Proceedings of the International Conference on

CAOS

Climate Smart Agriculture on Organic Soils

Climate Smart Agriculture on Organic Soils

23rd – 24th of November 2017, Uppsala, Sweden

Kerstin Berglund & Örjan Berglund (eds.)

Sveriges Lantbruksuniversitet
Institutionen för mark och miljö
Hydroteknik

Rapport 17
Report

Swedish University of Agricultural Sciences
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Uppsala 2017

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TABLE OF CONTENTS

Abstracts poster presentations

Preface

Peatlands store a major share of the world's soil organic carbon. Many European peatlands have been drained and cultivated in the past centuries. This fosters land surface subsidence and peat mineralization. Therefore, drained organic soils are a large source of greenhouse gases (GHG) emissions and, at the same time, at a high risk of being degraded and lost. At this conference, we want to discuss options for maintaining production on organic soils while reducing GHG emissions and buffering climate change. The meeting aims for the exchange of current research results both from natural and social sciences.

The conference is divided into 5 sessions with oral presentations covering the following topics:

- Water management
- Soil and management and nutrient leaching
- Economy and policy
- Growing adapted biomass
- Greenhouse gas emissions
-

There is also a poster session covering all topics of the conference.

You are all warmly welcome to Uppsala, Sweden. We hope the conference will inspire fruitful discussions on how to manage agricultural organic soils in the future.

Uppsala 2017-11-15

On behalf of the organizing committee,

Kerstin Berglund and Örjan Berglund

Department of soil and environment
SLU, the Swedish University of Agricultural Sciences

Day 1. Thursday 23 /11 SLU Campus, Ulls Hus, (address: Almas Allé 8)		
12:30-13:20	**Registration and coffee**	
13:20-13:30	**Welcome (Kerstin Berglund)**	
13:30-14:50	**Session 1. Water management (Chair Kristiina Regina)**	
	Jan van den Akker	Subsidence and CO2 emissions of peat meadow soils in The Netherlands and effectivity of submerged drains to conserve these peat soils
	Idse Hoving	Implementation of submerged drains on Dutch Dairy farms to protect organic soils
	Rob Hendriks	Effects of submerged drains on subsidence, water management and nutrient leaching in the Western peat soil area of The Netherlands: a modelling study
	Jean Caron	Impact of formation of a compacted layer on drainage of histosols in Quebec, Canada
14:50-15:20	**Coffee break**	
15:20-17:00	**Session 2. Soil Management and nutrient leaching (Chair Jan van den Akker)**	
	Synnøve Rivedal	Inversion of previously tile drained peat soil: I. Method and effects on hydrology, soil properties, grass yield and profitability
	Peter Dörsch	Inversion of previously tile drained peat soil: II. Effects on greenhouse gas emissions
	Bärbel Tiemeyer	How do peat type, sand addition and soil moisture influence the soil organic matter mineralization in anthropogenically disturbed organic soils?
	Arndt Piayda	Functions of European fen peat soils impacted by agricultural land use history
	Matthew Riddle	Are organic soils a major contributor of P to surface waters?
17:20-18:30	**Poster Session with refreshments, MVM centre, Lennart Hjelms väg 9**	
18:30-Late	**Conference Dinner, MVM centre**	
Day 2. Friday 24 /1 SLU Campus, Ulls Hus, (address: Almas Allé 8)		
8:30-9:50	**Session 3: Economy and policy (Chair Arndt Piyada)**	
	Norbert Röder	Impacts of the EU Common Agricultural Policy and the EU climate policy
	Christoph Buschmann	Low emission alternatives for agriculturally used drained peat soils: Which factors determine the land use options in dependence of socio-economic settings in six European regions?
	Jos Schouwenaars	Cost benefit analysis for land use options in peatland regions in the Netherlands
	Kati Häfner	Farmers' Preferences For An Agri-Environmental Measure Designed For Climate Friendly Peatland Management
9:50-10:20	**Coffee break**	
10:20-11:40	**Session 4: Growing adapted biomass (Chair Ülo Mander)**	
	Wendelin Wichtmann	Cinderella - first outcomes from the FACCE ERA NEt JPI Climate Smart agriculture project
	Poul Erik Lærke	Dry matter yield and nutrient balance of perennial grasses grown for biogas production on a fen peatland
	Martin Maddison	Carbon and nitrogen dynamics in reed canary grass (Phalaris arundinacea) cultivation on an abandoned peat extraction area with low soil pH
	Poul Erik Lærke	Greenhouse gas balance of a rewetted agricultural fen peatland established with reed canary grass
11:40-12:40	**LUNCH (Ulls restaurang, "Syltan", Duhrevägen 8)**	
12:40-14:20	**Session 5: Greenhouse gas emissions (Chair Poul Erik Lærke)**	
	Lorenzo Menichetti	The weight of peatland conservation and restoration in the global cycle of C and N
	Åsa Kasimir	Re-wetting drained peatlands: effects on greenhouse gas fluxes, plant production, and economics
	Ülo Mander	Nitrous oxide emission from tropical peatlands
	Kristiina Regina	Raised water table and sand addition for mitigating greenhouse gas emissions from cultivated peat soils
	Lars Elsgaard	Annual CO2, N2O and CH4 emissions from a Danish sphagnum peat bog under different land-uses
14:20-14:30	**Concluding remarks (Bärbel Tiemeyer)**	
14:30-15:00	**Fare-well coffee**	

ABSTRACTS ORAL PRESENTATIONS

A memory stone over the drainage work done 1904 to 1908 at the peatland “Bälinge Mossar”, orderd by governor Per Johan Bråkenhielm and executed by the local land owners. The inscription says: The harvest of future generations is worth the farmer's effort. (Photo Örjan Berglund)

Subsidence and CO_2 emissions of peat meadow soils in The Netherlands and effectivity of submerged drains to conserve these peat soils.

J.J.H. van den Akker, R.F.A. Hendriks and I.E. Hoving

Wageningen Environmental Research, Wageningen, The Netherlands

About 8% of all soils in The Netherlands are peat soils which are mainly all in agricultural use as permanent pasture for dairy farming and drained with ditches. Measured subsidence rates range from a few mm per year to up to 25 mm per year, mainly depending on the ditch water levels and whether the peat is covered with a thin layer of clay soil. About 30% of the peat soils in The Netherlands have a clay cover ranging from 10 – 40 cm thickness. This can reduce the subsidence and CO_2 emissions up to about 50%. The subsidence is mainly caused by peat oxidation and is a continuous process because the ditchwater levels are periodically adapted to the subsidence to assure the drainage level of the peat meadow parcels. The subsidence and the co_2 emissions of 15 – 45 t/ha/year become ever more an environmental and socio-economic threat. Attempts to conserve these soils and reduce subsidence and CO_2-emissions by raising ditchwater levels and converting the peat meadow areas mainly in very extensive grasslands or wet nature proved to be a very costly and slow process due to the strong opposition of farmers and many others who value the open cultural historic landscape and meadow birds. The use of submerged drains proves to be a promising solution acceptable for dairy farmers and effective in diminishing peat oxidation and so the associated subsidence and CO_2 emissions. Since 2003 several pilots with submerged drains are started and subsidence rates are measured. Measurements show that subsidence rates can be reduced by 50% and even more. This means that also CO_2-emissions are reduced in the amounts. In our presentation we will focus on the reduction of subsidence and on the results of a pilot in the Krimpenerwaard in the Province South-Holland concerning the hydrological aspects.

Implementation of submerged drains on Dutch Dairy farms to protect organic soils

Idse E. Hoving, Rob F.A. Hendriks and Jan. J.H. van den Akker

Wageningen University & Research

Peat soils in The Netherlands represent 19% of the dairy farms and 23% of the total agricultural grass area. These soils are mainly situated in polders with a regulated surface water level. The challenge of water management in these polders is to find a compromise between the reduction of soil subsidence and to provide sufficient soil baring capacity of the grass sward for machine traffic and grazing. The first aspect requires relatively high ditch water levels and the second low(er) ditch water levels. Soil subsidence is 1 cm per year on peat soils without a clay cover and a ditch water level of about 60 cm below soil surface. High water levels promote higher groundwater tables in dry periods and consequently hamper oxygen supply for oxidation of peat. However, high water levels are not sufficient to minimize soil subsidence. Water management is getting more and more difficult due to the ever-increasing difference between high-water-level areas for urban areas and infrastructure and the low-lying agricultural areas.
With ‘submerged drains’ the different interests can be better united. These drains are tube drains lying below ditch water level that enhance infiltration of ditch water as well as drainage to ditches. Potentially, application of submerged drains halves soil subsidence. Different research projects on the hydrological and agricultural effects of application of ‘submerged drains’ have been carried out during the last 15 years. On the basis of this research water boards are currently starting pilots at polder level. Submerged drains reduced annual variation in groundwater level significantly. This means that with submerged drains groundwater level gradients were flatter than in the undrained situation (lower during precipitation surplus and higher during evaporation surplus). This paper takes up the challenge to present the main hydrological and agricultural effects of submerged drains on peat soils in The Netherlands.

Effects of submerged drains on subsidence, water management and nutrient leaching in the Western peat soil area of The Netherlands: a modelling study

Rob Hendriks

Wageningen Environmental Research, Wageningen, The Netherlands

Most of the peat soils in agricultural use in the Netherlands are drained. Drainage causes oxidation of peat and subsequently leads to subsidence and greenhouse gas emission. Submerged drains that enhance submerged infiltration of water from ditches during the dry and warm summer half year are regarded as a promising tool for reducing peat decomposition by raising groundwater levels. Pilot field studies in the Western part of the Dutch peat area were conducted to study effectiveness of submerged drains in reducing peat decomposition and the side effects on water management and loading of surface water with nutrients. Most of these parameters are not easy to assess and are strongly depending on the meteorological conditions during the field studies. Therefore, some of the pilot studies were modelled. The SWAP model was used for evaluating the results on groundwater table and water management. Effects of submerged drains were assessed by comparing the results of fields with and without drains. An empirical relation between deepest groundwater table and subsidence was used to convert groundwater table effects to effects on subsidence. With the SWAP-ANIMO model nutrient loading of surface water was modelled on the basis of field results of nutrient concentrations. Calibrated models were used to assess effects in the present situation, as thirty-year averages, under extreme weather conditions and for two extreme climate scenarios.

