Martin Larsson, Holger Johnsson, Katarina Kyllmar, Kristina Mårtensson and Kristian Persson

Technical description of SOILNDB (V. 2.1)

Teknisk beskrivning av SOILNDB (V. 2.1)

Teknisk rapport 84 **Uppsala 2004**

Avdelningen för vattenvårdslära

Swedish University of Agricultural Sciences

Division of Water Quality Management

Preface

We would like to thank Hans Johansson (Department of Soil Sciences, Division of Hydrotechniques) for skilful programming. This work was carried out within the Swedish Water Management Research Programme, VASTRA, financially supported by the Foundation for Strategic Environmental Research, MISTRA. Funding was also received from SLU, the Nordic Council of Ministers and the Swedish Environmental Protection Agency, which is gratefully acknowledged.

Contents

Summary

To effectively allocate resources to reduce nitrate leaching and the resulting adverse effects on the environment, it is of great importance to quantify the contribution from different agricultural management practices and different agro-environmental conditions. In this paper we present a decision support tool, SOILNDB, that can be used to quantify nitrogen leaching losses from large areas of arable land where the availability of detailed data is limited. SOILNDB is also a useful tool for studying the effects of changes in agricultural management and land use on leaching, and for evaluating alternative management practices to minimise nitrogen leaching. The basis for SOILNDB is two widely used 'research models', SOIL and SOILN which describe water and heat fluxes, and nitrogen transformation and transport processes in the soil. A parameter database and parameter estimation algorithms are used to convert the input data in SOILNDB to parameter values for the SOIL-SOILN models. Model outputs can be presented either in a summarised form with yearly averages, or in more detail as time series with daily resolution.

Introduction

The increase in nitrate concentrations in groundwater, surface waters and coastal marine waters over recent decades is a subject of great concern because of the influence on eutrophication (e.g. Heathwaite, 1993; Owens, 1993) and because high nitrate concentrations in groundwater could lead to a deterioration in human health (e.g. O'riordan and Bentham, 1993). In many populated regions the largest source of nitrogen to these waters derives from arable land. To reduce nitrogen leaching losses from arable land, local authorities, national governments and international commissions have initiated several action plans. Consequently, the need for estimating nitrogen load from agriculture and its distribution, both on a local and regional level, has increased. Important objectives with such calculations may be; (i) to quantify N leaching from arable land and its temporal and spatial variation, (ii) to separate the contribution from arable land from other sources, (iii) to study the effects of changes in agricultural management and land use on the leaching losses, and (iv) to find and quantify alternative management practices which minimise nitrogen leaching losses.

For these objectives, simulation models are useful tools. Preferably, a model used for such calculations should be robust, meaning that it should rely on generally accepted scientific principles for the behaviour of the system described and that it should be thoroughly tested against experimental data under various agro-environmental conditions. On the other hand, it is also desirable that the model only requires a limited amount of input data since the availability of detailed data normally decreases with the increase in area. Also, it should be simple to use to reduce time and costs for the applications.

Management oriented models are often simplified, functional/empirical and easy to use while research models often are detailed, complex and normally quite difficult to use for management purposes (e.g. Håkanson, 1995; Addiscott and Mirza, 1998). However, an advantage of using an existing 'research' model for management purposes is that they often rely on more mechanistic descriptions of processes in the soil-plant system affecting nitrogen leaching. This increases the confidence in predictions of N leaching provided that relevant parameterisations can be made. An additional advantage of using an existing model is that the tests and parameterisations of these models (and of course also model development) already made in research applications can form the basis for the management applications. The extent, resolution and quality of data used for the parameterisations in research applications are normally quite high. Thus, the reliability of the results obtained for applied purposes will rely on the reliability of the model which, in turn, relies on previous evaluations of the model. An additional advantage of using a research model is that it can be utilised to relate research results, manifested through model development and parameterisation, to applications.

In Johnsson et al. (2002), a management oriented decision support tool to quantify nitrate leaching, SOILNDB, was presented. SOILNDB is based on the mechanistic research oriented models SOIL-SOILN, a parameter database and parameter estimation algorithms. In this technical description, we explain how the different parameter values in the parameter database were derived and we also describe in detail the parameter estimation algorithms.

System overview

SOILNDB (Fig 1.) is a shell program which links input data to automatic parameterisation procedures for the water and heat model SOIL (Jansson and Halldin, 1979) and the nitrogen model SOILN (Johnsson et al., 1987). No conceptual or mathematical differences exist between the research versions of SOIL/SOILN and SOILNDB. Thus, the results produced by SOILNDB can be fully reproduced by the research versions. Both SOIL and SOILN include the possibility of choosing between different submodels for some processes. In such cases, the best tested submodels, or in some cases those that require least parameterisation, have been chosen. A compilation off the submodels in SOIL/SOILN used for SOILNDB are shown in Appendix 1 (Tables A1 to A4). With SOILNDB the time-consuming process of parameterisation, administrating model runs, and presenting model results is reduced, allowing a large number of calculations for various agro-environmental conditions (e.g. scenario calculations) to be made efficiently. One or a group of sites can be simulated, where each site should contain at least two years of data.

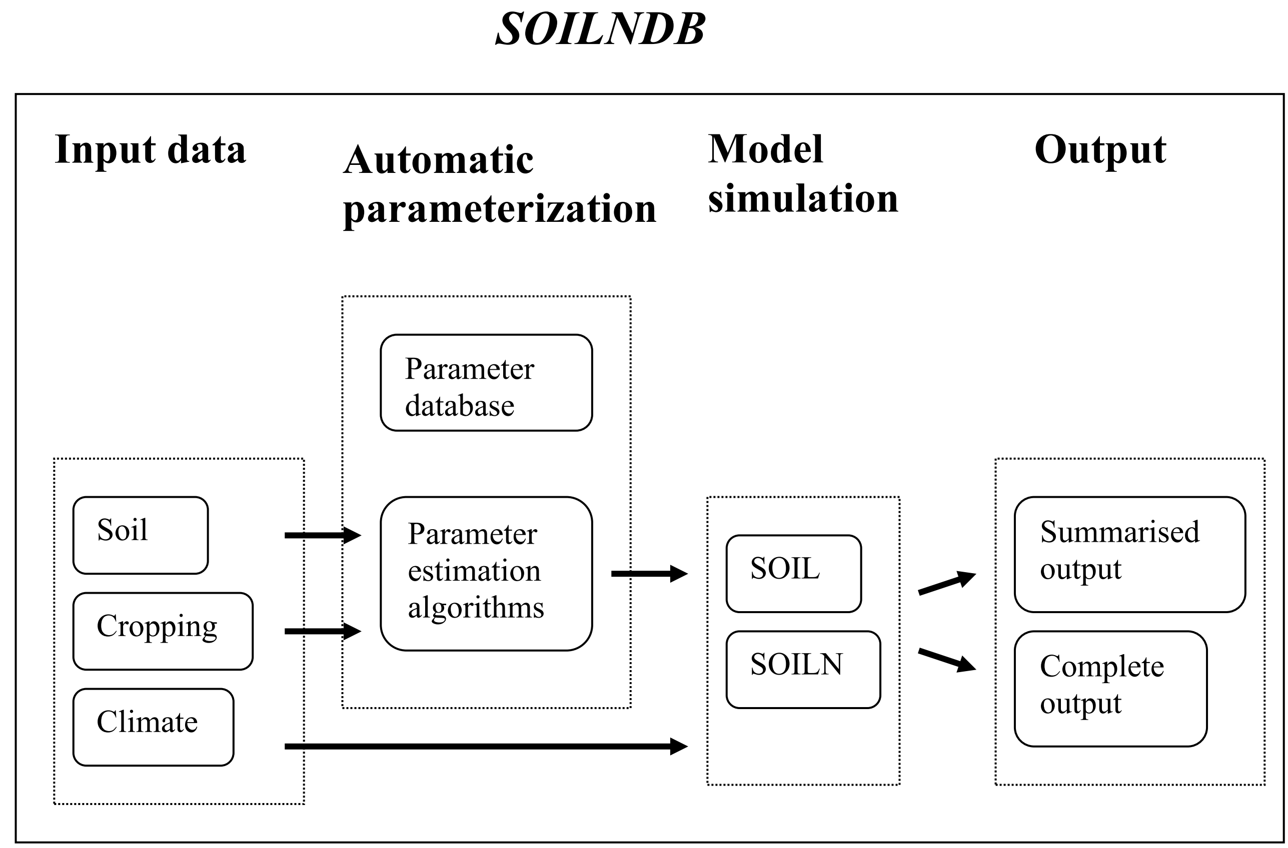

Fig. 1. Schematic description of the SOILNDB model system.

The requirements of input data for SOILNDB are more general, less detailed and less extensive than those required for direct use of the SOIL-SOILN models. A database is included in SOILNDB that contains parameter values for the SOIL and SOILN models for various situations, e.g., soil hydraulic properties for different soils, plant development and management parameters for different crops, etc. These values are based on previous applications of the models. SOILNDB also contains a number of parameter estimation algorithms. Also included in the system are presentations in summarised form of the outputs from the simulations. In the following sections, the main components of the system (models, input data, parameterisation procedures) are described in more detail.

