thus, more N was lost to the environment per unit of N produced in the farm. However, the studied farms showed lower N surplus and better environmental performance than other located in the North and Northwest of Spain, because they had more surface of agricultural land.

NITROUS OXIDE EMISSIONS FROM A SUGARCANE CROP UNDER DIFFERENT NITROGEN FERTILIZER RATES

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Objectives

Nitrogen (N) fertilization generally increases nitrous oxide (N_2O) emissions in soil [1].The application of N fertilizer greater than the demand of the plants has shown greater proportion of N_2O emissions per unit of fertilizer applied [1]. Therefore, the knowledge of N_2O emissions on a local level is necessary to identify N rates and management practices that reduces N_2O emissions. In this perspective, our objective was to estimate N_2O emissions, under different N rates applied to the sugarcane crop in southern Brazil.

Method

The experiment was conducted from September 2010 to July 2012 on a Typic Hapludalf (60% sand, 30% silt, 10% clay, total C 7.5 g kg^{-1}) at the Department of Soils, Federal University of Santa Maria (29°41'S, 53°48'W), Brazil.
The planting of sugarcane (RB956911 genotype) was done on 20 September 2010 in furrows, approximately 0.3 m deep, 1.4 m row spacing with a plant density of 18 gems per meter. The treatments were four rates of urea-N: 0 (N0), 40 (N40), 80 (N80) and 120 kg N ha^{-1} (N120). The experiment was organized in randomized complete block design (RCBD) with four replications. The treatments were evaluated in plant cane (2010/11) and first-ratoon cane (2011/12) cycles. In the plant cane cycle, N rates were splitted in three doses, i.e, 20 kg N ha^{-1} at planting, and sidedressing at 65 and 92 days after planting (50% of the remaining N at each time). In the first-ratoon cane cycle, N rates were splitted into two equal doses, sidedressing at 34 and 99 days after cane plant harvest. In sidedressing, N was applied on the soil surface near the planting row. Sugarcane was harvested without fire in July 2011 and June 2012 in plant cane and first-ratoon cane cycles, respectively. The average amount of straw on soil surface after plant cane harvesting in all treatments (N0, N40, N80 and N120) was 15.8 Mg ha^{-1}.
Soil N_2O fluxes were measured periodically by the closed static chamber technique. The N_2O concentrations in the samples were analyzed by gas chromatography (Shimadzu GC-2014 Greenhouse). Daily N_2O fluxes (µg N m^{-2} h^{-1}) were calculated by linear interpolation and the cumulative fluxes (g N ha^{-1}) were calculated by the integration of the daily N_2O emissions. Gravimetric soil moisture (105°C for 24 h), soil inorganic N ($NH_4$and NO_3) and water-filled pore space (WFPS) were determined in the 0-10 cm soil layer at each sampling date.

Results

The mean flux of N_2O in N0 treatment was 17.8 µg m^{-2} h^{-1} in the plant cane and 13.2 µg m^{-2} h^{-1} in first-ratoon cane. The N_2O flux increased after N application and in both crop cycles the effect of first N application on N_2O emission was greater than second application. In the plant cane cycle during first 30 days after N application, the observed average N_2O fluxes in N80 and N120 treatments were 80 and 116 µg of N_2O-N m^{-2} h^{-1}, respectively. After second N application, the values were low and reduced to 36 and 52 µg of N_2O-N m^{-2} h^{-1}. A similar trend was observed in first-ratoon cane cycle. During these periods, highest N_2O fluxes were related to the occurrence of rainfall that raised WFPS in soil. After 30 days of N application, the N_2O fluxes reduced in all treatments, without any emission peaks even after rainfall events. This was possibly due to the reduced mineral N availability in the soil during this period.
N application in both sugarcane crop cycles increased the amount of N_2O emission until the crop harvest. In the plant cane cycle, only N80 and N120 treatments emitted more N_2O than N0 treatment while in first-ra-

toon cane, all the three treatments emitted more N_2O compared to the control treatment (N0). The amount of N emitted as N_2O in the first cycle ranged from 0.67 kg ha^{-1} in N0 to 1.78 kg ha^{-1} in the N120 whereas in the second cycle it ranged from 1.09 kg ha^{-1} in N0 to 2.67 kg ha^{-1}in N120. During the two years of sugarcane crop, the N_2O emission factor (proportion of N applied at each dose lost as N_2O) was significantly lower in the N40 treatment (mean 0.71% N applied) and did not differ between N80 (mean 1.21%) and N120 (mean 1.22%) treatments. The productivity of stalks in cane plant and first-ratoon cane also increased with increasing N rates. Nevertheless, on an average of the two cycles, the increase in sugarcane yield decreased with increasing N application above 40 kg N ha^{-1} (22.0, 9.0 and 2.6 Mg ha^{-1}, respectively, to N40, N80 and N120). When considering the ratio of N_2O-N per unit stalk produced (yield-scaled emissions), the observed values were close to this relationship between the N0 and N40 (9.0 e 9.2 g Mg^{-1}, respectively). However in N80 (13.5 g Mg^{-1}) and N120 (17.0 g Mg^{-1}) treatments N_2O emissions per unit stalk produced increased significantly (nonlinear response).

Conclusions

N_2O emissions increased linearly with applied N rates in sugarcane crop. On an average of plant cane and first-ratoon cane cycles, 0.56 kg N_2O-N ha^{-1} was emitted per 40 kg N ha^{-1} applied. The N_2O emission factor (calculated by using IPCC methodology for the conditions of this study) was below the standard value of 1% for N rates lower than 40 kg N ha^{-1}. Emissions factors based on the relationship between N_2O emission and sugarcane yield indicated that increased stalk yields obtained with rate up to 40 kg N ha^{-1} resulted in higher amount of N_2O-N emitted per Mg of stalk/sugarcane produced.

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References

[1] McSwiney, C.P., Robertson, G.P. 2005. Global Change Biology 11, 1712-1719.
[2] Zebarth, B. J., Rochette, P., Burton, D. L. 2008. Can. J. Soil Sci. 88, 197-205.

APPARENT LONG-TERM FERTILIZER REPLACEMENT VALUE OF ORGANIC AMENDMENTS DEPENDS ON MINERAL FERTILIZER N RANGE ITSELF

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Objectives

Efficient use of nitrogen (N) requires careful matching of N supply to crop demand. Where mineral fertilizers are combined with organic amendments - such as farmyard manure (FYM), slurries, and crop residues - the N supplied by organic amendments must be estimated to assess the remaining mineral N fertilizer requirement. For this purpose, organic amendments are characterized by their 'apparent N fertilizer replacement value' (*NFRV*), which can be based on either equal yield or equal N uptake [1]. We used *NFRV* at equal yield, thus following the original definition by Herron and Erhart [2]. Factors known to affect *NFRV* (at given dose of the amendment) include the content and form of N in the amendment, and the method and time of application which may govern losses. Here we inspect the effect on *NFRV* of an additional factor: the N fertilizer rate itself at which *NFRV* is evaluated.

Method

We screened two databases on long term experiments (LTEs): EuroSOMNET (www.ufz.de/somnet/) and CATCH-C (www.catch-c.eu), and collected data from trials where crop yield response to mineral N fertilizer rates (F) was determined both in absence (Y^0) and in presence (Y^A) of annual organic amendments A of constant dose across all F levels. This allows for comparison between two response curves $Y^0(F)$ and $Y^A(F)$ that constitute a pair. Data per trial included at least four rates F each with and without amendment, and covered at least five years of yield data. Phosphorus and potassium were applied in all treatments. Where possible, yield data from the last 10 years of each crop per experiment were averaged. Alternatively, average yields over the last five years were used. Data from 20 LTEs resulted in 78 pairs of curves (one LTE often providing data on several crops or amendments). The LTEs were situated in Austria, Czech Republic, Germany, Estonia, Italy, Poland, Romania, Serbia, and Spain. To the yield data $Y^0(F)$ and $Y^A(F)$ we fitted response curves of the form

$$Y = \mathrm{a} + \mathrm{b}*0.99^{F} + \mathrm{c}*F \qquad (1)$$

where Y is crop yield (t/ha), F is the mineral N fertilizer rate (kg N/ha) [3]. *NFRV* at low mineral N fertilizer rate ($NFRV^{\mathrm{Lo}}$) was defined as the amount of mineral N fertilizer (F) needed in absence of amendment A to match the yield obtained with amendment A but without mineral fertilizer (F_0):

$$Y^0(F) = Y^A(F_0) \qquad (2)$$

$$NFRV^{\mathrm{Lo}} = F \qquad (3)$$

NFRV at high mineral N fertilizer rate ($NFRV^{\mathrm{Hi}}$) was defined as the amount of mineral N fertilizer that can be saved in the presence of amendment A, while still matching the maximum yield found with mineral fertilizer alone:

$$Y^A(F) = Y^0(F_{\mathrm{max}}) = \qquad (4)$$

$$NFRV^{\mathrm{Hi}} = F_{\mathrm{max}} - F \qquad (5)$$

where F_{max} is the mineral N fertilizer rate where the smoothed $Y^0(F)$ curve reaches its highest value $Y^0(F_{\mathrm{max}})$ within the range of rates F applied. (We used this definition rather than the economic optimum to avoid the use of price ratios which vary across years and countries.)