In this study the model results of the case study ‘de Krimpenerwaard’ is presented. Model results show a halving of soil subsidence, a strong increase of water recharge but a lower increase of water discharge, and generally small to moderate effects on nutrient loading , all depending (strongly) on meteorological conditions.

Impact of formation of a compacted layer on drainage of histosols in Quebec, Canada

Jean Caron, Renel Lherisson, Laura Thériault, Silvio Gumiere, Cédrick-Victoir Guedessou, Jacynthe Dessureault-Rompré

Université Laval, Québec Canada

Cultivated organic soils are recognized for their excellent agricultural quality. However, the nature of their constitutive materials and the physical-chemical and mechanical processes associated with their agricultural development make them be susceptible to surface drainage problems over time. The main results indicate that long-term use of histosols for vegetable production has led to the formation a compacted layer in the 25 cm to 35 cm depth, problematic for surface drainage. In shallower soil profile, the compacted layer may extend well beyond that depth. Our work has shown limited improvement with crop rotation and limited benefits associated with deep tillage. Our results also demonstrate that the disturbance of the soil profile improves soil drainage and considerably reduces the time to reach field capacity at the soil surface, but the duration of the effect associated with disturbance still remain to be determined.

Inversion of previously tile drained peat soil: I. Method and effects on hydrology, soil properties, grass yield and profitability

Synnøve Rivedal*, Samson Øpstad, Sverre Heggset, Trond Børresen, Torbjørn Haukås, Sissel Hansen, Peter Dörsch, Johannes Deelstra

**Norwegian Institute of Bioeconomy Research*

Many cultivated peatlands in Norway are tile drained, even though the physical properties of peat result in inefficient drainage under a wet climate. To sustain agricultural usage, while protecting peat C and N stocks, alternative methods need to be evaluated. When peats are situated on top of self-draining mineral soils, inversion can be an alternative. The peat soil is covered with a 0.5 - 1 m thick layer of the underlying mineral soil while maintaining connectivity to the self-draining subsoil through tilted mineral soil layers. This method is appropriate when the peat body has a thickness <1.5 m and has been practiced in Norway since the 1970s. We studied the hydrology, soil physical properties and profitability of a recently inverted peat used for forage production and compared it to an adjacent, traditionally tile drained site. Ground water table (GWT) dynamics suggested that inverted peat drained faster, reducing the number of events the GWT was less than 20 cm below the soil surface. Measurements in undisturbed soil samples showed significantly larger values of bulk density, air capacity and saturated hydraulic conductivity and less available water in the mineral soil covering the inverted peat than in the tile drained peat soil. Thus, inversion of peat soil fundamentally changes soil physical conditions and the hydrological behaviour resulting in a soil having good trafficability even shortly after heavy rainfall. Mean dry matter yield for the years 2014-2017 was 9.23 and 10.84 t DW ha^{-1} yr^{-1} for the tile drained and inverted peat respectively, despite a very nutrient poor layer of mineral soil of the inverted peat. The high yield increase makes inversion profitable although it is a very costly method. Depending on depth of the peat layer the costs of inversion can be estimated to 8 000 – 28 000 Euro ha^{-1}.

Inversion of previously tile drained peat soil: II. Effects on greenhouse gas emissions

Peter Dörsch*, Sverre Heggset, Synnøve Rivedal, Johannes Deelstra, Samson Øpstad and Sissel Hansen
**Faculty for Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences*

Peatland cultivation causes GHG emissions (CO_2, N_2O, CH_4), contributing substantially to anthropogenic climate forcing. However, the effect of alternative drainage methods on GHG emissions is not fully explored. Peat inversion, i.e. covering the peat with a 0.5 to 1 m thick layer of mineral soil fundamentally changes the biophysical conditions for GHG production and gaseous transport. We compared CH_4 and N_2O emissions in an inverted and tile-drained peat under grassland in Western Norway (Fræna) throughout two summers (Mai – October). In tile-drained peat, N_2O emissions showed pronounced emission bursts after fertilization, whereas inverted peat had more stable emissions. The average seasonal N_2O emission for both summers was 3.2 and 6.3 kg N_2O-N ha^{-1} in inverted and tile-drained peat, respectively, and was >95% fertilizer induced. Observations of soil air composition in the inverted peat (in 0.6 to 1.1 m depth) revealed a negative N_2O gradient with depth, suggesting that N_2O was mainly produced in the mineral top layer. Methane exchange in the inverted peat changed from a small source in the wetter summer of 2015 (0.2 kg C ha^{-1}) to a small sink in the drier summer of 2016 (-1.7 kg C ha^{-1}), while the tile-drained peat was a source of CH_4 emitting 121 and 29 kg C ha^{-1} in the wet and dry summer respectively. In the wet summer, CH_4 concentrations at the interface between mineral and organic soil reached up to 45 vol%, suggesting that the mineral layer efficiently oxidizes most of the CH_4 formed in the buried peat. To further constrain conditions conductive to peat decomposition, we now continuously measure O_2 concentrations in the top of the buried peat layer. Available data so far show that O_2 concentrations in inverted peat are often zero and significantly smaller than in tile drained peat down to a depth of 0.6 m.

How do peat type, sand addition and soil moisture influence the soil organic matter mineralization in anthropogenically disturbed organic soils?

Annelie Säurich[1], Bärbel Tiemeyer[1*], Axel Don[1], Stefan Burkart[1]

[1] *Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany Presenting*
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Drained peatlands are hotspots of carbon dioxide (CO_2) emissions from agriculture. As a consequence of both drainage induced mineralization and anthropogenic sand application, large areas of former peatlands under agricultural use contain soil organic carbon (SOC) at the boundary between mineral and organic soils. Studies on SOC dynamics of such "low carbon organic soils" are rare as the focus of previous studies was mainly either on mineral soils or "true" peat soil. However, the variability of CO_2 emissions increases with disturbance and at the same time, sand application is sometimes proposed as a mitigation measure. With this incubation experiment, we aim to understand the high variability of CO_2 emissions from strongly anthropogenically disturbed organic soils by systematically comparing strongly degraded peat with and without addition of sand under different moisture conditions and for different peat types. We sampled undisturbed soil columns from the topsoil and the subsoil (three replicates each) of ten peatland sites all used as grassland. Peat types comprise six fens (sedge, *Phragmites* and wood peat) and four bogs (*Sphagnum* peat). All sites have an intact peat horizon that is permanently below groundwater level and a strongly disturbed topsoil horizon. Three of the fen and two of the bog sites have a topsoil horizon altered by sand application and mixing. All columns are installed at 10°C in a microcosm system with online measurement of CO_2. The initially water-saturated soil columns were drained by stepwise increase of the suction. Bog peat reacted more strongly to drainage than fen peat and topsoils showed nearly tenfold fluxes of the subsoils. Most interestingly, in the case of fens, there were no differences in CO_2 fluxes between sand-mixed topsoils and disturbed peat topsoils. Specific CO_2 fluxes (standardized to SOC) were also in the case of bogs higher for sand-mixed topsoils.

Functions of European fen peat soils impacted by agricultural land use history

Arndt Piayda[1] (arndt.piayda@thuenen.de), Bärbel Tiemeyer[1], Ullrich Dettmann[1,2], Michel Bechtold[3], Norbert Röder[4] , Christoph Buschmann[4]

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Organic soils offer numerous functions from the global to the local scale: they constitute the biggest terrestrial carbon storage on the globe, form important nutrient filters for catchments and provide hydrological buffer capacities for local ecosystems. Cultivated organic soils, however, show extreme mineralization rates of the organic substance and turn into hotspots for green house gas emissions, are highly vulnerable to land surface subsidence, soil and water quality deterioration and thus crop failure. The aim of this study is to analyse the impact of past agricultural management on soil physical and chemical functions of organic soils in six European countries. We conducted standardized soil mapping, soil physical/chemical analysis, ground water table monitoring and farm business surveys across 7 to 10 sites in Germany, The Netherlands, Denmark, Estonia, Finland and Sweden. The results show a strong impact of past agricultural management on soil functions across Europe. Organic soil under intensive arable land use consistently offer lowest bearing capacities in the upper 10 cm compared to extensive and intensive grassland use, which is a major limiting factor for successful agricultural practice on organic soils. The difference can be explained by root mat stabilization solely, since soil compaction in the upper 25cm is highest under arable land use. A strong decrease of available water capacity and porosity is consequently observed under arable land use, further intensifying hydrological problems. Soil carbon stocks clearly decrease with increasing land use intensity, showing highest carbon stocks on extensive grassland. This is supported by the degree of decomposition, which is lowest for extensive grass land. Overall, findings indicate a strong impact of land use intensity and management on soil carbon losses and peat degradation on the European scale.

Are organic soils a major contributor of P to surface waters?