The simulation models

The modelling approach consists of a coupling in series of a nitrogen transport and transformation model, SOILN (Johnsson et al., 1987), and a soil water and heat model, SOIL (Jansson & Halldin, 1979). The SOIL model provides driving variables for the SOILN model (i.e., infiltration, water flow between layers and to drainage tiles, unfrozen soil water content and soil temperature). The models have a one-dimensional vertical structure, with the profile divided into layers, which may vary depending on required numerical accuracy as well as physical and biological characteristics of the soil. The models have been extensively used, both as research tools and for applied purposes (e.g. Bergström and Johnsson, 1988; Bergström and Jarvis, 1991; Lewan, 1994; Johnsson and Hoffmann, 1996; Aronsson and Torstensson, 1998; Johnsson and Hoffmann, 1998; Hoffmann and Johnsson, 1999b; Hoffmann et al., 2000; Larsson, and Johnsson, 2003). Since both models are described in detail elsewhere (Jansson and Halldin, 1980; Johnsson et al., 1987), only a brief description will be presented here.

The SOIL model

The SOIL model is based on two coupled differential equations describing heat and water transport in a soil profile. Snow dynamics, frost, evapotranspiration, infiltration, surface runoff and drainage flows are included. The model uses standard daily meteorological data as input to predict soil water and heat conditions at any level in the soil profile. In the SOIL model, either free drainage or horizontal flow to groundwater and tile drains can be selected as bottom boundary conditions. With free drainage, a unit gravitational gradient is assumed as the driving force for vertical flow out of the lowest soil layer. No groundwater level is then simulated within the soil profile. With the other option, a groundwater level, net horizontal groundwater flow and flow to tile drains can be simulated. Saturated water flow to tile drains, q_{pipe}, is calculated when the groundwater table rises above the depth of the tile drains, z_{pipe}, according to the hydraulic gradient:

$$q_{pipe} = k_s A_{rel} \frac{z_{pipe} - z_{gw}}{L} \qquad (1)$$

where k_{s} is the saturated hydraulic conductivity, A_{rel} is the ratio between the vertical area of the soil layer and the unit horizontal area, z_{gw} represents the depth of the water table and L the distance between the tile drains. Horizontal groundwater flow, q_{gr}, out of the one-dimensional soil profile is described with an empirical first order recession equation, so that when there is a groundwater level, z_{sat}, in the soil profile, outflow is given as:

$$q_{gr} = q_1 \frac{z_1 - z_{gw}}{z_1} \qquad (2)$$

where q_1 represents a potential maximum flow rate per day and z_1 the depth where flow ceases (Jansson, 1991). Water flow between soil layers is described by Darcy's law and the law of mass balance, while the description of heat flow is derived from Fourier’s law.

Parameter values in the SOIL model connected to hydraulic properties are assigned by the pedo-transfer functions described by Rawls et al. (1982) in SOILNDB, in which soil texture is given as input.

The initial water content is derived from the initail soil tension, which is uniform for the whole profile and set by the parameter ψ_{ini}. The flow of water in both partially frozen and unfrozen soil is calculated by combining Darcy's law and the law of mass balance. The soil water release caracteristics is described with three cut and join functions (Jansson, 1991). In the dry range, above a threshold value Ψ_{x}, the water release is assumed log-linear:

$$\frac{\log(\psi/\psi_x)}{\log(\psi_{wilt}/\psi_x)} = \frac{\theta_x - \theta}{\theta_x - \theta_w} \qquad \psi_x < \psi < \psi_{wilt} \qquad (3)$$

while in an intermittent range, above a threshold value Ψ_{m}, it is described by the Brooks and Corey (1964) equation:

$$\left(\frac{\psi}{\psi_a}\right)^{-\lambda} = \frac{\theta - \theta_r}{\theta_s - \theta_r} \qquad \psi_m < \psi < \psi_x \qquad (4)$$

and in the range close to saturation, by a linear expression:

$$\psi = \psi_m - \frac{(\theta + 4 - \theta_s)}{4}\psi_m \qquad \psi_0 < \psi < \psi_m \qquad (5)$$

where θ is the actual water content and Ψ is the actual tension, θ_{x} is the water content corresponding to the upper threshold tension (Ψ_{x}), Ψ_{wilt} and θ_{w} corresponds to the tension and water content at the wilting point, θ_{r} is the residual water content, θ_{s} is the saturated water content, Ψ_{a} is the air entry tension, λ is the pore size distribution index, and Ψ_{m} is the lower threshold tension corresponding to a water content of $\theta_{\mathrm{s}} - 4$. Above the lower threshold tension, Ψ_{m}, the unsaturated hydraulic conductivity, k_{w}, is described by the Mualem model (Mualem, 1976):

$$k_w = k_s\left(\frac{\psi_a}{\psi}\right)^{2+(2+n_{\mathrm{var}})\lambda} \qquad \psi_m < \psi < \psi_{wilt} \qquad (6)$$

where k_{s} is the saturated hydraulic conductivity and n_{var} is the tortuosity factor. When the water tension is between Ψ_{m} and Ψ, the hydraulic conductivity is described by:

$$k_w = 10^{\left(\log(k_w(\theta_s-4))+\frac{\theta-\theta_s+4}{4}\log\left(\frac{k_{sm}}{k_w(\theta_s-4)}\right)\right)} \qquad \psi_0 < \psi < \psi_m \qquad (7)$$

where k_{sm} is the saturated conductivity including macropores and $k_{\mathrm{w}}(\theta_{\mathrm{s}} - 4)$ is the hydraulic conductivity at Ψ_{m} calculated with *equation 4*.

The infiltration capacity is reduced when ice occur in the uppermost soil layer, and upward movement of water towards a frozen soil layer is minimized by the use of the lowest water content of the frozen soil layer or of the boundary between the adjacent soil layers.

Calculation of potential evaporation, transpiration, and evaporation of intercepted water is based on the Penman-Monteith combination equation (Penman, 1953; Monteith, 1965). The interception loss is partially determined by the surface resistance for intercepted water, r_{sint}, corresponding to the average distance within the canopy.

The root density is assumed to decrease exponentially from the soil surface to the root depth, where the exponential decrease is governed by the parameter, r_{frac}. Actual water uptake by roots from each layer is calculated according to a time-dependent depth distribution of roots and an empirical reduction function accounting for soil water availability. It is possible to account for compensatory uptake, governed by the parameter f_{umov}, if a deficiency occures in some layers simultaneously as an excess of water exist in some other layer.

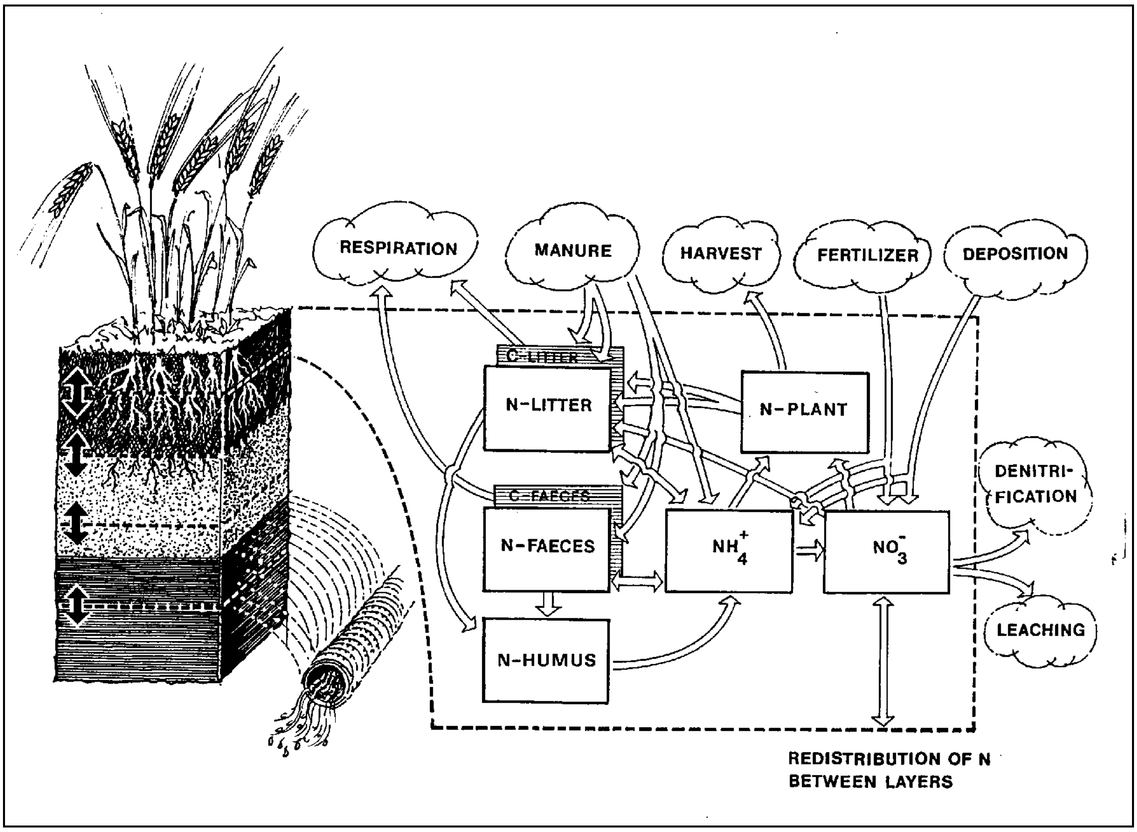

Fig. 2. Structure of the nitrogen model SOILN showing state variables (boxes) and flows (arrows) included in the model. The structure is replicated for each layer. Areas within the dotted line represent the top layer of the soil. Layers beneath have the same structure but have no direct input through fertilisation and deposition (Johnsson et al., 1987).