Results

The 78 suitable data sets (curve pairs, see above) found refer to wheat (n=24), barley (18), rye (2), sugar beet (13), maize (13), potatoes (8). The organic amendment varied between trials, and included FYM (n=37), slurry (7), straw (18), and straw mixed with other N sources (green manures, beet leaves, slurry; n=16). Based on the full data set, $NFRV^{\mathrm{Hi}}$ (mean 43.3 kg N/ha) was significantly higher than $NFRV^{\mathrm{Lo}}$ (30.4 kg N/ha) (p=0.035 based on paired test), the two differing by a factor 1.43. The full set included 33 curve pairs where the maximum yield with organic amendment was lower than that without ($Y^0(F_{\mathrm{max}})$). Excluding these, we repeated the analysis for the remaining ‘narrow set’ (n=45) and found a stronger contrast between the two *NFRV* values. Again, $NFRV^{\mathrm{Hi}}$ and $NFRV^{\mathrm{Lo}}$ differed significantly (p<0.001), now with means of 86.3 kg N/ha and 44.4 kg N/ha, respectively, differing by a factor 1.94. At the level of individual crops, using the full data set, the difference was significant only in potatoes (p=0.003) and almost in maize (p=0.081), with $NFRV^{\mathrm{Hi}}$ larger by a factor of 2.29 and 1.55, respectively, than $NFRV^{\mathrm{Lo}}$. For the individual amendments (using all data), the difference was significant only for FYM (with n=37 the dominant amendment in the set; p=0.025), where the ratio between $NFRV^{\mathrm{Hi}}$ and $NFRV^{\mathrm{Lo}}$ was 1.61. Based on the ‘narrow set’, $NFRV^{\mathrm{Hi}}$ was significantly higher than $NFRV^{\mathrm{Lo}}$ (p<0.002) in all crops with n>1, their ratio ranging from 1.77 (maize, n=11) to 2.24 (sugar beet, n=7). Similarly, all amendments with n>1 showed significantly larger $NFRV^{\mathrm{Hi}}$ than $NFRV^{\mathrm{Lo}}$ (p<0.04) in the ‘narrow set’, with ratios of 1.98 (FYM, n=23), 1.73 (slurry, n=6) and 2.24 (straw, n=6).

We did not investigate causes of the above differences in *NFRV*. For a start, two types of impact by an organic amendment on a reference response curve (to mineral N fertilizer) could be distinguished. The first (a) is an upward shift of the entire curve (same yield increment over the entire N range; no change of curve shape). Alternatively (b) the curve is shifted ‘laterally’ without changing shape, such that the same yield is achieved at lower F. In case (a), the typical shape of response curves (levelling off with increasing F) dictates that $NFRV^{\mathrm{Hi}}$ is larger than $NFRV^{\mathrm{Lo}}$. In case (b), *NFRV* is by definition independent of the N range, for any curve shape. Our findings suggest that most of our data resemble more case (a) than (b), implying that the amendment brings some other benefit than just N. This may relate to other nutrients, soil quality properties, or patterns of N release. Our *NFRV* must therefore be referred to as an ‘apparent’ replacement value.

Conclusions

This meta-analysis over 20 LTEs on different crops and organic amendments showed that the apparent N fertilizer replacement value (*NFRV*) of organic amendments was roughly up to two times larger at high than at low rate of mineral N fertilizer. While *NFRV* is commonly assessed using data at the ‘lower end’ of the N response curve (to reduce random error impact), farmers normally operate at high N availability and using $NFRV^{\mathrm{Lo}}$ here may introduce systematic error. If our findings can be further generalized, the observed contrast between *NFRV* in the respective N ranges may have practical implications that extend to fertilizer recommendations, and possibly to fertilizer equivalency coefficients used by some EU member states in their Action Programmes under the Nitrates Directive (e.g., Denmark, The Netherlands) to regulate the use of manures.

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References

[1] Schröder, J.J. 2005. Manure as a suitable component of precise nitrogen nutrition. Proceedings 574, 32

pp. International Fertiliser Society, Colchester, UK.

[2] Herron, G.M., Erhart, A.B. 1965. Value of manure on an irrigated calcareous soil1. Soil Science Society of America Journal, 29: 278-281.

[3] George, B.J. 1984. Design and interpretation of nitrogen response experiments. In: *The nitrogen requirement of cereals*, MAFF Reference Book 385, pp. 133-150.

ESTIMATION OF THE QUANTITY OF N2 FIXED BY CLOVER GROWN IN THE MIXTURE WITH GRASS IN LONG TERM FIELD EXPERIMENT

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Objectives

In sustainable agriculture, one of the most important characteristics of legumes is their symbiosis with Rhizobium to fix nitrogen for growth. For proper management and a full realization of the benefits of legumes, it is necessary to estimate the quantity of nitrogen fixed under different field conditions. A suitable method for accurately measuring the amount of N crops derived from the atmosphere is therefore, an actual and important requirement. The most appropriate and widely accepted method is so called 15N isotope dilution, but it is usually limited to pot experiments. In the paper, the quantity of nitrogen fixed by clover in long-term field experiment was calculated. The amount of N2 reduced was calculated as the difference between tested (clover grown in the mixture with grass) and reference crops (maize), grown under the same field and weather conditions and disposed to a parallel pool of nitrogen from manure applied for forecrop.

Method

The long-term field experiment was carried on in 1979 at Experimental Station Grabów of the Institute of Soil Science and Plant Cultivation in Puławy, in the split-block layout, in two crop rotations - including legume and non-legume crop (first factor), and in four replications. After clover-grass mixture (rotation 1) and maize (rotation 2), the following crops were grown in succeeding years: potato, winter wheat and spring barley. In the both crop rotation, five rates of manure (M) were applied under potato (second factor), which corresponds to: M0, M1-188, M2-376, M3-564 and M4-752 kg N/ha. Each crop was supplied with four rates of mineral fertilizers (third factor). The following rates of ammonium nitrate (N): N0, N1- 45, N2 - 90, N3 - 135 kg N/ha were applicated under clover with grass, and N0, N1-40, N2-80, N3-120 kg N/ha under maize.

The amount of nitrogen fixed by clover was calculated as the difference between total N uptake by clover-grass and the reference crop - maize. The paper presents the results of five rotations: III (years 1988-1991), IV (years 1992-1995), V (years 1996-1999), VI (2000-2003) and VII (2004-2007). Statistical processing of the results was performed using the Statgraphic 5 Plus package (Statgraphics Plus, Rockville, USA). The Tukey's test has been applied to evaluate the significance of differences between the treatments.

The expression levels nitrogenase (*nifH*), ammonia monooxygenase (*amoA*), nitrite reductase (*nirK* and *nirS*), and nitrous oxide reductase (nosZ) were determined by real-time quantitative PCR, using specific primers and microbial reporter genes (from *Nitrosomonas europaea, Azospirillum irakense, Azospirillum brasiliense, Pseudomonas stutzeri* and *Pseudomonas fluorescens*). Total soil RNA extraction was carried out by RNA PowerSoilTM Total RNA Isolation Kit Sample (Mobio) followed by a DNase treatment. Retrotra-cripts were purified by using the Wizard SV Gel and PCR Clean-Up System (Promega).

Results

On the basis of the assumption that the both - fixing and non – fixing crops take up N from soil in the same ratio, the difference corresponds to the quantity of nitrogen biologically fixed by clover. The total N uptake of maze increased with manure rates, and N uptake by clover did not respond to organic fertilization. The effect of mineral fertilization on total N uptake by the both crops was proven. In the treatment M0, maize took up from 80 to 147 kg N/ha, in M1 – from 93 to 171 kg N/ha, in M2 – from 101-158 kg N/ha, in M3 – from 101 to 157 kg N/ha, and in M4 – from 114 to 169 kg N/ha. Total N uptake by clover with grass was as follows: M0 234-292, M1 245-320, M2 238-328, M3 238-327, and M4 234-321 kg N/ha.

The average nitrogen uptake by the crops calculated for the total rate of N applied in form of manure and mineral fertilizers reached 131 kg N/ha for maize and 275 kg N/ha for clover. The difference in the uptake corresponds to the quantity of nitrogen fixed by clover. Thus, the contribution of di- nitrogen in the total quantity of N accumulated by green biomass of clover- grass mixture varies between 49% and 59% depending on N supply. The quantity differed statistically between the fifth rotations of the experiment. There was not found the effect of manure application, and mineral fertilization on N biologically fixed by clover. In the treatment without organic fertilization (M0), the estimated amount of N-fixed was as follows: at the rate N0 - 158 kg, at N1 – 148 kg, at N2 - 127, and at N3 – 144 kg per hectare. To compare, at the highest manure rate (M5) the quantities was: at N0 – 124 kg N/ha , N1 – 127, N2 – 143, N4 – 152 respectively. In the experiment, the mean value of the quantity of N fixed by clover accounted for 144 kg N per hectare, on the average. It is in accordance with results obtained by other authors on the base of the Hopkins – Peters coefficient of nitrogen fixation, which is widely used to access nitrogen fixation. This coefficient is related to biomass yield and is equal to 0,66 for clover grass mixture. In Polish conditions, the quantity of N fixed in investigations using the coefficient amounted to 120-130 kg N/ha.

The method proposed in the paper is based partly on N difference and 15N isotope method. In spite of strict isotopic dilution method, the experiment has been carried out in long term filed experiment. It can include both the weather and climatic conditions.