Matthew Riddle[1]

[1]Swedish University of Agricultural Sciences, Uppsala, Sweden

Phosphorus (P) leaching from arable mineral soils is known to result in significant amounts of P entering surface waters, causing eutrophication. However, the contribution to eutrophication from organic soils are less documented. In an attempt to identify potential concentrations, loads and types of P that leach from organic soils, two column studies were carried out utilising two organic soils. The aim of study 1 was to identify maximum potential P loads and from where in the soil profile P was released. Undisturbed columns, 20 cm deep and 20 cm in diameter were extracted from both Swedish soils at four depths: 0-20, 20-40, 40-60 and 60-80 cm. Four 50 mm rain simulations were applied at 5 mm h^{-1} over 10 h, with two days between each event. This resulted in 85-92% of leached total-P originating from the 0-20 cm layer. Total-P from this layer was comprised of 76-98% orthophosphate with smaller amounts of particulate and organic-P. Mean total-P concentration from soil 1 (0-20 cm) was 7.4 mg L^{-1} and 1.5 mg L^{-1} from soil 2. Combined mean leaching loads from the four layers of soil 1 resulted in 5.1 kg ha^{-1} (range 2.6-10.0) compared to 17.1 kg ha^{-1} (range 14.6-19.9) from soil 2. Ninety cm long (30 cm diam.) lysimeters utilising the same two soils were subjected to natural outdoor conditions in study 2. Three year mean tot-P concentration in leachate from soil 1 was 0.34 mg L^{-1} and soil 2, 0.68 mg L^{-1}. Accumulated mean tot-P loads during this period were 1.6 kg ha^{-1} (range 1.0-2.0) from soil 1 and 2.5 kg ha^{-1} (range 1.9-3.7) from soil 2. These results suggest that although these soils have potential for losses of high P loads, the organic subsoil acts as an efficient filter by removing a large portion of mobile P.

Impacts of the EU Common Agricultural Policy and the EU climate policy on the mitigation of greenhouse gas emissions from drained peat soils

Norbert Röder
Thuenen Institute of Rural Studies, Braunschweig, Germany

Due to high greenhouse gas (GHG) emissions from drained peat soils, rewetting of peatlands and the production of wetland biomass (paludiculture) have a large potential for climate mitigation. However, in the given legal context wetland restoration faces many disincentives and constraints resulting from EU policies for agriculture and climate. Without reforming and further developing relevant EU policies, this potential might remain under-utilised.

The EU Common Agricultural Policy (CAP) is favouring forms of agricultural land use depending on drainage, while rewetting and the conversion towards wetland biomass production is hampered. Plants like reed, sedges, rush or cattail are not eligible for direct payments of the CAP's 1^{st} pillar and thus excluded from this area-related support. When rewetting grassland, vegetation pattern change and patches of non-eligible plants might emerge. This causes conflicts with GAEC requirements (good agricultural and environmental condition) compulsory for land eligible for payments in the CAP. In addition, if grassland is converted to wetland or paludiculture, this may be accounted for as a loss of grassland, and compensations might be necessary.

In the EU climate policy, there is a slow process of stepwise integration of land-use related GHG sinks and emissions. Until 2020, emissions from drained peatlands are not accounted for the EU emission targets. From 2021 onward, the source group land-use, land-use change and forestry (LULUCF) will form a third pillar of the EU climate policy. Sinks and emissions are accounted against different reference levels, and overall the new LULUCF pillar should be at least neutral ("no-debit") at member state level. A limited number of GHG mitigation credits can be accounted for towards national mitigation targets in other sectors. Doubts remain whether these provisions will sufficiently incentivise climate actions for restoring peatlands in the next decade.

Low emission alternatives for agriculturally used drained peat soils: Which factors determine the land use options in dependence of socio-economic settings in six European regions?

Buschmann, Osterburg, Röder
Thuenen Institute of Rural Studies, Braunschweig, Germany

Agriculture on drained peat soils causes a multitude of problems such as soil mineralisation, subsidence and loss of biodiversity. Drained peat soils are a considerable source of Greenhouse Gas emissions especially in Northern and Central European countries even if their share of the agriculturally used soils is limited. Emission mitigation from peat soils is currently not included in the reduction commitments of the European Union's (EU) climate framework. However, emissions related to land use will be increasingly relevant for the EU climate targets. Since peat soils have a high mitigation potential, they will be likely in the focus of future regulations. We describe and compare the similarities and differences in the socio-economic and ecological business environment that policy makers, planners and farmers are confronted with when developing tailored proposals for low emission land use alternatives on peat land. The analysis is based on expert group discussions supplemented with literature reviews in different regions in The Netherlands, Germany, Finland, Estonia, Denmark, Sweden and Denmark. We discussed different land use alternatives including controlled drainage, wet grazing, paludiculture and land abandonment. Additionally, we interviewed 33 typical farmers cultivating organic soils across the study regions. The Social-Ecological System Framework (Ostrom, 2009) is a well-established tool to analyse the dependencies and feedback in the management of natural resources. Based on this framework we identify and cluster important variables. Our results show that mainly the productivity of the resource systems, the economic value of land and market incentives determine the economic efficiency of the land use alternatives. The most efficient alternative usually receives the highest level of acceptance in a given project region. Other variables are more important with respect to the implementation of alternatives, such as governance systems, property rights, heterogeneity and conflicts among users. We point out similarities and possibilities of solution transferability between regions.

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Cost Benefit Analysis for land use options in peatland regions in the Netherlands

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Water Board Fryslân, The Netherlands

Intensive dairy farming in peatland regions has increased the rate of land subsidence in the Netherlands. This results in increasing costs for water management, risks for saline waters in coastal polders and conflicts with other land use such as nature management and housing. In recent years in several regions a cost-benefit analysis has been made to support policy making.
Results for different peatland regions in the Netherlands will be presented, with special focus on the region of Fryslân. Attention will be given to key factors in socio-economic and geographic conditions which have an important impact on the prefered land use options for the future.

Farmers’ Preferences For An Agri-Environmental Measure Designed For Climate Friendly Peatland Management

Kati Häfner*, Julian Sagebiel, Ingo Zasada

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Across EU Member States greenhouse gas emissions are the highest in Germany. It is committed to reduce those emissions by 40 % by 2020 compared to 1990 and aims at cutting them by 80 – 95 % by 2050. To reach those goals more effort needs to be made. Drained and agriculturally used peatland areas are one major greenhouse gas emission source. To reduce greenhouse gas emissions from agriculturally used peatlands a new agri-environmental measure for climate friendly peatland management was recently established in the state of Brandenburg, Germany. We apply a discrete choice experiment to assess which factors influence the willingness of farmers to participate in a measure for climate friendly peatland management through water logging. We find the level of required compensation is with 522 €/ha*a above the current payment. In addition to the financial incentive, especially support for cooperation with neighbouring land managers and access to local market innovations are needed to enhance farmers’ willingness to participate. The very new scheme targeted at climate mitigation could be adjusted and better tailored to different farm types. A revised and improved measure design would enhance the farmers’ participation and therefore effectiveness of the measure regarding climate mitigation.

CINDERELLA

Wendelin Wichtmann
Institut for botany and landscape ecology, Greifswald university, Greifswald, Germany

The project CINDERELLA comprises a comparative analysis, integration and exemplary implementation of climate smart land use practices on organic soils (peatlands).

OBJECTIVES
The aim is to progress paludicultures after centuries of peatland destruction and neglect. Means are field and lab investigations, desk studies and activities for dissemination and awareness raising for paludiculture. Also extension of the scientific base for a sustainable use of wetlands and making alternative uses accessible to farmers and land authoritiesas well as advancing wet agriculture on peatlands by an integrated scientific approach are aims of the project.

METHODS

• Field tests on paludiculture systems comprising ecologic and economic monitoring as well as GHG measurements,
• Laboratory investigations and genetic analyses,
• Harvest-and use potentials in various European regions, Life Cycle Assessments for sustainability capability and the provision of ecosystem services,
• Micro-and macro-economic analyses and assessment of ecosystem services of paludiculture,
• Review of political and legal boundary conditions to analyse current opportunities and constraints for large scale implementation of paludiculture
• Develop management strategies and transfer them from lab to field and disseminate the innovative concept of paludiculture over Europe

KEY SCIENTIFIC FINDINGS
As the project is not finalized yet, only general preliminary findings are mentioned here:

¬Framework conditions for optimizing land use and area potential for climate smart agriculture on organic soils in participating countries in Europe are analysed and recommendations for optimizing of cultivation of wet peatlands (paludiculture) developed
¬Nutrient retention by paludiculture assessed by review and proven by lab and field investigations
¬Genetics described for clones of Phragmites australis as well as Typha latifolia, T. angustifolia and Arundo donax correlated with
¬

information on productivity and preferred site conditions, factors controlling primary productivities assessed

¬Analysis of management and productivity of paludiculture, assessing biomass utilization as fodder, building material or fuel for energy production

Dry matter yield and nutrient balance of perennial grasses grown for biogas production on a fen peatland

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Cultivation of perennial grasses for bioenergy on modestly drained peatland may be an economic and environmentally sustainable production option. This study was designed to show the effects of harvest time and harvest frequency of festulolium and tall fescue on biomass nutrient concentrations and total nutrient removal from a nutrient-rich fen peatland. In addition, specific methane yield (SMY) and methane yield per hectare (MYPH) were assessed after anaerobic digestion of the biomass. The harvest managements included a three-cut (3C) and three two-cut (2C) systems which differed by two-week delays of first cut as 2C-early, 2C-mid and 2C-late, representing phenological stages of pre-heading, inflorescence emergence, and flowering, respectively. Both grasses received 80-16-60 kg N-P-K ha^{-1} in spring and 80-0-100 kg N-P-K ha^{-1} after each harvest (except final). Annual dry matter (DM) yields of festulolium in 2C-early and 2C-mid managements (average 14.1 Mg DM ha^{-1}) were 22% lower compared to the 3C management (18.2 Mg DM ha^{-1}). Tall fescue senesced rather slowly in the second growing period resulting in similar total biomass yield (16.4–18.8 Mg DM ha^{-1} yr^{-1}) for all managements. Mean annual N removal of the two grasses from the field by 3C (315 kg N ha^{-1}) was 31% higher than by 2C (240 kg N ha^{-1}) managements, but net removals (removed minus applied N) from both managements were similar (75–85 kg ha^{-1}). Net P-removal by 3C (37 kg P ha^{-1}) was higher than by 2C (26 kg P ha^{-1}) managements. SMY ranged from 315 to 464 NL CH4 kg^{-1} volatile solids
(mean, 393 NL). MYPH ranged from 5277 to 6963 Nm^3 CH4 ha^{-1} (mean, 6265 Nm^3) and was predominantly influenced by biomass yield since SMY only deviated modestly in relation to harvest management (crop maturity).