The heat flow equation, which is derived from Fourier's law, includes both the freezing and thawing of water and the convective effect of water flow. In frozen soils the water and heat equations are coupled using a freezing point depression function. The initial temperature is set uniform for the whole profile according to the parameter T_{ini}.

The SOILN model

The SOILN model includes all the major processes determining transport and transformations of nitrogen in arable soils (Fig. 2). Input of nitrogen can be in the form of fertiliser, manure and atmospheric deposition, while harvest, leaching and denitrification constitute the output.

Litter, faeces and humus comprise the organic-N fractions. The litter fraction represents non-decomposed material (e.g., crop residues, dead roots), microbial biomass and metabolites. The faeces component represents the digested fraction in manure, i.e., excluding bedding material. The humus component represents stabilised organic material derived from litter decomposition. Organic carbon pools are included for litter and faeces in order to regulate nitrogen mineralisation and decomposition.

The mineralisation, $N_{h\leftrightarrow NH_4^+}$, of humus nitrogen, N_h, in SOILN is calculated as a first-order rate process controlled by a specific mineralisation constant, k_h, and response functions for soil temperature, e_t, and moisture, e_m:

$$N_{h\rightarrow NH_4^+} = k_h\, e_t\, e_m\, \mathrm{N_h} \tag{8}$$

Decomposition, C_l, of the soil litter carbon pool, C_l, (and similarly carbon in faeces) is described as:

$$C_l = k_l\, e_t\, e_m\, \mathrm{C_l} \tag{9}$$

where k_l is a specific rate constant. Decomposition products are partitioned into three fractions (Fig. 3.), one fraction is lost as carbon dioxide, another is stabilised as humus, and the remainder assimilated and recycled within the pool, as described by:

$$C_{l\rightarrow CO_2} = (1 - f_e)C_l \tag{10}$$

$$C_{l\rightarrow h} = f_e f_h C_l \tag{11}$$

$$C_{l\rightarrow l} = f_e(1 - f_h)C_l \tag{12}$$

where f_e is a synthesis efficiency constant and f_h is the litter carbon humification fraction. Decomposition of the organic litter (and faeces) carbon pools are governing the N mineralization from these sources according to:

$$N_{l\leftrightarrow NH_4^+} = \left[\frac{\mathrm{N_l}}{\mathrm{C_l}} - \frac{f_e}{r_o}\right] C_l \tag{13}$$

where $\mathrm{N}_{l\leftrightarrow NH_4^+}$ represents the litter mineralization rate, N_l is the litter N pool and r_o is the CN-ratio of microorganisms and humified products.

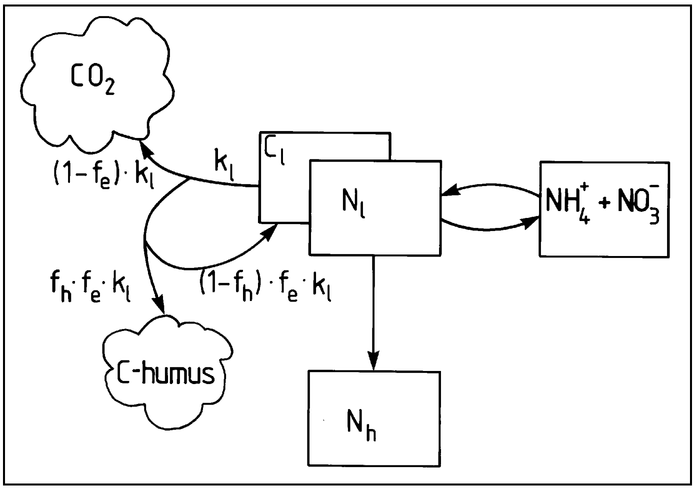

Fig. 3. Flow diagram illustrating the carbon and nitrogen balance associated with litter (or faeces) in SOILN. Explanations of parameter symbols are given in the text or in Johnsson et al., 1987.

A Q_{10}-expression is used for the soil temperature response function regulating all biological processes in the model. For all biological activity except denitrification, the effect of soil moisture is calculated based on the assumption that the activity decreases on both sides of an optimum soil moisture content range.

In SOILN, plant uptake of N is calculated from a time-dependent empirical function requiring specific parameter values for the different crops. A logistic growth curve, defined by the coefficients u_b and u_c, is used to define a potential uptake demand, u_a, during the growing season, which is distributed in the soil profile according to an assumed root distribution (i.e. root biomass decreases exponentially from the soil surface to the root depth, where the exponential decrease is governed by the parameter, r_{frac}). Accordingly, in SOILNDB, N uptake and crop growth is not simulated explicitly, and the harvested crop yield, S, is used to calculate the target N uptake, N_{totup}:

$$N_{totup} = \frac{S * c_{N1} + f_a * S * c_{N2}}{1 - f_r} \tag{14}$$

and the potential uptake demand, u_a, is then estimated as:

$$u_a = N_{totup} * \frac{1 - e^{-u_c * t_{UP}}}{1 - \frac{N_{totup}}{u_b} * e^{-u_c * t_{UP}}} + u_b \tag{15}$$

where c_{N1} is the nitrogen concentration in the harvested product (i.e. grain, seed or tuber) while c_{N2} is the nitrogen concentration in above-ground residues (i.e. straw, tops, stubble, chaff, stalks etc.), f_a is the ratio of above-ground residues to grain biomass, and f_r is the fraction of N in roots of total plant N (Johnsson et al., 2002). The target harvest yield, S, and the length of the uptake period, t_{UP}, are the only parameters in these two equations specified by the user, the remaining parameters are all included in the SOILNDB database. The length of the uptake period is calculated simply by subtracting the start of the uptake period from the time of harvest, or if no harvest takes place, the end of the uptake period.

Denitrification is calculated as a first order rate process controlled by a potential rate and a response function accounting for the effects of soil temperature, soil oxygen status and soil nitrate content. The effect of oxygen status is indirectly expressed as a function of soil moisture content, which increases linearly from zero at a threshold water content and reaches a maximum of 1.0 at saturation. The effect of nitrate is given as a Michaelis-Menten type expression, i.e. a hyperbolic function controlled by a half-saturation constant.

Roots and harvest residues (if the straw is not harvested) are incorporated into the soil litter pool at ploughing. Denitrification is calculated as a function of potential rate, soil temperature, soil oxygen status and soil nitrate content. Nitrate transport is calculated as the product of water flow and nitrate concentration in the soil layer from which the water flow originates, while ammonium is considered to be immobile in the soil profile.

Input data to SOILNDB

The basic idea of SOILNDB is that input data should be easy to obtain (or register) in ordinary agriculture. Consequently, the quantity of input variables in SOILNDB is considerably reduced and the level of resolution is also much lower compared to the requirement for the SOIL and SOILN models. The input for SOILNDB is categorised into "soil", "climate", "cropping system" and "local hydrology". Input data can be given either directly by the user or be supplied in database form. Several pre made databases can be run in sequence without further user input other than needed to start the simulations.

Soil

The soil is selected either by choosing one of ten standard soil texture classes according to the USDA classification system or by choosing a soil from a database that can be maintained by each user of SOILNDB. In addition to soil type, user input also includes organic matter content for the topsoil and subsoil.

Climate

Meteorological data can be stored in a database by the user. Data required for a simulation are daily values of rainfall, air temperature, solar radiation (or solar duration or cloudiness), wind speed and vapour pressure (or relative humidity) and the latitude of the meteorological station, d_{lat}, used for calculating daylength and global radiation. Nitrogen deposition rates can either be taken from a database by selecting a county in Sweden or the dry deposition rates and N concentration in rainfall can be given as input by the user.

Table 1. Concentration of NH4-N, cammN, organic N, corgN, and C-N ratios in bedding in manure, CNfec, in the SOILNDB database (Steineck et al., 1999)

Type of manure	c_{ammN} (kg N ton^{-1})	c_{orgN} (kg N ton^{-1})	CN_{fec}
Solid manure, cattle	1.3	4.1	15
Solid manure, pigs	2.3	4.5	15
Solid manure, hen	6.2	15.2	
Urine, cattle	1.5	0.4	
Urine, pigs	1.4	0.3	
Slurry, cattle	1.9	1.5	7
Slurry, pigs	3.2	1.6	5

Cropping system

Yearly input of crop and management information includes: crop type and sowing date, harvest date and yield, fertilisation amount and time, time and amount of manure applications, soil cultivation time and, if a catch crop is simulated, the expected N uptake of the catch crop. Currently, there is an option to choose between the following main crops: spring wheat, spring barley, oats, spring rape, winter wheat, rye, winter barley, winter rape, potatoes, sugar beet and grass ley.