Conclusions

The quantity of N fixed biologically by clover was calculated using the difference between N uptake by legume- and non - legume crop (maize).

The quantity of N biologically fixed by clover calculated using the difference method accounted to 144 kg/ha.

The amount of N2 fixed by clover was not affected by both, manure and mineral fertilization.

NITRIFICATION INHIBITION BY PEAT ENRICHED WITH NANOPARTICLES OF SILICATE MINERALS

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Objectives

Usually nitrification inhibitors are chemical compounds which slow down nitrification rates of different N fertilizers. These chemicals are widely used in intensive agricultural systems to reduce losses of N - both for keeping plant-available nitrogen as long as possible in soil and to reduce N losses from the soil-plant system because migration of NO_3^- into hydrosphere and of N_2O and NO into atmosphere cause severe environmental problems on different scales - from eutrophication of local waterbodies up to greenhouse effect and ozone layer depletion [1]. However there are many limitations of the application of chemical nitrification inhibitors - for example in organic farming or wastewater management. Thus, developing new methods of nitrification inhibition is a matter of high importance. The objective of this study was to develop an effective and cheap method to reduce nitrification rates in soil without using traditional chemical nitrification inhibitors, but only with safe natural products.

Method

Application of nanoparticles of silicate minerals in the forms of suspensions or aerosols without peat did not cause any significant changes of soil properties or crop productivity, as well as application of peat itself. In this study a mixture of nanoparticles of silicate minerals (50%) with milled and 1-mm sieved peat (50%) was used as a potential nitrification inhibitor (1 mg g^{-1} in laboratory experiments and 100 kg ha^{-1} in field experiments). A mixture (1:1) of analcime and rotten stone (SiO_2 78-83%, Al_2O_3 5-7%, Fe_2O_3 2-3%, CaO 4-7%, MgO 2-3%), both mined from local deposits, was used in this study. Simultaneously we tested the impacts of a mixture of 90% ATC (4-amino-1,2,4-triazole hydrochloride) with 10% of hydrophilic silica nanoparticles (1 mg g^{-1}) on nitrification rates. After preliminary research, where different nitrification inhibitors were studied, effectiveness of ATC was found to be almost identical to nitrapyrin ($ClC_5H_3NCCl_3$). Because of this fact and while ATC is still one of the most popular nitrification inhibitors in post-soviet countries it was chosen for future research.

Laboratory microcosm experiments. Twelve microcosms in 3 replicates were used in this study: soil+wheat, sand+wheat, soil+corn and sand+corn (without any treatment; ATC+hydrophilic silica nanoparticles, dispersed peat+nanoparticles of silicate minerals). Each microcosm contained 200 g of substrate. Samples of calcinated sand and *Gleyic Phaeozems* were used. We chose wheat and corn because they have different types of photosynthesis and nitrogen requirements. Content of NO_3^- in substrate was studied after 15, 30 and 45 days of incubation. Urea was used as N fertilizer.

Field experiments. Soil of the experimental plots was *Gleyic Phaeozem* under continuous monoculture of winter wheat. Basic agrochemical properties of the topsoil (0 - 20 cm) were: TOC content 18.1 mg g^{-1}, TN 2.5 mg g^{-1}, available P (0.2 M HCl) 150 mg kg^{-1}, water-extractable K 40 mg kg^{-1}, pH_{H2O} 7.2. Content of clay was 9.5 %, silt - 65.0% and sand - 25.5%. Urea was used as N fertilizer, superphosphate and potash - as P and K fertilizers. The fertilization regime was $N_{120}P_{60}K_{60}$. 10 kg of each studied nitrification inhibitor was applied per experimental plot.

Results

Laboratory microcosm experiments. Under wheat in the control treatment, concentration of $N\text{-}NO_3^-$ after 15 days of incubation was 115.7 in sand and 146,9 mg kg^{-1} in soil. After 30 days of incubation these values were 193.6 and 235.8 mg kg^{-1}; after 45 days - 298.1 and 334.2 mg kg^{-1} respectively. Application of ATC+hydrophilic silica nanoparticles significantly slowed down nitrification rates. In sand, content of $N\text{-}NO_3^-$ after 15, 30 and 45 days of incubations were 97.5, 83.9 and 92.4 mg kg^{-1} and in soil - 101.7, 88.3 and 95.6 mg kg^{-1}

respectively. Application of dispersed peat + nanoparticles of silicate minerals also showed high nitrification inhibition potential. In sand, content of N-NO_3^- after 15, 30 and 45 days of incubations were 81.5, 74.3 and 75.1 mg kg^{-1} and in soil - 87.1, 75.1 and 78.5 mg kg^{-1} respectively. Under corn in control these values were 99.3, 168.4 and 255.8 mg kg^{-1} for sand and 125.7, 191.0, 287.1 mg kg^{-1} for soil. After ATC+hydrophilic silica nanoparticles application: 81.2, 73.7 and 77.6 mg kg^{-1} in sand and 87.9, 76.4, 82.3 mg kg^{-1} in soil. After dispersed peat+nanoparticles of silicate minerals application - 72.5, 65.1 and 61.7 mg kg^{-1} in sand and 74.8, 72.1, 65.7 mg kg^{-1} in soil.

Field experiments. Application of studied nitrification inhibitors caused a significant decrease of N-NO_3 content in soil. Both inhibitors showed comparable results and significantly inhibited nitrification for 6-8 weeks. However even after that period of time - till the end of vegetation period content of nitrates in soil was 15-18% lower, where dispersed peat+nanoparticles was applied. We did not find such an aftereffect after application of ATC+hydrophilic silica nanoparticles, probably because of biodegradation of ATC. Both nitrification inhibitors significantly increased wheat productivity - up to 800 kg ha^{-1} in comparison to control - 693 kg ha^{-1}.

In our previous studies we showed that peat enriched with nanoparticles of silicate minerals and rocks such as rotten stone, analcime, glauconite and silica was an effective soil amendment and significantly increased productivity of maize, rice, sugar beet, soybean and wheat [2]. We also found that application of this amendment slows down mineralization rate of soil organic matter and organic fertilizers.

Application of organic matter surrounded by silica nanoparticles led to synthesis of polysilicic acids $nSiO_2 \cdot mH_2O$ in soil [3]. These acids are poorly soluble in water and form colloidal suspensions, which significantly improve agrophysical soil properties and can be used for soil remediation [4]. We explain slowing down the rates of nitrification by a significant increase of polysilicic acids content in soil.

Conclusions

This study has shown that a mixture of nanoparticles of silicate minerals with dispersed peat is an effective nitrification inhibitor. Application of this mixture is followed by an important aftereffect - content of N-NO_3 in soil was lower not only during the first 6-8 weeks, but till the end of vegetation period. This fact needs to be tested under different climate conditions and might be a useful tool to reduce N_2O emission.

Efficiency of nanoparticles of silicate minerals in nitrification inhibition depends on content of particulate organic matter in soil. If content of POM is low - dispersed peat is to be added, if high - nanoparticles of silicate minerals may be used without any other components to slow down nitrification rate in soil.

References

[1] Zaimenko, N. 2008. Scientific principles of structural and functional design of artificial biogeocenosis in the system soil-plant-soil. Kyiv. 303 p. (in Ukrainian)

[2] Zaimenko, N., Didyk, N., Dzyuba, N., Zakrazov, O., Rositska, N., Viter, A. 2014. Enhancement of drought resistance in wheat and corn by nanoparticles of natural mineral analcite. Ecologia Balkanica, 6(1), 1-10 p.

[3] Zaimenko, N., Slyusarenko, O., Bedernichek, T. 2016. Peat enriched with nanoparticles of silicate minerals is an effective soil amendment. Proceedings of the 15th International Peat Congress 2016, Kuching, Sarawak, Malaysia

[4] Telysheva, G., Lebedeva, G., Dizhbite, T., Zaimenko, N., Ammosova, J. 2000. Use of Silicon-containing Lignin Products for in situ Soil Bioremediation. Environmental science and pollution control series. p. 699-728

NITROGEN BALANCES IN FIELD EXPERIMENTS, FARMS AND REGIONS

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Objectives

The calculation of nitrogen (N) balances has been identified as one of the priority agri-environmental indicators. N balances can be calculated for whole countries and their regions from the statistical information, but also for individual fields using farm management data. Field experiments can show the relationships between different N rates, yields and N balances in controlled and often more optimal conditions than in practice. In this study, we compared the level of Finnish N balances from regions, farmers' fields and field experiments. The objective is to quantify the differences of N balances from various sources.

Method

Regional N balances have been calculated in Finland since 1990 [1]. National and regional N balances are calculated annually and the results are reported for Eurostat and Finnish Ministry of Agriculture and Forestry (MAF). N balances from farmers' fields have been collected by various research projects, agricultural companies and Finnish advisory service, Pro Agria. The available field data have been collected in one database during an on-going project funded by MAF, and database includes over 200 000 lines to where N balance can be calculated. Data of nitrogen field experiments with cereals in Finland have been collected and their N balances are determined when sufficient data exist [2]. Part of the data from farmers' field is reported [3] together with some additional field experiment data.

The level and variation of N balances from farmers' fields are compared against N balances in field experiments. Regions are divided according to their number of farm animals and area of grassland, and the size of regional N balances compared to N balances from cereal and grassland fields.