Carbon and nitrogen dynamics in reed canary grass (*Phalaris arundinacea*) cultivation on an abandoned peat extraction area with low soil pH

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Reed canary grass (RCG) cultivation on former peat extraction areas is a potential after-use option that provides a source of renewable energy while mitigating climate change through enhanced carbon (C) sequestration. We investigated C and nitrogen (N) dynamics of RCG cultivation on an abandoned peat extraction with very low soil pH area in eastern Estonia. RCG was seeded in July 2015. Eight experimental plots (6x8 m), four replicates with high (H) and four with low (L) ground water level (GWL) were established. All plots received 22 kg N, 25 kg phosphorus (P) and 53 kg potassium (K) of mineral fertilizer per hectare at the beginning of experiment. The fertilization rate in the second and third year was N45P11K45 and N100P25K100, respectively. Each year liming (8 t ha^{-1}) in all plots was carried out. It increased pH from the initial 2.7 up to 4.7 after the third liming event. The difference between high- and low-GWL plots during vegetation period (from May to September) was 1 cm in 2016 and 16 cm in 2017.

We analysed above- and belowground biomass and its nutrient content, soil and water samples for physico-chemical parameters, and measured fluxes of carbon dioxide (CO_2; net ecosystem exchange (NEE), ecosystem and heterotrophic respiration), methane (CH_4) and nitrous oxide (N_2O) using static and dynamic chambers.

On H-GWL plots, the mean aboveground biomass was 181 g m^{-2} in 2016 and 388 g m^{-2} in 2017. Respective values for L-GWL plots were 159 g m^{-2} and 137 g m^{-2}. Due to low plant productivity in all sites NEE was positive, i.e. ecosystem respiration was higher than fluxes of C assimilated by vegetation and the area functioned as a C source. Total organic carbon (TOC) values in piezometer water of L-GWL plots was 56 – 73 mg L^{-1} and 76 – 112 mg L^{-1} of H-GWL plots, whereas planted plots showed lower values than the bare soil. H-GWL plots showed lower CH_4 flux than the L-GWL plots (from -9 to 585 µg C m^{-2} h^{-1} and -13 – 2005 µg C m^{-2} h^{-1}, respectively). N_2O fluxes from H-GWL plots were between -3 and 335 µg N m^{-2} h^{-1}, and fluxes from L-GWL varied from -6 to 511 µg N m^{-2} h^{-1}.

Greenhouse gas balance of a rewetted agricultural fen peatland established with reed canary grass

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Rewetting has been recommended to reduce CO_2 emission and to restore the carbon sink function of drained peatland. Paludiculture, the combination of peatland rewetting and cultivation of flooding tolerant perennial grass for production of bioenergy, has gained interest as a possible alternative land use option. However, more knowledge on suitability of crops for paludiculture and the effects on GHG balance is needed. With intact soil cores (mesocosms) we have shown that reed canary grass (RCG) cultivation can offset the GHG emission from a drained peat soil if the water table is raised close to the soil surface and at the same time producing 12 Mg ha^{-1} DM per year in two cuts. To substantiate these findings, a two-year field experiment was carried out from March 2015 to February 2017. The level of groundwater table of four plots established with RCG in 2013 in a agricultural fen peatland was raised to soil surface by pumping water back from the drainage ditch. Emissions of CO_2, CH_4 and N_2O were measured with opaque chambers at two-weeks interval but more frequently after fertilization events, and Net Ecosystem Exchange (NEE) of CO_2 was assessed with temperature controlled transparent chambers. Two cuts of the biomass in 2015 yielded in total 14.0 Mg DM ha^{-1} and the NEE from March 2015 to February 2016 showed that 19.7 Mg CO_2 ha^{-1} was taken up by the ecosystem. However, in the same period 20.2 Mg ha^{-1} CO_2eq of CH_4 and 2.5 Mg ha^{-1} CO_2eq of N_2O were emitted. Data from the second year of measurements is under processing. Preliminary conclusions are that GHG emission from this agricultural peatland was off-set after rewetting assuming the harvested biomass was used for bioenergy production, but concurrently high emissions of CH_4 appeared from the flooded field.

Keywords: carbon dioxide, methane, nitrous oxide, paludiculture, wetland.

The weight of peatland conservation and restoration in the global cycle of C and N

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Abstract

In order to contextualize the problem of peatland degradation, we calculated the weight of peatland degradation on global C and N cycle and put it in perspective with the actual debate on C sequestration.

To do so we first crossed geographic data on peatland extension with land use data and a climate classification map. This allowed us to match peatland areas with the IPCC peatlands emission factors, obtaining the potential emissions if all the peat would degrade. By crossing this map with available data on the actual degradation of peatland (by country) we obtained a map estimating actual emissions from peat degradation. We aggregated this estimate and put it in perspective with estimates on global potential of cropland SOC sequestration.

The impact of the actually degrading peatland area on the global C cycle is comparable with the total amount of C we can sequester into croplands by implementing all the suggested strategies (possibly slightly superior). We estimated that emissions from peat degradation would be equivalent to cropland SOC sequestration in 104 to 1021 years. This would happen in 63-374 year in the likely case of doubling area of peatland degradation (with net emissions rising since then).
Moreover, due to their 3.4 times higher C:N ratio, the C stored in peatland is much less costly in terms of N compared to cropland. We estimated that sequestering the C amount in actually degrading peatland back into agricultural lands would need 30-80% of the N actually used in agriculture.

Although our study does not diminish the importance of C sequestration in agricultural soils, it points out the massive relevance of peatland conservation and restoration in a global perspective. Peatland conservation is clearly strategic in terms of global greenhouse gas balance and it should receive the due attention from politics and research.

Re-wetting drained peatlands: effects on greenhouse gas fluxes, plant production, and economics

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Drained peatlands are hotspots for greenhouse gas (GHG) emissions, which could be mitigated by rewetting and land use change. We performed an ecological/economic analysis of rewetting drained fertile peatlands in a hemiboreal climate using different land use strategies over 80 years. Vegetation, soil processes, and total GHG emissions were modeled using the CoupModel for four scenarios: 1) business as usual – Norway spruce with average soil water table of -40 cm; 2) willow with groundwater at -20 cm; 3) reed canary grass with groundwater at -10 cm; and 4) a fully rewetted peatland. The predictions were based on previous model calibrations with several high-resolution datasets consisting of water, heat, carbon, and nitrogen cycling. Spruce growth was calibrated by tree-ring data. The GHG balance of four scenarios, including vegetation and soil, were 5, 7, 9, and 6 Mg CO_2eq ha^{-1} yr^{-1}, respectively. The total soil emissions (including litter and peat respiration CO_2 + N_2O + CH_4) were 33, 19, 15, and 11 Mg CO_2eq ha^{-1} yr^{-1}, respectively, of which the peat loss contributed 35%, 24%, and 7% for the three drained scenarios, respectively. No peat was lost for the wet peatland. Draining increases vegetation growth, but not as drastically as peat respiration does. The cost benefit analysis (CBA) was sensitive to time frame, discount rate, and carbon price, however it indicated greater benefit with a somewhat higher soil water table and vegetated with willow and reed canary grass (Scenario 2 and 3). We conclude that saving peat and avoiding methane release, using fairly wet conditions, can significantly reduce GHG emissions, and that this strategy should be considered for land use planning and policy-making.

Nitrous oxide emission from tropical peatlands

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Abstract

In the current study nitrous oxide (N_2O) emission from tropical peatlands in French Guiana, Uganda, Myanmar and Malaysia (Sabah, Borneo) was measured and their relationships with soil chemical parameters, water regime, and abundances of genes encoding denitrification-associated nitrite and nitrous oxide reductases were analysed. From June 2013 to January 2017, 7–10-day gas- and soil-sampling campaigns were organised. In each country we established two sites, one in natural peatlands and another one in peatlands affected by human activities (e.g. drainage, intensive agriculture, fertilisation etc.). In all sites three sampling points were established. At each sampling point, N_2O emissions were measured in 3-6 sessions during two to three days using static closed chambers. Soil pH, NO_3-N, NH_4-N, P, K, Ca and Mg, TN and organic matter content were determined from the collected samples. In French Guiana fen samples the bacterial and archaeal 16S rRNA genes and functional genes involved in nitrogen cycling (*nirS*, *nirK*, *nosZI*, *nosZII*, bacterial and archaeal *amoA*, *nifH*, *nrfA*, ANAMMOX bacteria genes) in soil were quantified by using quantitative PCR method.
In all areas N_2O emissions were significantly higher in the affected sites than in the natural sites. Statistical analyses showed a strong positive correlation between the N_2O emissions and soil NO_3-N content ($p<0.05$), while soil moisture and water table level showed a negative correlation with N_2O emission ($p<0.05$) in all sites. Drainage had a clear impact on the communities of *nirS*, *nirK*, *nosZ*, archaeal *amoA* and *nifH* gene possessing microorganisms. The structure of the communities was mainly related to different N forms. The bacterial community was more abundant ($p<0.001$) in the natural site while the N_2O production potential (abundance of the *nir* genes) was not different between the drained and non-drained sites. N_2O reduction potential (abundance of *nosZ* genes) was higher ($p<0.01$) in the natural area where significantly lower mineral N content and high groundwater level were detected. Soil moisture and soil nitrate content are the key parameters regulating denitrification efficiency.