Table 2. Volatilisation loss of NH3, fsloss, for different types of manure and for various types of application techniques from the SOILNDB parameter database (after Claesson and Steineck, 1991)

					f_{sloss}			
Application time	Application technique	Incorpo-ration	Time until incorporation (hours)	Ley	solid manure	urine	deep straw manure (%)	slurry
Winter	Broadcasting	No	0	No	20	40	20	30
	Band-spreading	No	0	No	0	30	0	20
Spring	Broadcasting	Yes	1	No	15	8	15	10
		Yes	12	No	50	20	50	20
		No	0	Yes	70	35	70	40
	Band-spreading	Yes	1	No	0	7	0	5
		Yes	12	No	0	20	0	10
		No	0	Yes	0	25	0	30
Summer	Broadcasting	No	0	Yes	90	60	90	70
	Band-spreading	No	0	Yes	0	40	0	50
		No	0	No	0	10	0	7
Early autumn	Broadcasting	Yes	1	No	20	15	20	5
		Yes	12	No	50	30	50	30
		No	0	No	70	45	70	70
	Band-spreading	Yes	1	No	0	10	0	3
		Yes	12	No	0	25	0	15
		No	0	No	0	30	0	40
Late autumn	Broadcasting	Yes	1	No	10	10	10	5
		Yes	12	No	20	20	20	10
		No	0	No	30	25	30	30
	Band-spreading	Yes	1	No	0	4	0	3
		Yes	12	No	0	18	0	5
		No	0	No	0	25	0	15

Crops can be combined without restraint in the crop rotation. The yield (kg ha^{-1}) must be given with a water content of 15% for cereals crops, 9% for rape seed crops, 79% for potatoes, 74% for sugar beets and 0% for leys, respectively. A choice can be made between a number of the most common types of manure (Table 1). Alternatively, the user may specify the composition of the applied manure (i.e., NH_4-N concentration, c_{ammN}, organic N concentration, c_{orgN}, and C-N ratio in bedding in manure, CN_{fec}). To account for different volatilisation losses of NH_3 at manure application, f_{sloss}, various application techniques can be chosen from a database (Table 2), or alternatively, the user may specify the fraction of ammonia lost implicitly.

Local hydrology

The user can choose the between 5 (default) and 6 of computational layers. The difference is that with 6 layers the uppermost layer is divided in two, 10 respective 25 cm thick, Table 3.

Table 3. The thickness $\Delta z(l)$, fraction of potential denitrification in soil layers d_{frac}, Initial NO_3 and NH_4 content in each layer (NO_3) and (NO_4) with 5 respectively 6 layers.

5 layers				6 layers			
Δz(l) (cm)	d_{frac}	Initial NO_3 (g/m^2)	Initial NH_4 (g/m^2)	Δz(l) (cm)	d_{frac}	Initial NO_3 (g/m^2)	Initial NH_4 (g/m^2)
25	0.7	1.0	1.0	10	0.28	0.4	0.4
				15	0.42	0.6	0.6
25	0.3	0.05	0.05	25	0.3	0.5	0.5
25	0.0	0.3	0.3	25	0.0	0.3	0.3
25	0.0	0.2	0.2	25	0.0	0.2	0.2
50	0.0	0.0	0.0	50	0.0	0.0	0.0

The user also has the possibility to choose between free drainage (default) and tile drainage. If tile drainage is selected, the following parameters must be set. L the distance between tile drains, z_{gw} the depth to tile drains and q_{gr} lateral groundwater flow.

Automatic parameterisation

Input data given to SOILNDB, as described above, determines the parameter values used for the underlying SOIL and SOILN models. This parameterisation is done automatically by the use of a parameter database and parameter estimation algorithms included in SOILNDB. The parameter database in SOILNDB is separated in two files, 'autopar.mdb' where most parameters are specified and 'climate.mdb' where meteorological data is stored and some site-specific parameters related to climate are set (e.g. latitude and parameters related to the length of the growing period). The parameterisation of the SOIL model is based on previous applications with the research version of the model (e.g. Johnsson et al., 1987; Hoffmann and Johnsson, 1999b) and on the characterisation of the soils (see below). For the SOILN model, the parameter values are partly derived from literature surveys but mainly from applications where the model has been calibrated against measured data on various field sites with different agro-environmental conditions (see compilation by Hoffmann, 1999; Appendix I). Calibrations were typically performed against measurements on N concentration in drainage water, soil mineral N content at different depths, plant N uptake and N in grain exported at harvest.

Soil and hydraulic properties

For each of the 10 standard soil texture classes, the pedo-transfer functions described by Rawls et al. (1982) were used to assign values to parameters in the Brooks and Corey equation (i.e. the pore size distribution index, λ, the residual water content, θ_r, saturated water content, θ_s, and the air entry tension, ψ_a) and to the saturated hydraulic conductivity, k_s, used in the Mualem model (see Table 4). The tortuosity factor, n_{var}, used in the Mualem model, was set to 1 (as defined by Campbell's model) in all soils but the loamy sand (soil *a*) in the soils database where n_{var} was set to 5. The water content at wilting point, θ_w, and the upper limit for the use of the Brooks and Corey equation, ψ_x, was set to 1000 for the 10 standard soil texture classes, but for the soils in the 'soils database', ψ_x was set to unique values for the different soils (Table 4). The saturated hydraulic conductivities including macropores, k_{sm}, are rough esimates based on previous applications with the SOIL model (Table 4). The coefficients in the empirical function for the temperature dependence in the hydraulic conductivity A_{0T} and A_{1T}, (set to 0.54 and 0.025, respectively), were set equal to default values given by the SOIL model for all soils.

Table 4. Soil hydraulic parameters for the standard soil texture classes and for the specific soils in the database

Soil texture class for standard soils	Soil id. in database	k_s (mm h^{-1})	k_{sm} (mm h^{-1})	λ (-)	θ_r (%)	θ_s (%)	ψ_a (cm water)	$\theta_w{}^a$ (%)	ψ_x (cm water)
Sand		210	210	0.59	2	43.7	7.26	3.3	1000
Loamy sand		61.1	120	0.47	3.5	43.7	8.69	5.5	1000
Sandy loam		25.9	120	0.32	4.1	45.3	14.66	9.5	1000
Loam		13.2	120	0.22	2.7	46.3	11.15	11.7	1000
Silt loam		6.8	120	0.21	1.5	50.1	20.76	13.3	1000
Sandy clay loam		4.3	120	0.25	6.8	39.8	28.08	14.8	1000
Clay loam		2.3	120	0.19	7.5	46.4	25.89	19.7	1000
Silty clay loam		1.5	120	0.15	4	47.1	32.56	20.8	1000
Silty clay		0.9	120	0.13	5.6	47.9	34.19	25	1000
Clay		0.6	120	0.13	9	47.5	37.3	27.2	1000
Soil texture class for soils in the database									
Loamy sand	a	300	300	0.45	3	45	6	2.5	1000
Loamy sand topsoil sandy loam subsoil	b	180	180	0.22	0.01	45	5	6.6	2000
Silty loam	c	90	180	0.09	0.1	42	8	6.6	100
Loam	d	90	180	0.11	3	41	36	11.9	1000
Silty clay loam	e	30	180	0.1	9	44	50	18.0	1600
Silty clay	f	12	240	0.08	0.01	50	33.5	31.0	30000
Clay	g	6	300	0.03	0.1	54	6	41.0	1000

[a] at pF 4.2.

The selection of the soils for the 'soils database' was done within a project for calculating nitrate leaching from the Nordic countries (Hoffmann and Johnsson, 1999b), and the selection was done to include a range of representative soils regarding texture composition in this area (Table 5), where soil denoted as *a* is Danish, soil *g* Finish, soils *b*, *c*, *d* and *e* Norwegian and soil *f* Swedish. Parameters used in the SOIL model connected to the Brooks and Corey equation were estimated from measured data on water retention characteristics using least square fittings of equation 4. The saturated hydraulic conductivity, k_s, was measured, while the saturated hydraulic conductivity including macropores, k_{sm}, was estimated. Physical soil characteristics were assumed to be uniform for the whole soil profile. The water retention curves for the standard soils and for the specific soils in the database are shown in Figure 4.

Table 5. Soil texture composition for the specific soils in the database

Swedish classification system	USDA class. system	Soil	Sand (0.2-0.02 mm)	Silt (0.02-0.002 mm)	Clay (< 0.002 mm)
Svagt lerig sand	loamy sand	a	83	9	9
Lerig sand	loamy sand (sandy loam)	b	78	16	6
Lerig mo	silty loam	c	40	54	6
Moig lättlera	loam	d	43	38	19
Mellanlera	silty clay loam	e	17	50	33
Styv lera	silty clay	f	6	46	45
Mycket styv lera	clay	g	6	25	73

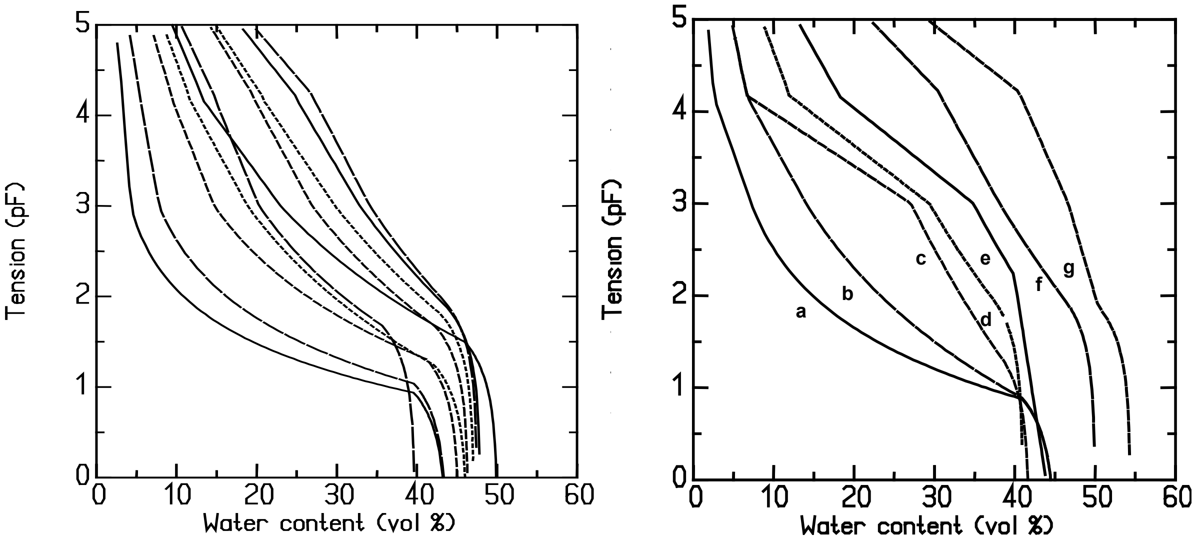

Fig. 4. Water retention curves (a) for the 10 soil texture classes (USDA) included in SOILNDB with: sand, loamy sand, sandy loam, loam, sandy clay loam, silt loam, clay loam, silty clay loam, silty clay, and clay following the arrow from bottom left to top right, and (b) for the specific soils in the soils database.