Results

National N balance has decreased from 90 kg/ha to 50 kg/ha in Finland since 1985. In 1990, regional N balances were approximately 40 kg/ha higher in regions with intensive animal production compared to areas of producing mostly cereals. Nitrogen balances have decreased in all regions, and especially in areas of intensive dairy production. N rates have decreased 30-40 kg/ha and N output in yields has increased approximately 10 kg/ha between 1990 and 2014. N input in manure has been rather constant during the last 25 years.

In field data from 1990 to 2014, mineral N rates of spring cereals decreased only 10 kg/ha, mineral N rates of winter cereals 40 kg/ha and mineral N rates of grassland 30 kg/ha. Yield increases resulted also slightly higher N outputs and thus further decreased field N balances.

Field experiments and data from farmers' fields showed linear relationships between N rate and N balance of cereals and other crops. The slope between N rate and N balance in field experiments was 0.50-0.74 and 0.81-0.94 in farmers' fields. Linear regression estimated 27-51 kg/ha N uptake from field experiments without N fertilization, while in farmers' fields the estimated N uptake without N application ranged from 44 to 56 kg/ha.

Conclusions

N balances calculated either from statistical data or from data collected by farmers have decreased in Finland since 1990. Currently N balances are not decreasing and the expectations of increased production due to climate change and improved cultivars has risen discussion, that N rates should be increased, which can lead also to increased N balances.

References

[1] Salo, T., et al. 2007. Agricultural and Food Science 16:366-375.
[2] Valkama, E., et al.. 2013. Agriculture, Ecosystems and Environment 164: 1-13.
[3] Salo, T., et al. 2013. MTT Report 102. 37 p. http://jukuri.mtt.fi/bitstream/handle/10024/481096/mttraportti102.pdf

ESTIMATING THE NITROGEN FERTILIZER REQUIREMENTS OF HIGH- YIELDING HYBRID GRAIN CORN VARIETIES

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Objectives

High-yielding hybrid corn varieties (*Zea mays* L. ssp. *May*) are widely cultivated in the Ebro Valley (Spain), where corn growers tend to apply N in large amounts. Current guidelines for grain corn N fertilization indicate that a maximum of 28-30 kg N per ton of grain yield are necessary [1], although the usual recommendations are around 25 kg N t^{-1}. While grain N concentration is not a very useful indicator for characterizing the N status of corn [2], it has been widely used to compute the N fertilizer requirements of corn. In the Ebro Valley, 78% of farmers apply more than 300 kg N ha^{-1} [3]. The objectives of this field study were to review and improve the guidelines for the use of N fertilizer for high-yielding hybrid grain corn varieties grown in irrigated calcareous soils in the Ebro Valley.

Method

We used experimental data from eight field experiments (316 experimental plots) carried out over four growing seasons (2012 to 2015). All the trials were done on commercial farms located in the Ebro Valley (North-East Spain) and received either sprinkler (seven fields) or surface (one field) irrigation. The plot area was 9 x 9 m. All the soils were calcareous and had medium textures and distinct organic matter contents (1.8-3%), but the soil depths were different. Eight hybrid cultivars (600-700 FAO cycles and one FAO 280) were planted with a row spacing of 70 cm. The planting dates were between 15 April and 1 May, except for the FAO 280 (on 1 July). N was applied at the V6 stage. The N sources were fertilizers such as urea and calcium ammonium nitrate, some of which included urease or nitrification inhibitors. The treatments also included a non-fertilized plot. The amounts of N applied ranged from 0 to 375 kg N ha^{-1}. Soil samples were taken from all plots before planting and/or applying N fertilizer (at V6 stage) and then at harvest to measure NO_3-N content. N concentration was determined by Kjeldahl digestion. A stalk nitrate test was performed on all the plots at harvest [4]. The experimental design was a randomized complete block with four replications.

Results

The mean percentage of N in the grain was 1.36% (±0.17, CV 12.5%), while the percentage of protein was 8.3%. The highest grain yields (>16 tha^{-1}) were obtained with grain N contents of between 1.2 and 1.4%. These results were consistent with [5] and [6].

Our results showed that there was no relationship between yield and grain N content. There was also no correlation between applied N and the N content in the grain or stalk. However, a positive correlation was observed between applied N and the concentration of nitrate in the cornstalk at harvest. A linear plus plateau model was adjusted between available N (Soil NO_3-N plus applied N) and grain yield. The critical level of available N at corn stage V6 was 370 kg N ha^{-1}. Above this critical level of available N, no increase in yield was obtained. On average, the harvest index was around 0.5. An appropriate concentration of N in the stalk is around 0.58%. An excess of available N tends to increase the concentration of N in the stalk at physiological maturity, causing a luxury consumption of N. The N fertilizer recovery never exceeded 50%. Under appropriate irrigation management, very high yields of corn can be achieved (>16 t ha^{-1}) in the Ebro Valley when the amount of N applied does not exceed 250 kg N ha^{-1}. When preparing a fertilization plan for corn, the previous crop [7][8], soil organic matter content, nitrate content in irrigation water, and soil nitrate test [9] should all be considered, in addition to the yield goal.

Conclusions

Our results indicate that the total amount of N fertilizer applied must not exceed 275 kg N ha^{-1} even when there is a high yield goal (more than 16 t ha^{-1}). In the Ebro Valley, we recommend that the amount of N fertilizer to be applied to properly managed, irrigated corn (weeds and irrigation) should range from 200 and 275 kg N ha^{-1} for yields of between 12 and 20 t ha^{-1}.

References

[1] Betrán J. 2010. In: Guía práctica de la fertilización racional de los cultivos en España. 135-141. Ministerio de Medio ambiente y Medio Rural y Marino.

[2] Cerrato and Blackmer. 1990. Agron J. 82:744-749

[3] Lloveras et al. 2012. Vida Rural, February. 24-30.

[4] Wilheim et al. 2005. Agron. J. 97: 1502-1507

[5] Gabriel and Quemada. 2011. Europ J. Agronomy 34, 133-143.

[6] Ciampitti and Vyn. 2012. Field Crops Research 133, 48-67.

[7] Bundy. 2004. Univ. of Wisconsin-Extension. Madison.

[8] Cela et al. 2011. Agron J. 103: 520-528.

[9] Ferrer et al. 2003. Agronomie, 23, 561-570.

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NITROGEN LOSSES FROM AUSTRIAN AGRICULTURAL SOILS - USE OF MODEL RESULTS FOR THE GREENHOUSE GAS INVENTORY

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Objectives

The project “NitroAustria” aims to broaden the data base for regional nitrous oxide emission factors in Austria from agricultural soils. The findings of model results of LandscapeDNDC [1] in seven regions will be further proofs for the usage of regionally/nationally differentiated emission factors instead of the IPCC default values for calculating direct and indirect N_2O emissions from soil.

A national N_2O inventory based on model and national greenhouse gas inventory results and on a literature review of different N_2O modelling approaches will be conducted. Site specific and regional nitrous oxide emission factors for more targeted mitigation measures on arable land and grassland in Austria will be derived.

The overall aim of NitroAustria is to identify the drivers for nitrous oxide emissions on a regional basis and to reflect the drivers and related amounts of N_2O emissions in the national greenhouse gas inventory.

Method

As party to the United Nations Framework Convention on Climate Change (UNFCCC) Austria is required to produce and regularly update National Greenhouse Gas Inventories and submit a National Inventory Report (NIR, [2]). For CRF Sector 3 Agriculture, CRF Category 3.D Agricultural soils, the emissions of N_2O that result from anthropogenic N inputs or N mineralization are calculated using the default emission factor of 0.01 kg N_2O-N/kg N applied for inorganic and organic N fertilizers (1 %). Results of the ACRP project “FarmClim” (2012-2015, [3]) highlight that the IPCC default emission factor is not able to reflect region specific N2O emissions from Austrian arable soils.

In “NitroAustria” the biogeochemical LandcapeDNDC model will be used to calculate N_2O emissions and nitrate leaching for seven regions in Austria representing the diversity of main land uses as well as climatic, soil and management characteristics. These simulated site- and region-specific C and N budgets will be compared with results from other process oriented models based on a literature review and from pre-projects and with the results from the GHG inventory reporting. A national N_2O emission inventory will be simulated using the gathered nitrous oxide data.

Trade off-effects will be explored and suggestions for policy implementation of mitigation measures will be made by means of literature review and expert judgement from the project partners Universität für Bodenkultur Wien, AGES, BfW, KIT and Environment Agency Austria.

Results

Simulation results of N_2O emissions at site and regional scale will be used to derive region specific emission factors and simulate nitrate leaching rates, which will allow estimating the importance of indirect N_2O emissions [4].

Based on a literature review on background publications of the IPCC default value (empirical regression relationship between fertiliser amount and induced emissions) and other process-oriented nitrous oxide modelling approaches the modelling results will be evaluated for the GHG inventory use. The model outcomes of LandscapeDNDC will be compared and discussed with the NIR conception and extrapolated to simulate a national N_2O emission inventory. Furthermore regional drivers for N_2O emissions will be identified taking

into account different land uses, soil types, climate and agricultural management.
Recommendations will be given on how mitigation measures can be implemented in a policy framework. Based on the proposed mitigation measures also trade-off effects between different greenhouse gases and other nitrogen emissions (e.g. ammonia, nitrate leaching) will be taken into account. Proposals for implementation of these measures will be elaborated focusing on the applicability for the agricultural sector and their policy frameworks.
The findings of the modelled regions will be further proofs for the usage of regionally/nationally differentiated emission factors for calculating N_2O emissions from agricultural soil. Validated nitrous oxide emission factors for Austrian agricultural managed soils will be evaluated to be integrated in the Austrian GHG emission inventory calculations. Results will be regionally modelled emission factors able to underpin future national deviations from the IPCC default emission factors.