Raised water table and sand addition for mitigating greenhouse gas emissions from cultivated peat soils

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Cultivated peat soils are a significant source of greenhouse gases (GHG) in countries with a high proportion of agricultural peatland. Carbon dioxide and nitrous oxide emissions from cultivated peat soils constitute 30-60% of the total agricultural emissions in Denmark (DK), Estonia (EE), Finland (FI) and Sweden (SE). One option to reduce peat decomposition and these emissions is to raise the groundwater level, either close to the soil surface for production of wet-tolerant crops (paludiculture) or less completely and temporarily using controlled subsurface drainage in production of traditional agricultural crops. Another management option to reduce the emissions is to add sand to the topsoil. Raised groundwater level was experimentally tested at three sites (DK, EE, FI) and sand addition at one site (SE). Reed canary grass was grown on the DK and EE sites, cereal on the FI site and fodder on the SE site. Fluxes of nitrous oxide and methane were measured about biweekly using opaque chambers throughout a monitoring period of two years. Net ecosystem exchange of carbon dioxide was estimated based on measurements of photosynthesis and ecosystem respiration, and subsequent gap filling by modelling. Both reed canary grass sites had a more favourable carbon balance compared to the site with cereals. The highest emissions of nitrous oxide and lowest emissions of methane were found at the site with cereals. Maintaining the desired groundwater level was found to be difficult at all sites. We will compare the GHG balances of these sites with varying production and management options and discuss the effect of groundwater level and other management and site-related factors on the emissions. The potential of these methods to reduce GHG emissions from cultivation and the practical applicability of the management options will be discussed as well.

Annual CO_2, N_2O and CH_4 emissions from a Danish sphagnum peat bog under different land-uses

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Peatlands drained for agriculture are sources of atmospheric CO_2 and potentially N_2O. Resulting emissions may depend on land-use intensity, often as grasslands or croplands, but few studies have directly compared the effects of land-uses. Here, we measured annual fluxes of CO_2, N_2O and CH_4 from a confined Danish sphagnum bog with study sites including undrained natural bog (NB), drained permanent grassland and three drained croplands with rotations of oat-potato, oat-spring barley and potato-spring barley in the study year. Annual fluxes were measured using static chambers at 1-2 week intervals (33 campaigns), and auxiliary data were obtained, such as temperature, depth of water table, ratio-vegetation index, pH and soil mineral N. Soil respiration was markedly lower at the NB site than at the drained sites where emissions were not systematically different. The N_2O emission was negligible at NB, low at three of the drained sites, but high at potato-spring barley site (37.7 kg N_2O ha^{-1} yr^{-1}). The CH_4 emission was high at NB (172 kg CH_4 ha^{-1}), but negligible at drained sites. Despite some uncertainty in equating soil respiration to peat mineralization, the results aligned with studies, indicating that, at drained peat soil agroecosystems, soil C losses may be rather similar among different cropping systems and depend mostly on drainage status of the soils. The pattern of N_2O emissions suggested that the summer period of potato growth may be surrounded by periods of increased N_2O emission risk at drained organic peat soils, likely due to availability of NO_3^- outside the growing season. For initiatives aiming at reduction of greenhouse gas emissions, this means that, e.g., conversion from cropland to permanent grassland should preferably be accompanied by measures of rewetting, whereas for potato cropping, N availability outside the growing season should be minimized.

ABSTRACTS POSTER PRESENTATIONS

Carrot and lay cultivation on peat soils. (Photo: Kerstin Berglund)

Review on economic incentives for wet peatlands

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Peatlands are marginal lands; their utilisation has been highly influenced by economic incentives. Nowadays, the negative impacts of drained peatlands are widely known. The Food and Agriculture Organisation of the United Nations (FAO) supports paludiculture as an option for the responsible management of peatlands. For achieving a shift from drainage-based to wet agriculture, major importance is assigned to the development of incentives that account for social and environmental costs and benefits.

Our review compiles economic incentives and instruments that already exist in different European countries (e.g. Germany, Netherlands, Sweden, UK) and that may be used to support the implementation of agriculture on wet peatlands. Incentives as payments for ecosystem services represent the changed societal demands, may initiate and reward the shift to sustainable peatland use and increase the economic viability and competiveness of paludiculture. Four different sources of financing are identified: a) government-financed instruments as agri-environment-climate measures within the 2nd pillar of the EU Common Agricultural Policy (CAP) or national payment schemes for nature management, b) compulsory measures compensating building or mining activities financed by enterprises, c) taxes, levies, charges and d) instruments such as voluntary markets for ecosystem services allowing for private sector or private persons investments. Payments can support investments, reward measures or remunerate results. Incentives can focus on any point of the production chain including rewetting, establishment of paludicultures, management, biomass processing and marketing of products including the provision of specific ecosystem services.

We present our preliminary analyses and selected examples. Furthermore, we are looking forward to meeting interested participants of the conference to learn about experiences in different countries and discuss recommendations for incentives to encourage paludiculture.

Effects of sand addition on trafficability, yield and CO_2 emission from an agricultural peat soil

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Peatlands store a major share of the world's soil organic carbon and are widespread in Northern and Central European countries. Drainage is a precondition for traditional agricultural production on organic soils. Drainage fosters peat mineralization and changes the physical and chemical soil quality. Only a few decades after initial drainage, agricultural systems on drained organic soils start experiencing a high risk of crop failure. Decreased hydraulic conductivities lead to decreased infiltration, ponding, and finally to abandonment as drainage will not be effective anymore. Another problem is the low trafficability.

The aim of this experiment is to investigate if the addition of foundry sand to the top soil will improve the trafficability without increasing the CO_2 emission. In the Swedish part of the EU-funded CAOS project, a field experiment (randomized block design, 3x3) was set up at a former cultivated, but now abandoned, fen peat located at Bälinge Mossar (60.02821N, 17.43008E). We compare trafficability, yield and CO_2 emission from plots sown with timothy (*Phleum pretense*) and treated with 0 cm, 2.5 cm or 5 cm foundry sand. The sand was applied in the autumn of 2015 and mixed in the top 10 cm of the soil. CO_2 emissions were measured with automatic chambers (ADC BioScientific, UK) taking 12 measurements per day in frames where we removed the vegetation. The first results from the autumn of 2015 (15/9-1/11) showed that the CO_2 emissions were highest from the plots without sand addition (3.4 µmol m^{-2} s^{-1}) and lowest from the plots where 5 cm sand was added (1.4 µmol $m^{-2}s^{-1}$). The emission from the 2.5 cm treatment was 1.8 µmol m^{-2} s^{-1}. During 2016 (4/5 – 27/9), the emissions were lowest from the plots treated with 5 cm foundry sand (4.26 µmol $m^{-2}s^{-1}$), and highest from the plots with 2.5 cm sand (6.10 µmol $m^{-2}s^{-1}$). The untreated plot had an average CO_2 emission of 5.09 µmol $m^{-2}s^{-1}$.

Max.Moor – A new compensation standard – CO_2-Certificates of rewetted Peat Bogs on the voluntary Carbon Market in Switzerland

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Introduction

The Swiss Prealps and the Jura mountains are covered by small peat bogs. 90% of the bogs have been drained in the last century. Although peat bogs are protected by constitution since 1989, only few of them have been rewetted so far. As the scientific data basis on CO_2 emissions of drained and rewetted peat bogs in Switzerland is very weak – and because of the constitutional protection and thus the supposed lack of problem – it was not possible to exploit the climate potential of the drained peat bogs so far. With a new approach, avoided CO_2-emissions of rewetted peat bogs can now be estimated and sold as CO_2-certificates on the voluntary carbon market in Switzerland.

Methods

Instead of measuring the CO_2 emissions, the new approach focuses on the content of organic carbon in the drained peat horizon. In a persisting drained state of the peat bog, the organic carbon will be mineralized and emitted into the atmosphere – as soon as the bog is rewetted and the peat is waterlogged again, the mineralization will be stopped. The organic carbon content of the drained peat horizon can therefore be counted as the avoided emission of CO_2 equivalents once the peat bog has been rewetted. On the basis of a cost analysis of 35 finalized rewetting projects in Switzerland, a price per ton of CO_2 could be determined.

Results

Max.Moor calculates with >1000 tons of avoided CO_2 per hectare of rewetted peat bogs for a price of 76 Swiss Francs per ton of CO_2. Two of the most known offset providers in Switzerland have accepted the new standard and are now offering peat certificates on the voluntary carbon market.

Seasonal effect of ground water level on soil CH_4 and N_2O emissions in peatland cultivation

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Raising the ground water level by using controlled subsurface drainage system is suggested to be an effective way to reduce the soil CO_2 emissions and soil organic matter losses in cultivated peatlands. However, it is equally important to explore the effect of raised ground water level on other greenhouse gases, CH_4 and N_2O, as the global warming potential of those gases is 25 and 298 times greater than for CO_2.

CH_4 and N_2O emission of peatland cultivation was studied in a field experiment in Mouhijärvi in Southern Finland. The experiment consists of 4 plots, of which two are equipped with controlled drainage system. Gaseous emissions of CH_4 and N_2O were determined using a closed-chamber method with subsequent gas chromatographic analysis. Emissions were measured twice a month in summer time and once a month in winter time (Jan 2015-Sep 2016). The ground water level was measured along with the gas measurement. Data was analyzed using linear mixed effect models.

Soil CH4 emissions decreased with lowering the ground water level especially during the growing season. The soil turned to sink for CH_4 at the ground water level of about 30cm. CH4 emissions were small in winter time. In contrast to CH_4, N_2O emissions were greater the lower the ground water level was, and wintertime emissions were equal or even higher than in the growing season. With respect to climatic impact, N_2O emissions turned out to be more critical than CH_4 emissions.