Table 6. Parameters related to hydraulic properties in frozen soil (f_{ci}, d_1, d_2) and root water uptake (ψ_c) for the standard soil texure classes and for the specific soils in the database

Soil texture class for standard soils --- Soil texture class for soils in database	Soil id. in database	f_{ci} (–)	d_1 (–)	d_2 (–)	ψ_{c} (cm water)
Sand		0	0.5	20	500
Loamy sand		8	1	30	800
Sandy loam		8	1	30	800
Loam		8	1	30	800
Silt loam		8	1	30	2000
Sandy clay loam		8	1	30	2000
Clay loam		8	1	30	3000
Silty clay loam		8	1	30	3000
Silty clay		8	1	30	4000
Clay		8	1	30	4000
Loamy sand	a	0	0.5	20	500
Loamy sand topsoil; sandy loam subsoil	b	8	1	30	800
Silty loam	c	8	1	30	800
Loam	d	8	1	30	800
Silty clay loam	e	8	1	30	3000
Silty clay	f	8	1	30	4000
Clay	g	8	1	30	4000

Initial state of soil N and C content

Initial soil N litter, $N_{\mathrm{lom}}(l)$, and humus, $N_{\mathrm{hom}}(l)$, contents are calculated from the soil organic matter content, *SOM*:

$$N_{lom}(l) = \frac{\Delta z(l) * \rho(l) * SOM(l)\, c_{Com}}{r_{CN}}\, r_{lh} \tag{16}$$

$$N_{\mathrm{hom}}(l) = \frac{\Delta z(l) * \rho(l) * SOM(l)\, c_{Com}}{r_{CN}}\, (1 - r_{lh}) \tag{17}$$

where $\rho(l)$ is the dry bulk density for the different soil layers, l, r_o is the C/N ratio of soil organic matter, r_{lh} is the initial litter to humus ratio and c_{Com} is the fraction of C in soil organic matter, set to 0.58 (e.g. Brady, 1990). The *SOM* content is given as input for the uppermost layer(s), (0 to 25 or 0 to 10 and 10 to 25 cm), ‘Organic matter (topsoil)’, and the second layer (25 to 50 cm), ‘Organic matter (subsoil)’. The C/N ratio of soil organic matter, r_{CN}, is set to 10 and the initial litter to humus ratio, r_{lh}, is set to 0.01 in SOILNDB, while the bulk density is set to 1.35 and 1.45 g cm^{-3} for the top and sub soil, respectively, for all soils. Initial soil C litter content, $C_{\mathrm{lom}}(l)$, is calculated from the soil organic matter content according to:

$$C_{lom}(l) = \Delta z(l) * \rho(l) * SOM(l)\, c_{Com}\, r_{lh} \tag{18}$$

In the layers 50 to 75 cm and 75 to 100 cm, the initial *SOM* is assumed to be 20% and 10%, respectively, of the *SOM* in layer 25 to 50 cm, while the organic matter content at 100 to 150 cm depth is assumed to be negligible. Both initial NO3-N and NH4-N contents were set to 1, 0.5, 0.3, 0.2, and 0 g m^{-2} for layers 1, 2, 3, 4 and 5, respectively.

As an alternative to the calculations based on user defined organic matter content and the pre-defined mineral N amounts, the user may apply an own file containing initial amounts of mineral N and organic C and N for the different pools and layers.

Properties related to snow and frozen soil

Parameters related to frozen soil in the SOIL model (i.e., the factor governing the decrease of unsaturated hydraulic conductivity due to freezing, fc_i, the fraction of the wilting point remaing as unfrozen water at –5°C, d_1, and the coefficient in the freezing point depression function, d_2) were set to default values given by the SOIL model for the sand. For all other soil texture classes (see Table 6), the values were somewhat increased.

Most parameters related to snow properties were set to deafult values given by the SOIL model (see List of Symbols). However, the global radiation in the snow melt function, m_{Rmin} (default = 15^{-8} mm J^{-1}), was set to 10^{-8} in SOILNDB, which was also used by Borg and Jansson (1988) in an application at Lanna in southwest Sweden. The temperature coefficient in the snow melt function, m_T (default = 4 to 6 kg °C^{-1} m^{-2} day^{-1} for open fields), was set to 3, which was also used by Torstensson and Johnsson (1996) in an application at Mellby in southwest Sweden. The radiation melt factor for old snow, S_1, was set to 2.5, which is close to the default value (i.e. 2) used in the SOIL model. The liquid water coefficient in the snow density function, S_{dl} (default = 200 kg m^{-3}), was set to 100 kg m^{-3}, which was also used by Jansson and Gustafsson (1987), and the water equivalent coefficient in the snow density function, S_{dw}, was set to 0.9 m^{-1}, which is in between the default value of 0.5 m^{-1} and 1.5 m^{-1} used by Jansson and Gustafsson (1987).

Water balance

The parameters governing correction of precipitation due to errors in the measurement for rain, c_{rain}, and snow, c_{snow}, is read from the climate database. The default values given by the model (c_{rain} =1.07 and c_{snow} =0.14) and are based on the correction factors estimated for the climatic station used in the application described by Hoffmann and Johnsson (1999a). To obtain reasonable simulation results on discharge of water from the soil profile, the correction factors for snow and rain may need to be adjusted, especially for local conditions at site specific applications.

Parameters related to evapotranspiration are divided into five groups (i) spring cereals and spring oilseed crops, (ii) winter cereals and winter oilseed crops, (iii) potatoes, (iv) sugar beet, and (v) ley (Table 7, Table 8 and Table 9). The surface resistance for transpiration when intercepted water occures, r_{sint}, was set to 5 s m^{-1} for all crops but ley, where it was assumed negligible. Some other parameters were set constant and assumed not to vary with crop (i.e. the albedo of vegetation and soil, a_r, set to 20, the form factor, $c_{\mathrm{form}}(i)$, governing the interpolation between adjacent day numbers, $t_{\mathrm{day}}(i)$, set to unity, and the interception storage capacity per leaf area index (LAI), i_{LAI}, set to 0.2 mm LAI^{-1}).

Table 7. Dates for specification of parameters related to crop development and associated evapotransiration parameters

Crop	$t_{day(1)}$	$t_{day(2)}$	$t_{day(3)}$	$t_{day(4)}$	$t_{day(5)}$
Spring cerals and spring oilseed crops	$t_{s(i)} + 12$ [a]	29 June	$t_{sk(i)} - 1$ [b]	$t_{sk(i)}$ [b]	–
Winter crops (year of sowing)	–	–	–	–	$t_{s(i)} + 12$
Winter crops (year of harvest)	$u_{st(i)} + 10$	$\frac{t_{day(1)} + t_{day(3)}}{2}$	$t_{sk(i)} - 1$ [b]	$t_{sk(i)}$ [b]	–
Undersown ley	–	–	–	–	$t_{s(i)} + 14$
Ley (not harvested)	$u_{st(i)} + 10$	$\frac{t_{day(1)} + t_{day(3)}}{2}$	$u_{et(i)}$ [c, d]	–	–
Ley with 1 harvest	$u_{st(i)} + 10$	$t_{sk1} - 1$ [b]	t_{sk1}	$\frac{t_{day(3)} + t_{day(5)}}{2}$	$u_{et(i)}$ [c, d]
Ley with 2 harvests	$u_{st(i)} + 10$	$t_{sk1} - 1$ [b]	$t_{day(2)} + 1$	$t_{sk2} - 1$ [b]	$t_{day(4)} + 1$

[a] $t_{s(i)}$ represents the sowing timepoint

[b] $t_{sk(i)}$ represents the harvest timepoint

[c] if soil cultication takes place, $t_{day(i)}$ is set to $t_{sc} - 1$, where t_{sc} is the time for soil cultivation

[d] if followed by a winter crop, $t_{day(i)}$ is set to $t_{s(i+1)} - 1$ where $t_{s(i+1)}$ is the sowing date for the winter crop

Table 8. Displacement height, $d_{h(i)}$, and leaf area index, $l_{ai(i)}$ for the different dates and crop groups. The numbers in parenthesis refers to the dates defined in Table 7

Crop	$d_{h(1)}$ (m)	$d_{h(2)}$ (m)	$d_{h(3)}$ (m)	$d_{h(4)}$ (m)	$d_{h(5)}$ (m)	$l_{ai(1)}$ (-)	$l_{ai(2)}$ (-)	$l_{ai(3)}$ (-)	$l_{ai(4)}$ (-)	$l_{ai(5)}$ (-)
Spring cerals and spring oilseed crops	0	0.6	0.6	0	0	0	5	3	0	0
Winter cerals and winter oilseed crops	0.02	0.6	0.6	0	0.02	0.1	5	3	0	0.1
Potatoes	0	0.3	0.3	0	0	0	5	3	0	0
Sugar beet	0	0.25	0.3	0	0	0	5	4	0	0
Ley	0	0.5	0.07	0.35	0.1	0	5	1	4	1
Undersown ley	–	–	–	–	$d_{h(1)}$ [a]	–	–	–	–	$l_{ai(1)}$ [a]