Conclusions

NitroAustria uses the LandscapeDNDC model to update the N_2O emission factors, the results will be evaluated for their integration into the national emission inventory.
Based on this and on a literature review on background publications of the IPCC default value for N_2O emissions, which is a mean value for global assessments, and results from other process oriented models, a "best available" national nitrous oxide inventory will be simulated. Thereby "mean" emission factors for regions considered with similar conditions for N_2O fluxes can be developed.
The results of the process-oriented model LandscapeDNDC will be utilized in future GHG inventory methodology development, if representativeness for Austria is ensured and model results are validated and published in international or national peer reviewed journals.

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NITROGEN DYNAMICS AND N-CYCLING BACTERIAL COMMUNITIES IN A MEDITERRANEAN OLIVE ORCHARD UNDER A SUSTAINABLE FARMING SYSTEM

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Objectives

In the recent years, soils has been recognized to play a double role in the entire agro-ecosystem: it is important for a good production as well as for a healthy environment [1, 2]. The conventional, non-sustainable, agronomic practices should evolve in a more sustainable management addressed to ameliorate the ecological networks and nutrient cycling in which soil microorganisms are involved [3, 4, 5].

The main objective of this study was to analyze N dynamics in an olive orchard managed with sustainable agricultural practices. For improving the system and better characterizing the components responsible for the transformation of the different forms of soil N and their availability for plants, a biological and biochemical N indicator was used, and the expression of genes of N-cycling bacterial communities were investigated.

Method

The trial was in a 2-ha mature olive grove located in Southern Italy managed using sustainable and organic agricultural practices for 15 years. Plants were drip irrigated with urban wastewater (total N = 18.3 mg L^{-1}; with a mean presence of *Escherichia coli*, Enterococci and *Clostridium* spores of 3500, 7000 and 2300 CFU 100 mL^{-1}, respectively) and pruned every year. The soil was permanently covered by spontaneous self-seeding weeds mowed twice a year. Cover crop residues and prunings were shredded and left on the ground as mulch. Two sampling areas were identified: along the row (under the emitters) and along the inter-row (rainfed). Three soil samplings (composite bulk samples collected from the 0-10 cm soil layer) were performed in a year.

The degree of soil quality was expressed by the ratio Nc/Nk, where Nk is Kjeldahl total soil N, while Nc is a linear function of microbial biomass carbon and N mineralization capacity, combined with three enzyme activities, calculated by the following equation [5]:

$$\text{Total N} = (0.38\times10^{-3})\ \text{microbial biomass C} + (1.4\times10^{-3})\ \text{mineralized N} + (13.6\times10^{-3})\ \text{phosphomonoesterase} + (8.9\times10^{-3})\ \beta\text{-glucosidase} + (1.6\times10^{-3})\ \text{urease}$$

The expression levels nitrogenase (*nifH*), ammonia monooxygenase (*amoA*), nitrite reductase (*nirK* and *nirS*), and nitrous oxide reductase (*nosZ*) were determined by real-time quantitative PCR, using specific primers and microbial reporter genes (from *Nitrosomonas europaea, Azospirillum irakense, Azospirillum brasiliense, Pseudomonas stutzeri* and *Pseudomonas fluorescens*). Total soil RNA extraction was carried out by RNA PowerSoilTM Total RNA Isolation Kit Sample (Mobio) followed by a DNase treatment. Retrotracripts were purified by using the Wizard SV Gel and PCR Clean-Up System (Promega).

Microbial biomass C was determined by the fumigation-extraction method [6]. Mineralized N was evaluated as the difference of inorganic N at the beginning and at the end of an incubation period [5]. Inorganic N was determined by the method of Bremner [7]. Urease, phosphomonoesterase, and *β*-glucosidase activities were measured following the methods described in [7], [8] and [9], respectively.

Together with N analyses, counts of specific N-cycling bacterial groups, soil organic matter, soil moisture and soil physical structure, were monitored.

Results

In a soil, a large number of physical, chemical and biochemical properties are involved. However, due to the impossibility of considering all of them, it is of key importance to make a selection. In this study, the ratio Nc/Nk exhibited all the attributes of a good soil fertility indicator, as it was sensitive to changes that occur in the soil, capable of reflecting the improvement of soil quality and not too sensitive to environmental and fluctuations. Nc/Nk showed significant differences in the different areas of each orchard (row and inter-row), being generally higher along the row (in the areas wetted by drippers and with high organic matter content) and so indicating a better soil quality. This ratio, together to the microbial biomass carbon, N mineralization capacity and enzyme activities, gave a precise idea on nitrogen soil dynamics (fixation, mineralization, immobilization, organication, nitrification and denitrification) in the different parts of the olive orchard studied. In the areas along the row, a higher bacterial functional activity and diversity was also found, compared to the inter-row areas.

The sequences of DNA with high phylogenetic information content, such as the rRNA genes, has been used for the description of the N microbial networks, increasing our knowledge on the bacterial diversity in soils [10]. Studies based on DNA mainly provide information on the community structure, while the RNA studies, and in particular the analysis of mRNA expression, provide information on the activities of specific populations. Considering the different conditions in the different parts of the orchard (along the row, under the emitters, with high soil moisture; and along the inter-row, where cover crop residues and prunings were shredded) and the seasonal effects (mainly due to rainfall distribution, soil moisture and soil temperature), mRNAs from N-cycling communities were considered for this study. The number of ammonifying bacteria, proteolytic bacteria and nitrogen-fixing Azotobacter in the wetted areas under the drippers were significantly higher than along inter-rows, whereas denitrifying Pseusomonas were not significantly different between the two parts of the orchard. The higher bacterial counts along the row were accompanied by higher expressions of *nifH, amoA, nirK* and *nirS*.

Conclusions

This study confirms the need for Mediterranean orchards to encourage farmers to practice soil management based on organic matter inputs associated with zero tillage, in order to improve soil fertility. The increase of knowledge on biochemical processes of the soil microorganism involved in soil N dynamics influencing N availability for plants, can lead to optimize management strategies for a modern and multifunctional concept of agriculture, based on product quality, environmental protection, resource saving and promotion of human health.

[1] Sofo, A., Palese, A.M., Casacchia, T., Dichio, B., Xiloyannis, C. 2012. In: Ahmad, P., Prasad, M.N.V. (eds) Abiotic Stress Responses in Plants. Springer, New York, USA. p. 105-129

[2] Ding, G.C., Piceno, Y.M., Heuer, H., Weinert, N., Dohrmann, A.B., Carrillo, A., Andersen, G.L., Castellanos, T., Tebbe, C.C., Smalla, K. 2013. PLoS ONE 8: e59497

[3] Graf, D.R.H., Jones, C.M., Hallin, S. 2014 PLoS ONE 9: e114118

[4] Gil-Sotres, F., Trasar-Cepeda, C., Leirós, M.C., Seoane, S. 2005. Soil Biology & Biochemistry 37: 877-887

[5] Trasar-Cepeda, C., Leirós, M.C., Gil-Sotres, F., Seoane, S. 1998. Biology and Fertility of Soils 26: 100-106

[6] Vance, E.D., Brookes, P.C., Jenkinson, D.S. 1987. Soil Biology & Biochemistry 19: 703-707

[7] Bremner, J.M., 1995. In: Black, C.A. et al. (eds) Methods of Soil Analysis. ASA, CSSA, SSSA, Madison, WI, USA. p. 1179-1237

[8] Tabatabai, M.A., Bremner, J.M., 1972. Soil Biology & Biochemistry 4: 479-487

[9] Eivazi, F., Tabatabai, M.A., 1977. Soil Biology & Biochemistry 9: 167-172

[10] Eivazi, F., Tabatabai, M.A. 1988. Soil Biology & Biochemistry 20: 601-606

NITROUS OXIDE AND NITRATE LOSSES – INFLUENCING FACTORS IN WILLOW CROPPING INVESTIGATED BY MODELLING

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Objectives

Bioenergy crops are expected to play an important role in securing the energy supply and mitigating greenhouse gas emissions. However, to increase the yield, mineral N fertilizer and sewage sludge fertilizer are normally applied which might in turn increase the risk of soil N_2O emissions and also nitrate leaching. This paper thus focuses on the N_2O emissions and soil nitrate leaching and their influencing factors for a conventional Swedish willow bio-energy plantation.

The following research questions were addressed:

1. What influencing factors are found for N_2O emissions and nitrate leaching, respectively?

2. What is the optimum fertilization amount rate to minimize N_2O emissions in relation to gain in biomass?

3. What is the possible impact of drainage on the willow biomass growth and also N losses?

Method

We calibrated a detailed process-oriented model, CoupModel with a number of measured high resolution data obtained from the Skrehalla field experiment site in Grästorp, Sweden (N58°16' E12°46'), having willow (*Salix viminalis*). The site has heavy clay soil with pH 5.8 (±0.1). Soil C/N ratio was 12 (± 0.4) for the first 0-50 cm soil layers. The site was drained by a tile pipe drainage system, depth of ~ 1 m and 10 m spacing.