The results suggest that raising the ground water level outside growing season would be the most feasible way to reduce the adverse effect of CH_4 and N_2O emissions on climate.

Summer CO_2 and CH_4 fluxes from emerging *Sphagnum* lawns in a rewetted extracted peatland in Sweden

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16 years (2015) after rewetting a nutrient-poor extracted peatland, a functioning wetland ecosystem with stable hydrology and characteristic peatland vegetation has been established. Some parts of the restored wetland are covered by almost 100 % of *Sphagnum* and terrestrialization by *Sphagnum* of the newly established shallow lakes is proceeding rapidly. To monitor the *Sphagnum's* climate impact, sites with dense *Sphagnum* lawns were investigated with transparent automated chambers for methane (CH_4) and carbon dioxide (CO_2) fluxes in summer 2015.

In June, July and August 2015, the *Sphagnum* sites were CO_2 sinks (-15, -28 and -15 g CO_2-C equivalents m^{-2}) but also CH_4 sources (28, 22, 55 g CO_2-C equivalents m^{-2}). Adding for both gases, the sites were sinks in July (-6 g CO_2-C equivalents m^{-2}) and sources in June and August (13 and 40 g CO_2-C equivalents m^{-2}).

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Drained peat soils as sources of HONO (nitrous acid) gas

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Nitrous acid (HONO) is not a greenhouse gas. The photolysis of HONO is an important source for OH radicals, which can oxidize e.g. methane from the atmosphere. HONO is very reactive gas and the concentrations of HONO in the atmosphere show diurnal pattern; high concentrations at the night and low concentrations during daytime due to rapid photolysis in sunlight. The emissions of HONO from soils have been recently reported in few studies (e.g. Su et al. 2011, Oswald et al 2013). These emissions are regarded as missing sources of HONO when considering the chemical reactions in the atmosphere. The soil-derived HONO has been connected to soil nitrite (NO_2^-) and directly to the activity of ammonia oxidizing bacteria, which has been studied with pure cultures (Oswald et al. 2013).

In our studies boreal drained peat soils (including agricultural soils) were significant sources of HONO (Maljanen et al. 2013). We measured a range of dominant northern acidic soils and showed in microcosm experiments that soils which have the highest nitrous oxide (N_2O) and nitric oxide (NO) emissions also have the highest HONO production rates. Natural peatlands and boreal coniferous forests on mineral soils had the lowest HONO emissions. It is known that in natural peatlands with high water table and in boreal coniferous forest soils, low nitrification activity (microbial production of nitrite and nitrate) limits their N_2O production. Low availability of nitrite in these soils is the likely reason also for their low HONO production rates. We have also found that soil moisture in agricultural soils is an important controlling factor for HONO; emissions increase when soil moisture decreases. However, the seasonal/annual HONO emissions from e.g. drained peatlands are not known and therefore we cannot calculate e.g. HONO/N_2O emission ratio and speculate how much OH production related to HONO emissions could compensate the GHG emissions from such soils.

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Do cover fills reduce peat oxidation and carbon emissions from managed organic soils?

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Peatlands have served as important carbon sinks in the past. The agricultural use of organic soils usually requires drainage thereby transforming these soils from a net carbon sink into a net source. Besides CO_2 emissions from peat oxidation, drainage also results in subsidence of organic soils. The drainage system requires a periodic renewal to sustain agricultural use. Finally, pumping systems are used after progressive subsidence. In Switzerland there is a high demand for maintaining agricultural use of organic soils while simultaneously reducing environmental impacts. One solution may be to cover the organic soils with excavated material in order to improve the productivity without the costly step to renew the draining system. Previous studies showed that the agricultural use seems do benefit from this measure; however, the impact on the greenhouse gas balance is unclear. Our newly established study site is situated in Rüthi, St. Gallen, Switzerland on the former flood plain of the Rhine River. In the 1970s, the land was drained, pastures established and intensively managed since then. Nowadays agriculture becomes problematic since the soil is water-saturated most of the season. Due to the high cost, drainage renewal was not an option to ensure the existence of the farm located at the study site. Instead, it is planned to cover 30 ha with excavated soil material. As a pilot project, 2 ha were covered with 30 to 50cm silty material already in 2006. The aim of the project is to evaluate the impact of soil coverings on the carbon balance. The carbon balance of the covered and an adjacent reference site will be measured with an Eddy-Covariance system for two years. In addition, the ^{14}C signature of the emitted CO_2 will be measured occasionally to differentiate between carbon deriving from old peat and from newly formed soil organic matter.

Soil respiration of a covered fen peat as affected by mineral layer thickness

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Drained and agricultural utilized peatlands are known as hot-spots for greenhouse gas emissions as a consequence of peat oxidation. However, in riverine fen regions a significant share of peatlands is often covered by mineral layers of river sediments deposited during natural or anthropogenic flood events. Depending on flood frequency, river-site distance and topography, these mineral layers might be extremely variable in terms of thickness and composition. In this study, we investigated the combined effects of thickness and texture of a mineral peat cover as well as environmental variables on soil respiration. The study site, located in the Upper Rhine Rift in Southwest Germany, has been identified as a significant source of CO_2 by eddy covariance and manual chamber measurements with annual budgets in the range of those known from agricultural sites on peat rather than on mineral soils. In 2017, the site was cropped with grain maize. After seeding, plots with bare soil were established on three locations (n = 3) differing in thickness of the mineral soil layer (32.5, 77.0 and 111.5 cm, respectively) and soil texture (silty clay at the plots with shallow cover and silty loam at the plots with thicker cover). At each of the three locations the groundwater level, the soil volumetric water content, the soil temperature and the electrical conductivity in the soil were continuously measured. The soil respiration was measured with closed manual chambers and an attached infrared gas analyzer during 12 campaigns between late May and late October. First results showed that most of the variability in soil respiration could be attributed to differences in soil moisture while no systematic differences between different thicknesses of the mineral soil layer could be identified. However, analyses of the isotopic signature of soil carbon reveal potentials for a source estimation of CO_2 efflux.

The influence of agricultural management on carbon losses and subsidence of selected peatlands in Central and Northern Europe

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Peatlands constitute the most efficient carbon store of all terrestrial ecosystems. Due to cultivation of organic soils the positive carbon balance is disturbed, because atmospheric CO_2 uptake is prevented, extreme mineralisation takes place, and thus organic soils turn into greenhouse gas emitters. Europe has lost around one half of its natural peatlands mainly due to agricultural management. Peat cores taken from nine drained and cultivated peatland sites in Denmark, Estonia, Finland and the Netherlands were analysed in this study with the main focus on the amount of carbon losses. All cores were cut into three cm segments and analysed regarding to density and loss on ignition. With additional measurements of carbon stocks in the reference part of each peat core subsidence and carbon losses were calculated. Results for carbon losses range from zero to 877.19 (±79.85) t ha^{-1} with a corresponding total subsidence between nearly zero and 1.04 (±0.03) m. All results for subsidence and carbon loss were analysed with regard to differences in agricultural management particularly land use, time since cultivation, and the depth of drainage. Sites with long cultivation time showed extremely high carbon losses, but a clear functional dependency could not be inferred due to limited data. Carbon losses from sites used as cropland were determined two times higher than from sites used as grassland, because tillage and aeration is more intense. Additionally, highly groundwater influenced horizons (Hw) identified in soil profiles were correlated with low carbon losses. Overall, results of this work indicate a strong influence of agricultural management especially type of land use and the corresponding intensity of soil aeration and the depth of drainage on the amount of carbon losses from European organic soils.

Quantifying the contribution of plant-induced pressurized flow to CH_4 emission from a *Phragmites* fen

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Abstract

Phragmites australis has the ability to transport gases through their stems via a pressurized flow, resulting in oxygen transport to the rhizosphere and soil gas (CH_4 and CO_2) transport in the opposite direction to the atmosphere. This raises the question how pressurized gas transport through plants affects CH_4 emission compared to a situation where gas transport is dominated by diffusion and ebullition.

A field experiment was set-up in a *Phragmites*-dominated fen in southwest Germany, measuring CH_4 fluxes with transparent chambers. CH_4 emissions from intact *Phragmites* plants were compared to fluxes from plots where *Phragmites* culms were removed (to exclude the pressurized flow) and to fluxes from plots where culms were removed and sealed (to exclude any transport through the plants). Ebullition from the soil was determined to assess the relative contribution of all three gas transport pathways (plant-mediated, diffusion and ebullition).

Excluding pressurized flow by cutting the *Phragmites* stems reduced CH_4 flux (without ebullition) by about 60%. On the other hand, ebullition increased by a factor of 13. When ebullition is accounted for, the total CH_4 flux from intact reed was 1.3 to 2.3 times higher than for cut and sealed and cut reed. In other words, the increase of ebullition by cutting off the *Phragmites* stems did not fully compensate for the excluded pressurized flow through the living *Phragmites* plants. Thereby, the pressurized flow does not result to overall higher CH_4 oxidation, even though it increases the oxygen levels in the rhizosphere. Our study shows that pressurized gas transport through wetland plants is an important contributor to the CH_4 emission from *Phragmites* wetlands.

Combustibility and nutrient export potential of biomass from rewetted fens in North Eastern Germany

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Paludiculture can be applied for water buffer zones as an integrative concept using biomass from wet peat soils. Solid biofuels are one option for biomass utilisation from paludiculture, but have to meet high quality standards to fulfill legal requirements. The late harvest in winter is a common practise to increase combustibility of solid-biomass, especially for herbs and grasses. Critical elements for combustion will be reduced in the standing biomass by leaching through precipitation. Additionally some plant species reallocate nutrients to the rhizomes during autumn (f.e. Common Reed).