[a] for undersown ley at $t_{day(5)}$, the value corresponding to $t_{day(1)}$ for ley is used

Table 9. Reference height, z0(i), and surface resistance, rs(i), for the different dates and crop groups. The numbers in parenthesis refers to the dates defined in Table 7

Crop	$z_{0(1)}$	$z_{0(2)}$	$z_{0(3)}$	$z_{0(4)}$	$z_{0(5)}$	$r_{s(1)}$	$r_{s(2)}$	$r_{s(3)}$	$r_{s(4)}$	$r_{s(5)}$
Spring cerals and oilseed	0.005	0.08	0.08	0.005	0.005	150	40	100	150	150
Winter cerals and oilseed	0.005	0.08	0.08	0.005	0.005	150	40	100	150	150
Potatoes	0.005	0.045	0.05	0.005	0.005	150	40	80	150	150
Sugar beet	0.005	0.035	0.043	0.005	0.005	150	40	80	150	150
Ley	0.005	0.07	0.01	0.05	0.014	150	40	150	50	150
Undersown ley	–	–	–	–	$z_{0(1)}$ [a]	–	–	–	–	$r_{s(1)}$ [a]

[a] for undersown ley at $t_{day(5)}$, the value corresponding to $t_{day(1)}$ for ley is used

The empirical coefficient regulating surface resistance, r_{ψ}, used to calculate soil evaporation was set to 200 s m^{-1} for all soils but for sand, in the 10 standard soil texture classes, and for loamy sand, in the 'soils database', for which it was set to 100 s m^{-1} in agreement with an application of the SOIL model on a loamy sand soil (Lewan, 1993). The contribution of LAI to the total areodynamic resistance from measurement height to the soil surface, r_{alai}, was set to 50 s m^{-1} for all crops, and the extinction coefficient, k_{rn}, used for calculating net radiation at the soil surface from LAI, was set to 0.5 for all crops (Johnsson & Jansson, 1991).

The effect of catch crops on the water balance has shown to be negligible (Aronsson and Torstensson, 1998) and water uptake of catch crops is therefore not treated in SOILNDB.

Root development and root water uptake

Roots are assumed to develop stepwise from zero at sowing to a maximum at harvest, and the distribution between soil layers is assumed to depend on crop and soil type. Root development and root depths (Table 10, Table 11 and Table 12) are rough estimates based on studies and reviews by Haak (1993), Lewan (1993), and Myrbeck (1998). Root density is considered to decrease exponentially from the soil surface to the root depth, and to be deeper on more clayey soils and for perennial crops than for coarse textured soils and annual crops. The fraction of the exponential function remaining below the root depth, r_{frac}, that is to be allocated within the maximum root depth given by, z_{r}, was set to the default value given by the SOIL model (i.e. 0.05), while the corresponding parameter in SOILN, r_{fracN}, was set to 0.001. The critical tension for reduction of water uptake during dry soil conditions, ψ_{c}, was set to relatively high values (Table 6), allowing for water uptake during rather dry periods. The parameter for compensatory uptake, f_{umov}, was to default in SOIL (i.e. 0.5).

The coefficients for soil temperature influence on transpiration, t_1 and t_2, were set to default values given by the SOIL model (i.e. 0.8 and 0.4 respectively), and the parameters in the water tension respons function for transpiration, p_1 and p_2, were set to 0.2 and 0 respectively.

Table 10. Maximum root depths for different crops, zr(3), for the 10 standard soil texure classes (and the soils in the soils database) used in both the SOIL and SOILN models. The maximum root depth for the specific soils in the database relates to the soils with corresponding texture. The index 3 in zr(3), refers to the dates, troot(3), defined in Table 12

	Maximum root depth, $z_{\mathrm{r(3)}}$, (m)									
Crop	clay	silty clay	silty clay loam	Clay loam	Sandy clay loam	silty loam	loam	sandy loam	loamy sand	sand
Spring wheat	-1	-1	-0.9	-0.9	-0.9	-0.8	-0.8	-0.7	-0.6	-0.5
Spring barley	-1	-1	-0.9	-0.9	-0.9	-0.8	-0.8	-0.7	-0.6	-0.5
Oats	-1	-1	-0.9	-0.9	-0.9	-0.8	-0.8	-0.7	-0.6	-0.5
Spring rape	-1	-1	-0.9	-0.9	-0.9	-0.8	-0.8	-0.7	-0.6	-0.5
Winter wheat	-1.2	-1.2	-1.1	-1.1	-1.1	-1	-1	-0.9	-0.8	-0.7
Winter rye	-1.2	-1.2	-1.1	-1.1	-1.1	-1	-1	-0.9	-0.8	-0.7
Winter barley	-1.2	-1.2	-1.1	-1.1	-1.1	-1	-1	-0.9	-0.8	-0.7
Winter rape	-1.3	-1.2	-1.1	-1.1	-1.1	-1	-1	-0.9	-0.9	-0.7
Potatoes	-1	-1	-0.9	-0.9	-0.9	-0.8	-0.8	-0.7	-0.6	-0.5
Sugar beets	-1.2	-1.2	-1.1	-1.1	-1.1	-1	-1	-0.9	-0.8	-0.7
Ley	-1.4	-1.4	-1.3	-1.3	-1.3	-1.2	-1.2	-1.1	-1	-0.9

Table 11. Maximum root depth in autumn for different crops, zr(5), for the 10 standard soil texure classes (and the soils in the soils database) used in the SOILN model. The maximum root depth for the specific soils in the database relates to the soils with corresponding texture. The index 5 in zr(5), refers to the dates, troot(5), defined in Table 12

	Maximum root depth in autumn, $z_{r(5)}$, (m)									
Crop	clay	silty clay	silty clay loam	clay loam	sandy clay loam	silty loam	loam	sandy loam	loamy sand	sand
Winter wheat	-0.25	-0.25	-0.25	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Winter rye	-0.25	-0.25	-0.25	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Winter barley	-0.25	-0.25	-0.25	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Winter rape	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.25
Undersown ley [b]	-0.7	-0.7	-0.65	-0.65	-0.65	-0.7	-0.6	-0.55	-0.5	-0.45
Catch crops	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26

[a] the values for maximum root depth in autumn are not defined for the SOIL model. However, root water uptake still occur from the uppermost soil layer (0 to 25 cm depth) if a crop exists.
[b] this depth is estimated as half the maximum root depth for ley, $z_{r(3)}$, (Table 10)

Table 12. Derivation of root development dates, $t_{root(i)}$

Crops	$t_{root(1)}$	$t_{root(2)}$	$t_{root(3)}$	$t_{root(4)}$	$t_{root(5)}$
Spring sown crops	$t_{s(1)}$ + 14 [c]	($t_{root(1)}$ + $t_{root(3)}$) / 2	$t_{sk(1)}$ [b]	$t_{sk(1)}$ + 1 [b]	—
Winter crops [f]	—	—	—	$t_{s(1)}$ + 14 [c]	$t_{root(4)}$ +30 [e]
Winter crops [g]	$u_{st(1)}$ [a]	($t_{root(1)}$ + $t_{root(3)}$) / 2	$t_{sk(1)}$ [b]	—	—
Ley	$u_{st(1)}$ [a]	15 June	15 July	15 August	15 September
Catch crops	—	—	—	$t_{sk(1)}$ + 1 [b]	31 Dec. or t_{cu} [d]

[a] where $u_{st(1)}$ is the start of the plant uptake period
[b] where $t_{sk(1)}$ is the harvest date
[c] where $t_{s(1)}$ is the sowing date
[d] where t_{cu} is the date for soil cultivation (e.g. ploughing)
[e] if $t_{root(4)}$ +30 occures after the 31 December, $t_{root(5)}$ is set to 31 December
[f] for the calendar year of sowing
[g] for the calendar year of harvest

Mineralization and decomposition of organic matter and related parameters

The litter specific decomposition rate, k_l (set to 0.035), and the related efficiency constant, f_e (set to 0.5), the litter carbon humification fraction, f_h (set to 0.2), the specific nitrification rate, k_n (set to 0.2), and the C/N ratio of microorganisms and humified products, r_o (set to 10), were all set to be equal to those used by Johnsson et al. (1987). The nitrate-ammonium ratio in the nitrification function, n_q, was set to 6 in SOILNDB, which is in between the value of 8 used by Johnsson et al. (1987) and 5 used by Torstensson and Johnsson (1996). Since no manure was applied in the experiment described by Johnsson et al. (1987), corresponding faeces-N parameters were set to be identical to those used by Borg et al. (1990), that is, the faeces decomposition rate, k_f, was set to 0.035, and the related efficiency constant, f_{efe}, was set to 0.5, and the faeces carbon humification fraction, f_{chf}, was set to 0.2. The humus-N mineralisation rate, k_h, is assumed not to vary with soil type, and was set to 0.00006 d^{-1}, which is slightly higher than the default value of 0.00005 d^{-1}. The increase in k_h, was set to match the plant N uptake and to keep a quasi-steady state in the humus pool in the test application of SOILNDB described by Hoffmann and Johnsson (1999a).