The field experiments started in 2012, the year before the fifth harvest. NH_4NO_3 was added in June 2012, 100 kg N ha^{-1}. Harvesting was performed 29th of March and sewage sludge from a local waste water treatment plant was then added in May, in total 270 (80-460) kg N ha^{-1}.

The current general model structure setups and basic parameterizations were based on previous usage of CoupModel on similar ecosystems. The calibration and uncertainty analysis method used in this study is the Generalized Likelihood Uncertainty Estimation (GLUE). For the GLUE calibration, a number of high resolution data including biotic and abiotic variables were used together with eddy covariance measurements of CO_2 and N_2O fluxes. The application of mineral fertilizer was assumed to directly add ammonia and nitrate to the soil surface N content pool. Sewage sludge was analogously treated as "Faeces" in the model, adding to both soil mineral and organic pools, and assumed to be mixed into the soil surface. The initial conditions of the willow plants are defined by measured plant growth biomass data. Soil physical structure was defined by soil water retention curves derived from pedo-functions from measured soil texture fractions. Where measured data show large variations, coefficients with high uncertainties were included into calibration. Since initial values for total soil organic matter content was unknown, this was subject for calibration. Meteorological data, hourly resolution, was used as model forcing.

Results

A detailed investigation of the period, June to July 2012 and May to October 2013 shows an emission peak in June 2012 to be closely connected to the soil surface water content variation induced by rainfall soon after mineral fertilizer application. Despite some discrepancies in capturing the measured peaks, the simulated emissions after commercial fertilizer addition were 0.05 (0.02 to 0.15) g N_2O-N m^{-2}, similar to what was measured in the year of 2012, 0.035 g N m^{-2}. The simulated emissions after adding sewage sludge in 2013 were estimated to be 0.2 (0.1 to 0.37) g N_2O-N m^{-2} which was slightly higher than measured, 0.17 g N m^{-2}.

After the mineral fertilizer addition leaching was estimated to 0.66 (0.34 to 1.08) g NO_3^--N m^{-2} yr^{-1}, where high leaching was found connected to intense rainfall, also being a period with high N_2O emissions. Sewage sludge application resulted in lower nitrate leaching, 0.2 (0.05 to 0.35) g N m^{-2} yr^{-1}. Our modeling also describes the leaching of dissolved organic N (DON), which is simulated to be 0.14 (0.13 to 0.15) g DON-N m^{-2} for the first year but only 0.02 (0.01 to 0.03) g N m^{-2} for the second year. The simulated leaching dynamics was linked to precipitation patterns, where the total precipitation in 2012 was 919 mm yr^{-1}, much higher than the 30 years mean 683 mm yr^{-1} (data from a nearby SMHI station), while 2013 was dry with only 524 mm yr^{-1}, which explains the small soil nitrate leaching in 2013 despite sludge application. The relatively low N_2O emissions and soil nitrate leaching can also be explained by large plant N uptake, simulated to be 108 (83 to 133) kg N ha^{-1} in 2012, and 147 (108 to 186) kg N ha^{-1} in 2013. Therefore the plant nitrogen uptake is the dominating controlling factor in the soil N cycle, leaving relative small amount of available N for N_2O production and nitrate leaching.

Conclusions

Our modeling indicates that N_2O emissions are mainly produced by the nitrification process, most influenced by soil water content and the amount of fertilizer added. The modelled soil nitrate leaching was negatively influenced by the denitrification and positively by water drainage flow. Model sensitivities indicate that to minimize the N_2O emissions in relation to biomass gain, the application rate of mineral fertilizer should be within the range of 50 to 100 kg N ha^{-1}, sewage sludge within 150 to 300 kg N ha^{-1}. The high sensitivity to drainage suggests that an optimum drainage is of need both to achieve high plant yield and minimize N losses.

HOW DOES GRAZING ABANDONMENT AFFECT SOIL MICROBIAL ACTIVITY AND AMINO ACID UTILIZATION?

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Objectives

In mountain pastures of the Basque Country (northern Spain), grazing has been an important economic activity since the Neolithic However, management changes - shorter stays in the mountains, lower stocking rates and less shepherd control - have recently been detected [1]. If these trends continue, a progressive grazing abandonment is expected. On the other hand, soil microbial communities play a key role in many soil processes, providing a direct measure of soil functioning [2]. Nevertheless, the question of whether soil microbial functioning and diversity may be modified by livestock grazing remains poorly explored. The objective of this study was to assess the effect of the abandonment of grazing on the functioning and diversity of soil microbial communities. In addition, the use of amino acids by soil bacterial populations was studied as protein degradation could be a rate-limiting step in the overall N cycle of soils.

Method

The current study was carried out in the Gorbeia Natural Park (43ºN 2.5ºW), in the Atlantic region of the Basque Country (northern Spain). The climate is humid temperate, with an annual mean temperature of 10 ºC and a mean precipitation of 2,000 mm. This area has traditionally been ranged by mixed and unguarded livestock (sheep, beef cattle and horses). Within the Natural Park, five locations of contrasting characteristics of elevation, vegetation type according to the Habitats Directive (European Commision, 2006), and parent material were chosen: Oderiaga (mountain at 630-720 m, Habitats Directive code 6230a, siliceous), Usotegieta (mountain, Habitats Directive code 6230c, siliceous), Arimegorta (mountain, Habitats Directive code 6170, siliceous), Ipinaburu (valley at 240-410 m, calcareous) and Urigoiti (valley, siliceous). In spring 2012, four permanent exclusions of 10 x 10 m were placed in the mountain locations (3 locations x 4 exclusion cages) and two in the valley locations (2 locations x 2 exclusion cages). Two years after the establishment of the exclusions, in autumn 2014, topsoil samples from 0-10 cm were collected using a core soil sampler (25 mm diameter). Soil humidity was determined at sampling time. For the measurements of physicochemical parameters, soil samples were air-dried at ambient temperature until constant weight. Total nitrogen (TN), pH, organic matter (OM), Olsen phosphorus (P) and extractable potassium (K) were measured according to standard methods. For biological parameters, soils were stored fresh at 4˚C for a maximum of two months until analysis. Basal and substrate-induced respirations (SIR) were measured following ISO 16072 Norm (2002) and ISO 17155 Norm (2002), respectively. Community-level physiological profiles (CLPPs) of cultivable heterotrophic bacteria were determined with Biolog Ecoplates™ (Insam, 1997). Measurements corresponding to an incubation time of 48 h for Biolog Ecoplates™ were chosen to study the utilization of the following amino acids: L-arginine, L-asparagine, L-phenylalanine, L-serine and L-threonine. In addition, plant richness was determined by throwing at random a 50x50 cm square (5 times per sampling area). Root depths were measured *in situ*. Soil compaction was measured using a digital penetrometer (Rimik CP40II).

Results

Soil microbial activity was not significantly affected by grazing abandonment. Mean basal respiration rates were 2.6 (±1.3) and 2.2 (±1.4) μg C g^{-1} soil h^{-1} for excluded and grazed soils, respectively. Similarly, substrate-induced respiration averaged 19.6 (±6.4) and 19.4 (±7.3) μg C g^{-1} soil h^{-1} for both treatments, respectively. As expected, the OM content of sampled soils was positively related to soil microbial activity, especially the soil basal respiration ($R^2 = 0.87$; $P < 0.05$). After two years of differing management, results demonstrated that grazing abandonment did not have any significant effect on soil OM content at Gorbeia Park ($P > 0.05$). Amino acid utilization by bacterial populations was not different between excluded and grazed soils ($P > 0.05$). Soils, in which grazing herbivores were excluded, presented the following absorbance values in the Biolog Ecoplates^{TM}: 1.1 for L-arginine, 2.1 for L-asparagine, 0.5 for L-phenylalanine, 1.7 for L-serine and 0.08 for L-threonine. On the other hand, amino acid utilization showed the following mean values for grazed soils: 1.1 for L-arginine, 2.0 for L-asparagine, 0.6 for L-phenylalanine, 1.6 for L-serine and 0.1 for L-threonine. Interestingly, grazed soils showed a higher variability concerning the amino acid utilization by bacterial populations in all the experimental sites. Therefore, the mean coefficient of variation (CV) for all the amino acids accounted for 32.8% in grazed sites whereas CV of soils under exclusion was 18.9%. Results from CLPPs analyses demonstrated that microbial amino acid utilization tended to be higher in valleys compared to mountains for L-arginine (1.4 vs 0.9), L-serine (1.9 vs 1.6) and L-threonine (0.15 vs 0.07). This pattern could be related to the lower OM (5.1% vs 12.8%) and TN content (0.4% vs 0.7%) recorded in the valleys. It is suggested that amino acids would have been utilized more efficiently by microbes under limited C and N conditions [3]. The type of soil, which has been described as a key factor modulating amino acid utilization, did not show here any effect on their use ($P > 0.05$). Soil microbial activity, measured as respiration rates, was not affected by the type of soil ($P > 0.05$). Overall, grazing abandonment reduced significantly soil compaction (mean, 1212 vs 1912 MPa) but did not modify the nutritional status of soils. Mean N, P and K contents were close to 0.6 g kg^{-1}, 16 mg kg^{-1} and 140 mg kg^{-1}, respectively, for exclusion and grazing treatments. The current animal stocking rate at Gorbeia Park seems not to be enough to modify significantly the soil characteristics. Finally, plant diversity H' index (≈ 2) and plant root depth (≈ 19 cm) were not affected by grazing abandonment.