Combustion quality of Common Reed (*Phragmites australis*) and Sedges (*Carex* spp.) are also increased by a late harvest in winter. Common Reed showed low critical elemental concentration, with 0,5% N, 0,1% S and 0,08 % Cl (d.b.) in February. Sedges lost 95% of the total chlorine concentration, from 0.62 (summer) to 0.03 % (winter), but N and S decreased only slightliy from summer (1.4 % N/0.21 % S) to the winter (1.24 % N/0.16 % S (d.b.)).

Coincidently, winter harvest of the plants goes along with lower yields and lower nutrient contents resulting in lower nutrient uptake potential. *Carex-acuta* yield decreased from August (4.5 t/ha) to February (3 t/ha) with nutrient contents of 6 kg P/ha and 63 kg N/ha in August and 4 kg P/ha and 37 kg N/ha in February. *Phragmites australis* yields of the studied sites were relatively low with 6.5 t/ha (October) and 3.8 t/ha (February) in comparison to values from other studies in Northeast Germany that ranged from 2-12 t/ha (d.b.), in February. The measured biomass nutrient content was 4 kg P/ha and 50 kg N/ha in October, and 1.7 kg P/ha and 21 kg N/ha in February.

Harvesting in early autumn is most appropriate to combine the production of solid biofuels with the removal of nutrients in water buffer zones. If nutrient export from the wetland buffer zone is the more important issue, harvesting should be realised in summer. This biomass with low quality for combustion can be mixed with high quality biomass (f.e. wood) or other kinds of pre-conditioning (washing, mechanical dehydration) are required.

REPEAT: REstoration and prognosis of PEAT formation in fens - linking diversity in plant functional traits to soil biological and biogeochemical processes (2017-2019).

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REPEAT is a research project funded from ERA-NET co-funded BiodiVERsA program. REPEAT consists of partners from Poland, Germany, Belgium, Norway and Romania and has all together 96 study sites in Wales, the BeNeLux, Germany, Poland and Romania. Our main research question is to assess how environmental factors and human management interact with soil biodiversity in determining rates of peat accumulation in undrained and rewetted fens. Specifically, we study the impacts of drainage degree (i.e. pristine, drained and rewetted sites), trophy (sites with different nutrient availability and associated plant productivity) and mowing (on sites that are used for paludiculture) on peat formation and decomposition using an assembly of state-of-the-art and innovative methods. We record hydrological, hydrochemical and management statuses, peat decomposability (C/N ratios and OM fractions with CN analyzer and FTIR, respectively) as well as greenhouse gas concentrations and nutrient stoichiometry (along depth gradients) for each of the sites in 2017. Subrecent peat formation at the sites is measured using fine-resolution macro- and microfossil and radio-isotope studies (^{14}C, ^{210}Pb, ^{137}Cs). Peat formation and decomposition is assessed using in-growth and litter bags, respectively (2017-2018). Additionally, we will carry out in depth studies on taxonomical and functional biodiversity of both producer and decomposer communities. We aim at developing and improving existing peat accumulation models to be better suited for fen ecosystems as well as for providing information on management practices, particularly on rewetting. We will also provide recommendations for management and restoration of fens and develop a practical method to assess peat formation in restored fens feasible to be implemented by stakeholders.

Strength and permeability of cultivated Histosols characterized by differing degrees of decomposition

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Cultivated organic soils (Histosols) are an important part of the agricultural economy in Canada. Although highly productive, they are very sensitive to degradation and compaction (Parent and Millette, 1982). The objective of this work was to characterize the soil penetration resistance (PR) and the saturated hydraulic conductivity (ksat) in cultivated organic soils that differed by their degree of decomposition. Three fields in the plain of Montreal, in southwestern Quebec, were selected to provide a gradient of degrees of decomposition. Site 1 was classified as a Limnic Fibrisol (LM.F), Site 2 was classified as a Terric Mesic Humisol (TMH), and Site 3 was classified as a Terric Humisol (TH) (Canadian soil working group (CSWG), 1998). At each site, penetration resistanceand ksat were measured directly in the field. Penetration resistance was found to increase with increasing soil degradation. The inverse relationship was observed for ksat in the compact layer. The results presented in this study indicate that penetration resistance and ksat are both linked to the degree of soil decomposition. The relationship between both parameters is complex, however, and both parameters are to be measured to achieve a more accurate characterization of organic soils. Penetration resistance could be used to assess the depth of the compact layer as well as the degree of decomposition of organic soils at different spatial scales. Accurately mapping ksat would help in designing field drainage system.

The results of soil conditions monitoring for purpose of the planned active birds protection in the area of Northern Polder of National Park „Ujście Warty”

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The National Park “Warta Mouth” was established in 2001 and covers area of 8074 ha. It is located at the western part of the Poland in a fragment of Toruń – Eberswald valley. The Warta River flowing through the middle of Park and is the natural border between floodland and the area of so-called Northern Polder. The northern area of the Park was separated from the direct influence of the Warta’s by formed levee along the river bed. The soils of the Northern Polder mainly consist of peat or gyttja, and their layer may reach a thickness up to 6 meters. The main objective of this study was to evaluate the impact of water management practices on subsidence rate of organic soils of North Polder area. The filed monitoring of soil subsidence and soil surface pulsation was conducted at two spots from September 2013 till end of May 2017. The selection of the measurements points was made according to the planned construction of the weirs for irrigation. Therefore one monitoring point was located close to the planned construction (point 27) whereas second one was located out site the area maintain by water table from the weir (point12). The results of our study showed that in measurements period the average subsidence of soil profile was equal to 1.9 cm in the field with planned irrigation schedule. In the spot 12 the average soil subsidence was lower and equal to 1.2 cm. Based on the monitoring results and soil physical properties the yearly emission of CO_2 for both spots was calculated. Assuming that 40% of soil subsidence can be loss as a carbon the average yearly emission in both analyzed cases was comparable and equal approximately 5 t ha^{-1}.

Modeling of drainage systems suitable for cultivated organic soils with a compact layer Study in Monteregie

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Key words: Organic soils, Compaction, Penetration resistance, Saturated hydraulic conductivity, Bulk density

The project takes place at Laval University of Quebec in partnership with growers in Monteregie region of southwestern Quebec facing muck soils compaction problems. The overall objective is to model drainage systems adapted to organic soils cultivated with a compact layer. However, such models require mapping saturated hydraulic conductivity as one of the key variables influencing drainage or building easier to collect co-variables like penetration resistance (RE) and bulk density (MVA) to increase sampling density. We therefore performed various measurements of RE, MVA and Ksat in different and to explore relationships with simple and multiple regressions and a random forest approach. The data are preliminary but indicated so far few relationships between RE, Ksat and MVA and suggest that penetrometer resistances are relevant to detect the location of the compacted zones and map zone where Ksat should be sampled with higher resolution but provide limited value as a covariable to predict Ksat.

Hydraulic Properties of Peat Soils – A Meta Study

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There is a limited understanding of hydraulic properties of peat soils as compared to mineral substrates. In this study, we aimed at deducing possible alterations of hydraulic properties of peat soils during the course of soil degradation resulting from peat drainage. A data set of peat hydraulic properties (188 soil water retention curves (SWRCs), 64 unsaturated hydraulic conductivities curves (UHCs) and 189 saturated hydraulic conductivity values) was assembled from the literature; the analysed data originated from peat samples with a soil organic matter content ranging from 23 to 97 wt% and an according variation in bulk density. The results showed that the Mualem-van Genuchten model (MVG) can appropriately describe all of the tested SWRCs with the residual water content being set to zero. The values of the MVG model parameter α were greater for less decomposed peat than those of mineral soils because of a large fraction of macroporous pore space in more pristine peat. An increasing bulk density from below 0.1 to 0.2 g cm^{-3} caused a dramatic decrease in volume of macropores as well as water yield, whereas these quantities remained almost constant with bulk densities further increasing from 0.2 to 0.76 g cm^{-3}. The UHCs of less decomposed sphagnum peat, wooden peat and highly decomposed sphagnum and sedge peat differed completely from each other indicating a high impact of the peat forming plants as well as stage of decomposition on hydraulic properties. The pronounced diversity of peat soils demands an individual treatment of soil samples and data bases (e.g. SODA etc.) shall define the peat development process resp. botanical origin as selection criteria in addition to organic matter content and bulk density.

Greenhouse gas emissions from a fen covered with riverine silt

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Drainage is necessary for conventional agriculture on peatlands, but this practice causes high emissions of the greenhouse gases carbon dioxide (CO_2) and nitrous oxide (N_2O). The effect of hydrological conditions and management on greenhouse gas emissions (GHG) from "true" peat soils is relatively well examined, but there is little data on GHG emissions from organic soils covered with mineral soil. Such a cover may either be man-made to improve the trafficability of the fields or natural, e.g. due to the deposition of riverine silt. Here, we aim to evaluate the effect of hydro-meteorological conditions and properties of the mineral cover on the emissions of CO_2, N_2O and methane (CH_4). As the majority of peatlands in North-Western Germany, the study area is artificially drained and used as high-intensity grassland. The fen peat is covered by riverine silt deposited by the river Weser. Six measurement sites have been chosen to represent typical agricultural management, soil properties and hydrological conditions. They differ in the soil organic carbon content of the riverine silt, the occurrence of a ploughed horizon as well as water and agricultural management. We use manual chambers to measure CO_2, CH_4 and N_2O fluxes. CO_2 measurement campaigns using transparent and opaque chambers and a portable IRGA take place every third or fourth week depending on season. CH_4 and N_2O samples are taken every second week and more frequently after fertilizer application. N_2O fluxes were controlled by soil moisture and temperature with the highest peaks occurring during freeze-thaw cycles. Annual N_2O emissions (4 to 14 kg N_2O-N) from peat soils covered with riverine silt were in the same range as emissions from true peat soils with comparable fertilisation rates. Due to low groundwater levels, there was a slight uptake of CH_4. First results on CO_2 emissions will be presented as well.