Table 13. Parameters related to water response functions for mineralisation and denitrification used in the SOILN model for the standard soil texure classes and for the specific soils in the database

Soil texture class for standard soils --- Soil texture class for soils in database	Soil id. in database	$\Delta\theta 1$ (%)	$\Delta\theta 2$ (%)	xm	e_s
Sand		3	32	1	0.6
Loamy sand		4	27	1	0.6
Sandy loam		8	18	1	0.6
Loam		10	16	1	0.6
Silt loam		14	13	1	0.6
Sandy clay loam		8	9	1	0.6
Clay loam		10	8	1	0.6
Silty clay loam		12	6	1	0.6
Silty clay		11	5	1	0.6
Clay		10	4	1	0.6
Loamy sand	a	6	13	1	0.6
Loamy sand topsoil; sandy loam subsoil	b	17	9	1	0.6
Silty loam	c	10	22	1	0.6
Loam	d	20	4	1	0.6
Silty clay loam	e	19	4	1	0.6
Silty clay	f	10	4	1	0.6
Clay	g	7	3	1	0.6

The soil moisture response function in SOILN is parameterised so that for each soil an optimal range of activity is achieved for soil moisture tensions between 100 to 500 cm water (e.g. Miller and Johnson, 1964; Stanford and Epstein, 1974). These tensions of 100 to 500 cm water corresponds to the parameter values of the water contents in the soil moisture response function defining ranges for increasing, $\Delta\theta 1$ and decreasing, $\Delta\theta 2$ biological activity (Table 13). The empirical constant, xm, in the soil moisture function, was set to unity for all soils, reflecting a linear respons, and the coefficient defining the relative effect of moisture when the soil is saturated, e_s, was set to 0.6 for all soils (Johnsson et al., 1987).

Soil temperature effect on biological activity

The Q_{10}-function is used when the temperature is above 5°C with optimum activity at 20°C, (i.e the switch TEMPR was set 'ON', and the parameter t_b was set to 20) and the Q_{10}-value, Q_{10}, reflecting the effect of temperature changes on biological activity, was set to 2 in accordance with measured data from laboratory studies (Lindén and Nouno, 1983). Below 5°C a linear decrease is assumed to 0°C, where biological activity is assumed negligible.

Denitrification

The parameter settings related to denitrification are based on the an application for a barley crop on a loamy soil on a experimental field in central Sweden (Johnsson et al., 1987). The switch 'DENDIST' regulating the choice of 'sub-model' in SOILN is set to zero implying that the potential denitrification is divided in separate fractions for the different soil layers according to the parameter d_{frac}, set to 0.7, 0.3, 0, 0, and 0 for the soil layers from top to bottom in SOILNDB. The potential rate of denitrification, $k_d(z)$, was set to 0.1 and c_s, the half-saturation constant, which gives the effect of nitrate concentration on the denitrification, was set to 10. The water content activity range, θ_d in the function describing the effect of soil moisture on denitrification was set to 17 % which is roughly a mean of 10 % (used by

Johnsson et al., 1987) and 26 % (used by Johnsson et al., 1991). The empirical constant, *d*, used in the function regulating the soil moisture effect on denitrification was set to 2.

Fertiliser, manure and deposition

Input of manure derived NH_4-N and faeces-N is estimated from the input information. The amount of N in faeces, N_{faeces}, in the soil at manure application is simply given by:

$$N_{faeces} = c_{orgN}(m) * M \tag{19}$$

where c_{orgN} is the concentration of organic N in manure, as a function of manure type, *m*, and *M* is the applied amount. The net amount of NH_4-N applied to the soil with manure, N_{amm}, is calculated as:

$$N_{amm} = c_{ammN}(m) * M * \left(1 - f_{sloss}(m, a, t)\right) \tag{20}$$

where c_{ammN} is the concentration of NH_4-N in the applied manure, and f_{sloss} is the fraction of NH_4-N lost through volatilisation of NH_3 at application as a function of manure type *m*, application technique *a* and application date *t*. The values of f_{sloss} used in SOILNDB (Table 2) were taken from Claesson and Steineck (1991). Table 1 show all parameter values for c_{ammN}, c_{orgN} and C-N ratios used in SOILNDB.

Information about deposition of N presented in Table 14, was taken from the Swedish Environmental Protection Agency (1997), and in SOILNDB the deposition is set according to the region selected.

Table 14. Deposition of N used in SOILNDB

County	Wet deposition (mg l^{-1})	Dry deposition (kg ha^{-1} $year^{-1}$)
Stockholms län	0.83	0.5
Södermanlands län	0.73	1
Östergötlands län	0.74	1.5
Jönköpings län	0.92	2
Kronobergs län	0.98	2.5
Kalmar län	1.09	2
Blekinge län	1.18	2
Skåne län	1.33	3
Hallands län	1.35	3
Göteborgs och Bohus län	1.14	3
Älvsborgs län	0.98	2
Skaraborgs län	0.82	1.5
Värmlands län	0.59	1.5
Örebro län	0.69	1
Västmanlands län	0.74	0.5
Kopparbergs län	0.55	0.5
Gävleborgs län	0.64	0.5

Table 15. Parameters related to crop characteristics based on Swedish surveys (Hansson et al., 1987; Mattsson, 1991; Bengtsson et al., 1992; Haak, 1993; Mattsson, 1994; Hessel Tjell et al., 1999)

Crop	Grain N content c_{N1}, c_{N3} (%)	Residues/grain ratio f_a (-)	N content in residues [a] c_{N2} (%)	Water content for residues wc_2 (%)	Straw/grain ratio f_b (-)	Root N/plant N ratio f_r (-)
Spring wheat	2.1	1.3	0.85	15	0.4	0.2
Spring barley	1.7	1.3	0.85	15	0.39	0.2
Oats	1.8	1.3	0.85	15	0.39	0.2
Spring rape	3.5	4.5	1.2	16	0.67	0.2
Winter wheat	1.9	1.1	0.85	15	0.35	0.2
Rye	1.7	1.1	0.85	15	0.35	0.2
Winter rape	3.8	3.5	1.2	16	0.83	0.2
Potatoes	0.25	0.27	0.78	80	0.17	0.13
Sugar beet	0.2	0.5	0.45	80	0.17	0.17
Ley (25 % clover)	2.0	2.0	2.0	0	0	0.2

[a] Given at the specified water content for residues, wc_2

Plant N uptake and root related parameters

Crop N uptake and N removed as grain and straw at harvest are calculated from values of 'target' harvest yields, which is specified by the model user as input. However, if the amount of mineral N in the soil is insufficient for the N uptake corresponding to the target harvest yield, the simulated N uptake will be reduced proportionally and the target harvest yield will not be attained.

For spring crops, the target N uptake, N_{totup}, as a function of year, y, and crop type, c, is calculated as:

$$N_{totup}(y,c)=\frac{S_1(y,c)*c_{N1}(c)+f_a(c)*S_1(y,c)*c_{N2}(c)}{1-f_r(c)} \tag{21}$$

where S_1 is the target harvest yield (i.e. grain, seed or tuber), c_{N1} is the nitrogen concentration in the harvested product while c_{N2} is the nitrogen concentration in above ground residues (i.e. straw, tops, stubble, chaff, stalks etc.), f_a is the ratio of above ground residues to grain biomass, and f_r is the fraction of N in roots of total plant N. The target harvest yield, S_1, is the only parameter in equation 21 specified by the user, the remaining parameters are all included in the SOILNDB database (Table 15). For spring crops, the uptake parameter, u_{a1}, which is an input parameter to SOILN, is estimated as:

$$u_{a1}=N_{totup}*\frac{1-e^{-u_{c1}*t_{UP}}}{1-\frac{N_{totup}}{u_{b1}}*e^{-u_{c1}*t_{UP}}}+u_{b1} \tag{22}$$

where u_{b1} and u_{c1} are coefficients in the plant uptake function (see Table 16) and t_{UP} is the length of the uptake period, calculated simply by subtracting the start of the uptake period $u_{\mathrm{st(i)}}$ from the time of harvest, $t_{\mathrm{sk(i)}}$, or if no harvest take place, the end of the uptake period, $u_{\mathrm{et(i)}}$. For catch crops, u_{a1}, is calculated similarly to equation 22, substituting the coefficients in the plant uptake function for spring crops with those for catch crops (i.e. u_{b2} and u_{c2}; see Table 17).