Conclusions

Soil microbial activity and microbial amino acid utilization were not affected by grazing abandonment. The microbial efficiency for soil amino acid utilization could be related to C and N status of soils. Grazing abandonment reduced significantly soil compaction but did not change the nutritional status of soils at Gorbeia Park. Plant diversity and plant root depth were not affected by grazing abandonment.

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References

[1] Aldezabal, A., Moragues, L., Odriozola, I., Mijangos, I. 2015. Applied Soil Ecology 96, 251-260.

[2] Garbisu, C., Alkorta, I., Epelde, L., 2011. Applied Soil Ecology 49, 1-4.

[3] Farrell, M., Prendergast-Miller, M., Jones, D.L., Hill, P.W. 2014. Soil Biology and Biochemistry 77, 261-267.

DYNAMIC OF SOIL O_2 AFFECTS N_2O PRODUCTION PATHWAYS AFTER APPLICATION OF CATTLE SLURRY AND DMPP NITRIFICATION INHIBITOR

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Objectives

The application of cattle manure provides nitriogen (N) rich substrates for autotrophic nitrifiers under aerobic conditions, and heterotrophic denitrifiers in low-oxygen or anoxic soil environments. Thus, soil O_2 plays an important role as "a controller" of nitrogen transformation pathways and has significant impacts on N_2O emission [1]. Monitoring spatial and temporal distribution of O_2 in soil can help to understand the mechanisms governing the production of N_2O in the soil. Futhermore, N_2O isotopomer analysis can provide new insights in the pathways leading to N_2O formation [2, 3]. The aims of this study were to 1) gain an understanding how soil O_2 dynamic after surface application of cattle manure affect N_2O formation in soil; 2) understand how these processes are affected by the application of the nitrification inhibitor DMPP.

Method

Soil sample (4mm) was collected (0-15 cm) from a grassland site, Rollesbroich, Germany (50°37′18″N, 6°18′15″E), and cattle slurry was obtained from a dairy cattle house at AU-Foulum (Tjele, Denmark). The slurry has a dry matter content of 11.5%, pH 7.0 (H_2O, 1:2.5 v/v), total ammonical N of 2.15 g (kg^{-1} fresh wt). The oxygen planar optode system was described in detail by [1] and [4].

The experiment consisted of three treatments (4 reps) of cattle slurry (CS), cattle slurry with DMPP (CSDMPP), and a control (CTR). Soil was packed into optode chambers to a depth 4 cm (1 g cm^{-3}), and soil water was adjusted twice during the experiment: 85% WFPS (the first 5 days), and 90% WFPS (the last 13 days). Surface application (120 kg NH_4-N ha^{-1}) of cattle slurry was restricted to a 12cm^2 frame (50% of surface area). For CSDMPP, 0.5 ml DMPP solution (1.495 kg L^{-1}) was mixed into the cattle slurry corresponding to 1.2 kg ha^{-1} (1% of applied NH_4-N). The incubation was conducted in darkness at room temperature for 18 days. Optode images were taken every 60 minutes during the incubation.

The gas sampling was performed at day 0, 1, 2, 3, 5, 7, 11, 14 and 18 for measurement of CO_2, CH_4 and N_2O by Gas Chromatography (Clarus 580, PerkinElmer, Rodgau, Germany), and on day 0, 1, 3, 5, 7, 11 and 14 for N_2O isotopomer analysis by an isotope ratio mass spectrometer (IsoPrime 100, Elementar Analysensysteme, Hanau, Germany). N_2O isotope signatures were determined and calculated following an approach described in [5]. The source partitioning of N_2O production (i.e nitrification and denitrification) was calculated using a two endmember mixing model.

Results

The spatial and temporal distribution of soil O_2 was significantly affected by treatments of cattle slurry and DMPP. The greatest effects were observed within the top 1.5 cm soil layer. In this layer, soil O_2 was decreasing rapidly to between 42% and 56% (% air sat.) for CS and CSDMPP, respectively, within the first 48 hours after manure application, while soil O_2 of the CTR remained at 83%. In the deeper layer (1.5- 4 cm), negligible changes in O_2 concentration were observed for all treatments. After 5 days, the soil water content was increased and soil O_2 was depleted rapidly in CS (from 56% to 42%) and CSDMPP (from 73% to 63%), but only slowly in CTR (from 83% to 79%) throughout the soil core. The O_2 depletion zone was larger and lasted longer in CS compared to CSDMPP. During the last 7 days, soil O_2 gradually increased in all treatments. Soil O_2 depletion can be due to microbial respiration or nitrification. For the CS and CSDMPP treatments, the lowest O_2 content coincided with peaks of CO_2 evolution, suggesting most soil O_2 was consumed by microbial respiration.

N_2O emissions were significant higher from CS compared to CSDMPP and CTR. For CS, N_2O flux peaked at day 1 and day 15 with 2 and 1.7 µg N kg^{-1} soil h^{-1}, whereas it reached at a peak of 1.8 µg N kg^{-1} soil h^{-1} at day 1 and then steady decreased for CSDMPP. At the end of the experiment N_2O flux of CS declined to 1 µg N kg^{-1} soil h^{-1}, and remained much higher than that of CSDMPP. The greatest effect of DMPP was observed between day 5 and 18 (90% WFPS). At this soil moisture content, apparently it likely that DMPP infiltreated better into deeper soil layers (2 – 4 cm) and inhibited nitrification more effectively. Over 18 days incubation, CSDMPP reduced N_2O emission by 60% in comparision with CS treatment. This reduction is lower than observed in field studies [6,7].

N_2O sources partitioning indicated that nitrification was the dominant source of N_2O for both CS (58%) and CSDMPP (65%) in the first 24 h, then bacterial denitrification was gradually taking over when soil O_2 content was signififcantly depleted between 48 and 96 hr. After that the predominance of nitrification took placed relative to detrinitrification and followed the increase of soil O_2 throughout soi columns. Total cumulative N_2O source partitioning underlined that denitrification dominated nitrification over a period of 18 days incubation, and contributed to 58.1 % and 57.2% in CS and CSDMPP, respectively.

Conclusions

The results demonstrated that soil O_2 content was significantly reduced by cattle slurry application on the soil surface. The most severe O_2 depletion ocurred within the top 0-1.5 cm. Soil O_2 concentration remained for the CS than CSDMPP treatment, while soil O_2 of CTR treatment remained relatively high. Soil O_2 dynamic influenced significantly sources of N_2O production. Nitrification was the dominant source in the initial 24 hours after slurry application, but after this when soil O_2 decreased denitrification dominated, and as oxygen returned towards the end of the experiment nitrification was again dominating. However, over the whole period of 18 days incubation, denitrification was the main source of N_2O production from soil. The application of DMPP reduced total N_2O emission by 60% compared to CS treatment without DMPP.

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References

[1] K, Bruun S, Larsen M, Glud RN, Jensen LS. Soil Biology and Biochemistry 2015;84:96–106.

[2] Baggs EM. Rapid Commun Mass Spectrom 2008;22:1664–1672.

[3] Well R, Kurganova I, Lopesdegerenyu V, Flessa H. Soil Biology and Biochemistry 2006;38:2923–2933.

[4] Larsen M, Borisov SM, Grunwald B, Klimant I, Glud RN. Limnology and Oceanography: Methods 2011;9:348–360.

[5] Toyoda S, Yoshida N. Anal Chem 1999;71:4711–4718.

[6] Scheer C, Rowlings DW, Firrel M, Deuter P, Morris S, Grace PR. Soil Biology and Biochemistry 2014;77:243–251.

[7] Abalos D, Sanz-Cobena A, Andreu G, Vallejo A. Agriculture, Ecosystems & Environment 2016.

UK-CHINA VIRTUAL JOINT CENTRE FOR IMPROVED NITROGEN AGRONOMY

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Objectives

The use of synthetic nitrogen (N) fertilisers in agriculture supports c 50% of the current global population, but its inefficient use has led to increasingly serious environmental consequences. The problem is especially acute in fast developing countries such as China, where the subsidised production and use of N fertilisers has succeeded in helping to deliver food security, but at the expense of severe environmental problems. This project will bring together researchers in the UK and China with the specific objectives of: 1) developing novel indicators of nitrogen use efficiency (NUE) incorporating soil health and quality; 2) using these indicators and other emerging knowledge to test and develop farm systems that permit the sustainable intensification of (especially Chinese) agriculture; 3) to translate these developments to Chinese farmers using the proven 'Science and Technology Backyard' programme developed by CAU and CAAS that is moving farmers out of poverty and enriching whole communities.

Method

The UK-China Centre for Improved Nitrogen Agronomy (CINAg) is one of two Newton-funded UK-China Centres on Agricultural N, which will work closely together. The research in CINAg will be delivered through 4 integrated work packages:

WP1 will work towards an improved fundamental understanding of N cycling and improved NUE prediction through development of biological, physical and chemical soil quality indicators. Soil samples will be collected in both the UK and China across a broad range of land uses and N use intensities. Biological measurements will include abundance and activity of key N-cycle genes using qPCR with primers to amplify denitrification genes *nirS, nirK, nosZ*, the nitrification gene *amoA* from archaea and bacteria and *nifH* for nitrogen fixation, together with community diversity using high throughput sequencing assays for bacteria/archaea and fungal communities. We will also explore the use of protease and chitinase genes (e.g. *apr, npr, chiA,*) for looking at the upstream controls of mineralization as this represents a major bottleneck in soil N cycling. Measurements of plant performance and climate will support the biological data.