Project „Gnarrenburger Moor“
Testing climate smart agriculture on bog sites in Lower Saxony (Germany)

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Drained peatlands are hotspots for greenhouse gas (GHG) emissions, in particular carbon dioxide (CO_2). The water table position within the peat layer in general determines the amount of CO_2 released to the atmosphere. Agricultural peatland usage requires suitable drainage to ensure management practices (e.g. fertilization, harvest) as well as plant growth. Thus, especially deeply drained and agriculturally used peatlands are characterized by high GHG emissions. Based on their areal importance (about 256,000 ha on fens and bogs) and their high GHG emissions, agriculturally used peatlands represent a key source of GHG emission in Lower Saxony (contributing about 10% to the overall GHG emissions). Thus, water table optimization in agriculturally used peatlands may have a considerable reduction potential of GHG emission.

GHG emission reduction by raising the water table faces the need of a firm sward and a suitable trafficability for management purposes, which is currently fulfilled by deep water tables. Thus, a main goal of the project “Gnarrenburger Moor” is the establishment of raised water tables for GHG emission reduction while allowing an intense agricultural grassland usage. In addition, a permanent involvement of farmers in the project is intended to increase the acceptance for water management options on grassland areas.

Field experiments are key elements in the project. Depending on current land use intensity (extensive grassland, intensive grassland) different water management options (e.g. water regulation with weirs, subsurface irrigation) will be tested. All conducted water management options are assessed by feasibility, management limitations, plant growth as well as water table dynamics.

The poster presents the principle setup and aim of the project and provides further information about field experiments as well as the communication structure within the project.

Controlled drainage on a peat soil

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Raised water table is reported to be an effective measure to diminish the oxidation of organic material on cultivated peat soils, and thus emissions of gaseous carbon and nitrogen to the atmosphere. Water table can, in theory, be regulated by the means of controlled drainage. The aim of this study was to monitor the reactions of the water table on the field to the changes of the control level in practical field conditions.

The experimental site was situated on a private farm on a fen peat soil in Southern Finland. There were two control wells, where the control level was kept either 30 cm or 60 cm below the soil surface throughout the year except for the periods of sowing in May, and harvesting and cultivation in August or September. The level of the ground water table on the field was monitored by observation wells (diameter 50 mm), which were installed on the field at different distances from the drainage pipes.

The level of the ground water table in the observation wells, as well as the control level in the control wells were read manually from November 2013 to March 2017. The data was analyzed by visual observation of the diagrams drawn.

The data showed that that water table reacted to the changes of the control level, but slowly. Water table did not stay at the adjusted level in dry periods but lowered below the control level. Thus, controlled drainage could help to regulate the water table level to a certain degree, but was not a guaranteed method to regulate water table on the studied peat soil.

Crop yield estimates of the SWAP-WOFOST model on peat soil in northern Europe.

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Peat soils form a major share of soil suitable for agriculture in northern Europe. Successful agricultural production depends on hydrological and pedological conditions, local climate and agricultural management. Climate change impact assessment on food production and development of mitigation and adaptation strategies require reliable yield forecasts under given emission scenarios. Coupled soil hydrology - crop growth models, driven by regionalized future climate scenarios are a valuable tool and widely used for this purpose. Parametrization on local peat soil conditions and crop breed or grassland specie performance, however, remains a major challenge. The subject of this study is to evaluate the performance and sensitivity of the SWAP-WOFOST coupled soil hydrology and plant growth model with respect to the application on peat soils under different regional conditions across northern Europe. Further, the parametrization of region-specific crop and grass species is discussed. First results of the model application and parametrization at deep peat sites in southern Finland are presented. The model performed very well in reproducing two years of observed, daily ground water level data on four hydrologically contrasting sites. Naturally dry and wet sites could be modelled with the same performance as sites with active water table management by regulated drains in order to improve peat conservation. A simultaneous multi-site calibration scheme was used to estimate plant growth parameters of the local oat breed. Cross-site validation of the modelled yields against two years of observations proved the robustness of the chosen parameter set and gave no indication of possible overparametrization. This study proves the suitability of the coupled SWAP-WOFOST model for the prediction of crop yields and water table dynamics of peat soils in agricultural use under given climate conditions.

Influence of Deep-rooted Plants in a Rotation on Water Infiltration in Organic Soils Used for Vegetable Production

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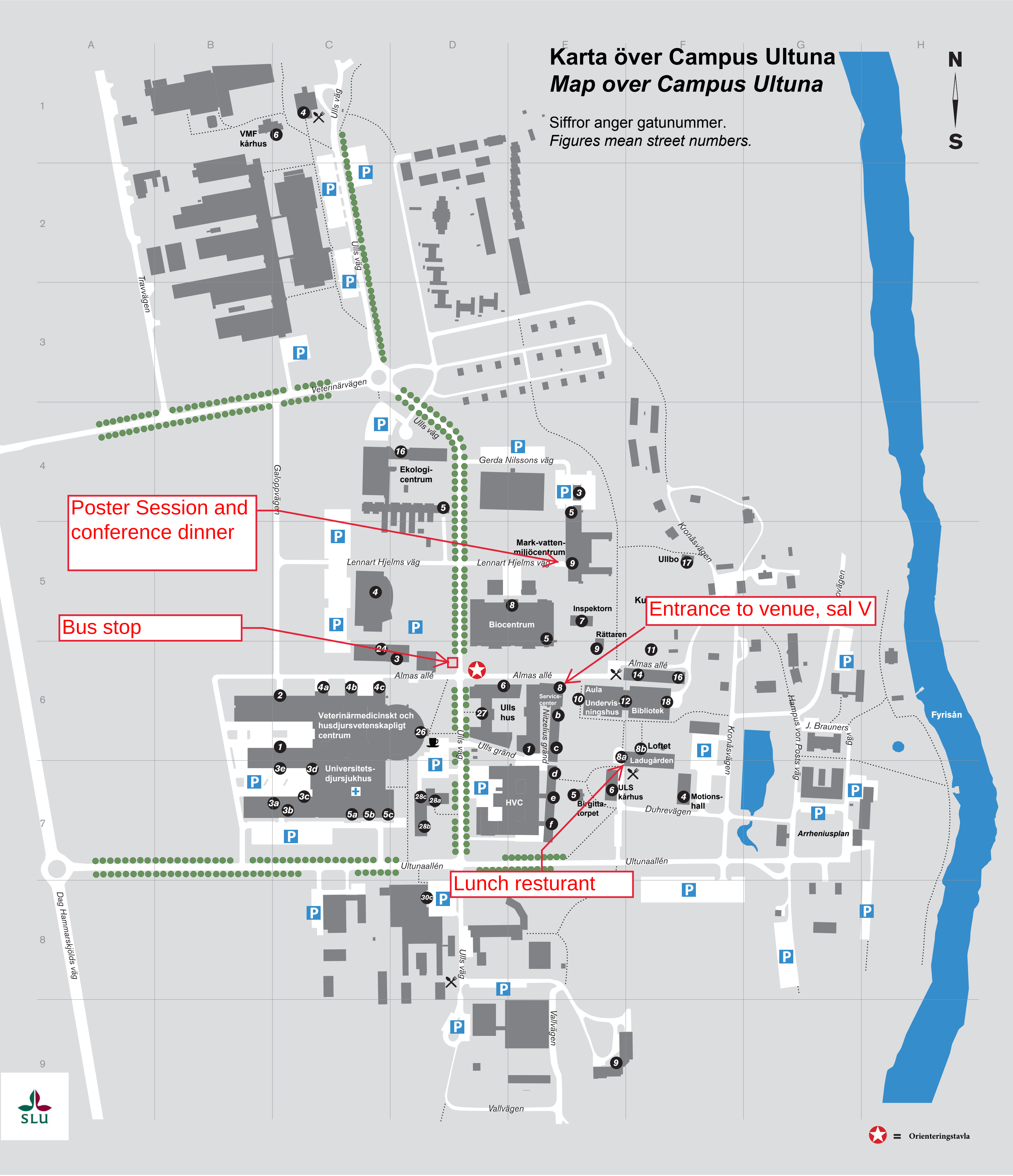
In Québec, most of organic cultivated soils are used for vegetable and peat production. Although highly productive, organic soils are subject to intense degradation from initial drainage and cultivation. This degradation accelerates as the water level decreases into the profile, and the development of a compact layer at a 20-40 cm depth can be observed. This compact layer is associated with the accumulation of fine and compact particles, which can lead to the formation of a perched water table in the root zone. It has been hypothesized that the integration of deep-rooted plants could improve drainage of organic soils, as previously demonstrated in compacted mineral soils. The objectives of the project were to identify a plant species to be used in rotation to improve water infiltration into degraded organic soils, and to determine the long-term residual effects. Experimental plots of deep-rooted crops were planted in Montérégie (Québec, Canada) on different sites, which were mesic and fibric Histosols. Saturated hydraulic conductivity measurements were taken at the soil surface and at 30 cm depth. Measurements of soil penetration resistance were also taken using a digital penetrometer. The results of soil penetrometer measurements and hydraulic conductivity were variable and differed between sites. We observed significant effects of water infiltration the year of the rotation, but it disappeared the following year, after the re-introduction of the main crop, which was lettuce. It can therefore be concluded that the effect does not persist after the end of the rotation. Future research should probably focus for longer rotation and for introduction of fibric material, as a way of conservation for organic soils.


Karta över Campus Ultuna
Map over Campus Ultuna
Siffror anger gatunummer.
Figures mean street numbers.
N
S
Poster Session and conference dinner
Bus stop
Entrance to venue, sal V
Lunch resturant
Ekologi-centrum
Mark-vatten-miljöcentrum
Biocentrum
Inspektorn
Rättaren
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