WP2 will focus on harnessing novel N technologies which will be assessed through a series of plot scale experiments. Technologies to be assessed and developed will include 'smart fertilisers' (e.g. inhibitors, slow release), novel sensors providing information on soil N supply, novel treatments and practices in the recycling of organic materials and novel crop varieties. Measurements will be made of crop yield, N offtake and quality, soil N transformations and losses to the environment, soil quality indicators as described above and meteorology.

WP3 will assess improved agronomic practices to enhance NUE as identified from WP1/2 at the field scale. Data from these field-scale studies will be used to validate predictions from the 3D-Rhizosphere [1] and SPACSYS [2] models and to feed through to the development of decision support tools.

WP4 is concerned with developing predictive capacity and knowledge exchange. Current limitations to agronomic extension in China and the UK will be examined, focusing on identifying the main barriers preventing the adoption of 'best practice' and formulating new ways of promoting NUE on farm.

Results

The project has only just commenced, so no results are available to date. However, expected deliverables include:

- New soil quality indicators for NUE; a gene-to-landscape understanding of N cycling.
- Enhanced understanding of where and when ‘smart fertilisers’ will work including predictive models describing the environmental fate of nitrification inhibitors and their efficacy.
- An understanding of spatial variability of key soil quality indicators responsible for NUE in a range of cropping systems, from which spatial optimisation of sensors can be based; transfer of soil nitrate sensor technology to UK and Chinese research groups.
- Identification of the best manure processing technologies to improve NUE during both the processing and land-application stages, improved algorithms to describe mineralisation rates of organic N from acidified and digested slurry ‘fractions’ to feed into statistical and process-based models such as SPACSYS and guidance on fertiliser replacement rates for different manure ‘fractions’ following advanced slurry processing techniques.
- Evaluation of theoretical (from modelling) and actual (by experimentation) impact of changes in crop species or trait on N capture and NUE.
- Evaluation of combined technologies for enhancing NUE; validation of mathematical models and creation of new Decision Support Tool Frameworks for better managing inorganic and organic fertilisers and for reducing N losses.
- Shared information on knowledge transfer approaches to improve NUE in UK and China (from Backyard Programs to sophisticated (and improved) DSSs and mobile phone Apps), a critical analysis of the barriers to extension and adoption and the generation of a series of policy and practice briefs targeted to policymakers, industry, regulators and farmers which contains a Road Map for implementing and delivering lasting NUE in agronomic systems.

Through an increase in the skills and knowledge base of Chinese agricultural researchers the VJC will improve China’s ability to undertake and disseminate research to maximise impact on the issues of rural and economic growth through the sustainable intensification of agriculture.

Conclusions

The formation of a UK-China Virtual Joint Centre for Improved Nitrogen Agronomy will accelerate an improved understanding of how NUE can be increased across different cropping systems in the UK and China. The Centre will deliver enhanced outputs and impacts through the sharing of key resources, working on complementary Farm Platforms and networks, sharing experimental methodologies, results, databases and modelling approaches, joint scientific publications and sharing approaches to knowledge exchange. The UK-China Virtual Joint Centre for Improved Nitrogen Agronomy will also be an excellent platform for training young scientists (including Postdoc, PhD and MS students etc.) and conducting integrated research on agricultural nitrogen management in both China and the UK.

CALIBRATION OF A SIMPLE MECHANISTIC WHEAT MODEL FOR WITHIN-FILED VARIABLE N APPLICATION

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Objectives

In precision agriculture (PA) crop management strive for considering spatial and temporal variability in soil and crop factors within a field [1]. One of the issues in PA is N management. At the time for N application, it is difficult to predict the crop N requirement and the soil capacity to release N to the crop. Computer models of agricultural systems can make predictions of the soil-and-crop interactions and give indications of coming soil and crop status.

In this study, the overall objective was test the potential of a simple and fast-simulating crop model to be used as a decision support for practical site-specific N fertilization in Sweden. More specifically, we tested the model applicability to Swedish climate data and the model potential to predict grain yield with input data from different places in a field that varies largely in both texture and organic matter content.

Materials and Methods

The mechanistic wheat model Sirius [2] was used in this study. In the model, the physical properties of the soil are described by the hydrological parameters (HP:s); porosity (P), field capacity (FC) and wilting point (WP). Fertilizers and mineralization of soil organic N (SON) are the sources of crop N uptake in the model. Mineralization is restricted to the top 40 cm and depends on the amount of SON, temperature, soil moisture and soil type.

Observed data from a field in the south-west of Sweden (58°06'N, 12°50'E) was used to calibrate model outputs under Swedish conditions. The field varies largely in texture and soil organic matter (SOM). Site-specific data of texture, SOM and soil mineral N for 12 study plots located across the field was used to derive input data to the model. Three N treatments (0, 80 and 200 kg N ha^{-1}) were available at each study plot and grain yield and grain N were analysed at harvest. The 12 study plots showed large variations in grain yield, grain N, protein content and residual soil N.

Four different simulation set-ups were tested during the calibration process with weather and management data kept the same in all simulations. Soil and crop parameter values were modified step by step and every new modification was kept in the next set-up. In set-up 1, site-specific estimated data on HP:s, SON, soil mineral N at time of sowing and percolation coefficient (estimated from clay content) were used as input for every study plot. In set-up 2, modifications were made in the crop parameter values related to thermal time requirements according to the estimates for Swedish conditions. In set-up 3, further adjustments were made in the crop parameters related to grain filling duration and maximum protein concentration, to agree with field observations. In set-up 4, modifications of soil parameters (minimum mineral N content of soil, constant for denitrification pulse and mineralization constant) were made to further improve the agreement of simulated and observed values in the unfertilized treatments.

Results and discussion

The initial simulation, set-up 1, greatly overestimated grain yield (at most 4300 kg ha^{-1}) and grain N (at most 175 kg N ha^{-1}), especially for plots with high SON. In set-up 2, crop parameters were adjusted to Swedish estimates which improved particularly the grain yield, but also the grain N, agreement to observed data. Still, e.g. in the unfertilized treatments, grain yield and grain N were overestimated by at most 2000 kg ha^{-1} and 110 kg N ha^{-1}.

In set-up 3, the adjusted maximum protein concentration value did not affect grain yield at all, whereas it decreased the maximum level of simulated grain N remarkably in the 200 kg N-rate. Grain yield levels were improved to some extend by increasing the grain filling duration value from 320 to 380 degree days (DD). Simulated grain yield were overestimated at plots with high SON in the unfertilized treatments and grain N were overestimated in all treatments. In set-up 4, changing the values of minimum mineral N content of soil and the constant for denitrification pulse had no impact on the results. However, the mineralization constant showed large influence on the outputs and it was modified site-specifically to further correct simulated grain yield and grain N for better agreement with observed data. The effects of changes in mineralization constant were greatly dependent on the SON-content. For study plots with low SON ($\leq$ 10.0 ton ha^{-1}), constituting half of the plots, mineralization constant was increased and for the other half of the study plots (SON = 15.7-31.8 ton ha^{-1}), it was decreased, compared to the default value of mineralization constant. The values of mineralization constant correlated well to SON and the correlation may be useful in other simulation studies as well where SON is known but not the mineralization constant.

The root mean square error (RMSE) of the simulated grain yield was improved considerably using the calibrated model set-up 4 (RMSE = 446-757 kg ha^{-1} or 11-12% of observed mean) compared to the uncalibrated set-up 1 (RMSE = 1920-2844 kg ha^{-1} or 30-76% of observed mean). However, although the RMSE for grain N was improved with set-up 4, grain N was still overestimated and residual soil N underestimated.

Conclusions

In this study, we wanted to test the Sirius model applicability to Swedish conditions and its potential to predict site-specific grain yield within a field. Results showed that the model has potential to be used as decision support for site-specific N fertilization in Sweden, after some adjustments of input data values to current climate and soil conditions.

A model set-up based on site-specific weather, soil hydrologic properties, soil organic N, soil mineral N at sowing and percolation coefficient, gave the right variation in yield, but grain yield (and grain N) levels were highly overestimated. Crop parameters describing thermal time for crop phenology (mainly grain filling duration and phyllochron) showed to be important for maximum yield levels. The input parameter maximum protein concentration did not affect grain yield but governed maximum grain N levels. Adapting the mineralization constant depending on the SOM content instead of using the same static mineralization constant for the whole range of SOM content in the field at the start of the simulation improved the total simulated grain yield at harvest.

In the calibrated set-up, the model generally overestimated grain N levels and underestimated residual N in soil at harvest. So, at least with the current input data used, the simulated N dynamics in soil and crop did not work properly. However, the model gave realistic grain yield levels and variation in grain yield over a field, although not always the right absolute grain yield amount at every place.

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References

[1] Stafford, J V. (2000). Implementing Precision Agriculture in the 21st Century. *J. agric. Engng Res*, *76*, 267-275.

[2] Jamieson P D., Semenov M A., Brooking I R. and Francis G S. (1998). Sirius: a mechanistic model of wheat response to environmental variation. *European Journal of Agronomy 8*, 161-179.