Table 16. Parameters associated to plant N uptake and development for all crops but ley

Crop	u_{a3}, u_{aiL} (gN m^{-2})	u_{b1} (gN m^{-2} yr^{-1})	u_{b3} (gN m^{-2} yr^{-1})	u_{c1} (d^{-1})	u_{c3} (d^{-1})	u_{et}
Spring wheat	—	0.4	—	0.07	—	t_{sk}
Spring barley	—	0.4	—	0.09	—	t_{sk}
Oats	—	0.4	—	0.08	—	t_{sk}
Spring rape	—	0.4	—	0.09	—	t_{sk}
Winter wheat	1.4	0.4	0.4	0.06	0.11	30 Dec. and t_{sk}[a]
Winter rye	1.9	0.4	0.4	0.06	0.11	30 Dec. and t_{sk}[a]
Winter rape	3.4	0.4	0.4	0.07	0.1	30 Dec. and t_{sk}[a]
Winter barley	1.9	0.4	0.4	0.06	0.11	30 Dec. and t_{sk}[a]
Potatoes	—	0.4	—	0.06	—	t_{sk}
Sugar beets	—	0.4	—	0.05	—	t_{sk}

[a] 30 December for the calender year when the winter crop is sown and t_{sk} for the year of harvest

For winter crops, the target N uptake for the spring/summer, N_{totup}, which is assumed to start, u_{st}, on the 10th of April, is approximated as:

$$N_{totup}(y,c) = \frac{S_1(y,c) * c_{N1}(c) + f_a(c) * S_1(y,c) * c_{N2}(c)}{1 - f_r(c)} - (u_{a3} - u_{b3}) * f_{lr} \tag{23}$$

where $u_{a3} - u_{b3}$ represents the potential N uptake for the autumn period and f_{lr} is a parameter regulating plant death during winter, currently set to unity, which signify that no plant death will occur. As shown in Table 16, the potential N uptake for the autumn period ($u_{a3} - u_{b3}$), is set to 1.0, 1.0, 1.5 and 3.7 gN m^{-2} for winter wheat, winter barley, rye and winter rape, respectively. These are somewhat low compared to mean values of measured uptake from field experiments in Sweden; 1.1, 2.7, and 7.1 gN m^{-2} for winter wheat, rye and winter rape, respectively (Torstensson et al., 1996). However, the variation in uptake was considerable (e.g. the measured range for the 10 rye samples was from 0.4 to 5.4 g N m^{-2}). By using somewhat low values for the potential autumn N uptake, the risk for attaining large deviations between actual and potential N uptake during the autumn will also be minimized, and as a consequence, the risk for attaining large deviations between simulated and target N harvest yields will probably be reduced. Equally to spring crops, the empirical N uptake parameter, u_{a1}, for winter crops for the spring/summer period is described by equation 22. Values for the coefficients in the uptake function for the autumn period, u_{c3}, and for the stop date for uptake, u_{et}, are shown in Table 16.

For grass ley, the target N uptake is calculated as:

$$N_{totup}(y) = S_{L1}(y) * \frac{c_{N3}}{f_{harvL}} + S_{L2}(y) * \frac{c_{N3}}{f_{harvL}} + N_{L3up} \tag{24}$$

where S_{L1} and S_{L2} are the target harvest yields for the first and second harvests, respectively, c_{N3} is the nitrogen concentration in the harvested ley (Table 15), f_{harvL} (set to 0.5) is the fraction of N in harvest corresponding to the total N amount in the plant at harvest, and N_{L3up}

is the potential N uptake after the last harvest each year or if no harvest is specified. The potential N uptake, N_{L3up}, was set to small values to ensure that target N yields, N_{harvL}, could be reached for normal harvest yields (Table 17).

Table 17. Plant N uptake and developement parameters for ley and catch crops

Number of harvests	N_{L3up} (g m^{-2} yr^{-1})	$u_{b(i)L}$, u_{b2} (g m^{-2} yr^{-1})	u_{c1L}, u_{c2} (d^{-1})	u_{c2L} (d^{-1})	u_{c3L} (d^{-1})	f_{sL} (—)	f_{sL}[c] (—)
0	30	0.3	0.05	—	—	0.1	0.6
1	15	0.3	0.1	0.06	—	0.1, 0.1[a]	0.6
2	7	0.3	0.1	0.09	0.08	0.1, 0.1, 0.1[b]	0.6
Undersown ley, year 1	7	0.3	—	0.08	—	1	0.6
Catch crops	—	0.5	—	0.07	—	0.1	—

[a] first value for first harvest second value for end of uptake period

[b] first value for first harvest second value for second harvest and third value for end of uptake period

[c] for the uptake period before ploughing of ley

The uptake parameter, $u_{a(i)L}(y)$, corresponding to the period before harvest one and between harvest one and two (if two harvests are specified), is calculated as:

$$u_{a(i)L}(y) = S_{L(i)}(y) * \frac{c_{N3}}{f_{harvL}} * \frac{1 - e^{-u_{c(i)L} * t_{UP}}}{1 - \frac{N_{totup}}{u_{b(i)L}} * e^{-u_{c(i)L} * t_{UP}}} + u_{b(i)L} \qquad (25)$$

where $S_{L(i)}$ is the target ley yield, $u_{b(i)L}$ and $u_{c(i)L}$ are coefficients in the uptake function, and *i*, set to *1* or *2*, denotes the first and second harvest, respectively (Table 17). Plant uptake in spring, u_{st}, is for established ley set to start on 5th April, while for undersown lay and catch crops to the day after harvest of the main crop, and the plant uptake period is set to end, u_{et}, at 30 November for ley and undersown ley, and at 31 December for catch crops.

The C/N ratio for roots, C/N_{root} was set to 20 for all crops, which is slightly lower than the default value of 25. The parameter for compensatory uptake of N, f_{umov}, was set to unity in SOILN (i.e. total compensation) to minimize the risk for obtaining large discrepancies between target and simulated N uptake. The fraction of available mineral N for plant uptake and immobilization, f_{ma}, was set to 0.08 d^{-1}, which is equal to the default value used in SOILN.

Description of parameters and algorithms associated with harvest

For all crops except ley, the target N yield, N_{harv}, is calculated as:

$$N_{harv}(y,c) = S_1(y,c) * c_{N1}(c) \qquad (26)$$

if only the grain or equivalent is harvested. If above ground residues (i.e. straw, tops, stalks, etc.) are also harvested, the target N yield, N_{harv} is calculated as:

$$N_{harv}(y,c) = S_1(y,c) * c_{N1}(c) + f_b(c) * S_1(y,c) * c_{N2}(c) \tag{27}$$

where f_b is the ratio of harvested straw to grain biomass (Table 15). The target N yield of ley is calculated as:

$$N_{harvL}(y) = S_{L1}(y) * c_{N3} + S_{L2}(y) * c_{N3} \tag{28}$$

For all crops except ley, the harvested N fraction, f_{harv}, which is an input parameter to the SOILN model, is simply given by:

$$f_{harv}(y,c) = \frac{N_{harv}(y,c)}{N_{totup}(y,c)} \tag{29}$$

As described previously, the corresponding parameter for ley, f_{harvL} is not calculated but assumed to be 0.5. For catch crops f_{harvL} is logically set to zero. The above ground residue fraction of plant N at harvest, f_s, also an input parameter to SOILN, is calculated for all crops but ley according to:

$$f_s = 1 - f_{harv} - f_r - f_{reslr} \tag{30}$$

where f_{reslr} is the fraction of living root N remaining after harvest, currently set to zero for all crops. For ley and catch crops, the above ground residue fraction of plant N at harvest, f_{sL}, is set as shown in
Table 17.

The C/N ratio of above ground residues, C/N_{hres}, which is an input parameter for the SOILN model, is given by:

$$C/N_{hres}(y,c) = \frac{C_{C2}}{\left(c_{N2}(c)\left(1 - wc_2(c)\right)\right)} \tag{31}$$

where C_{C2} is the carbon concentration in plant biomass (set to 0.5) and wc_2 is the water content in above ground residues (Table 15).

Outputs

Outputs from a simulation include both the detailed output files from the SOIL and SOILN models and a summarised output in tabular form given within the SOILNDB program. In the files from the SOIL and the SOILN models outputs from all model variables are given on daily basis and as a summary for the entire simulated period. The detailed output files from the SOIL and the SOILN models include two binary formatted files '.bin' files where outputs from all model variables are given on daily basis and two additional ASCII files '.sum' includes a summary of all parameter values used in the simulation.
Within the SOILNDB system, the results are presented in three groups "Input, output & change in storage", "Transport, concentration & discharge" and "Internal flows & mineralization". The output is displayed in tabular form covering yearly averages and whole-simulation averages. Se Table 18, Table 19 and Table 20 for the displayed variables.

Table 18. The data presented in the "Input, output & change in storage" table.

Input (kg/ha)	Total harvest export (kg/ha)	Losses (kg/ha)	Change in storage (kg/ha)
Fertilization	Target	Denitrification	Soil organic N
Organic N	Simulated	Total transport in water	Soil mineral N
NH_4-N			
Deposition			

Table 19. The data presented in the "Transport, concentration & discharge" table.

NO_3-N transport (kg/ha)	NO_3-N concentration (mg/l)	Discharge (mm)
Total	Streamwater (total)	Total
In surface runoff	Surface water	In surface runoff
To tile drains	Tile drain discharge	To tile drains
To groundwater	Groundwater	To groundwater

Table 20. The data presented in the "Internal flows & mineralization" table.

Plant uptake (kg/ha)	Mineralization (kg/ha)	NO_3-N transport 1.0 m (kg/ha)
Potential	Mineralization	NO3-N transport 1.0 m
Actual		
Catch crop, potential		
Catch crop, actual		

The result tables can be saved as files or printed out. For each simulation session, results are temporarily stored in a separate database. For convenience, the information concerning the chosen soil, climate and cropping system, given as input, are also presented and stored together with the simulation results.

If whole input databases are simulated the simulation results are automatically saved in result databases.

References

Addiscott, T.M., Mirza, N.A., 1998. Modelling contaminant transport at catchment or regional scale. Agriculture, Ecosystems and Environment 67, 211-221.

Aronsson, H., Torstensson G., 1998. Measured and simulated availability and leaching of nitrogen associated with frequent use of catch crops. Soil Use and Management 14, 6-13.

Bengtsson A., Larsson, S., Magnét, B., 1991. Stråsäd, trindsäd, oljeväxter: sortval 1992. Report, Speciella skrifter 48, SLU, P.O. Box 7075, SE-75007 Uppsala, Sweden. (In Swedish). 36 pp.

Bergström, L., Johnsson, H., 1988. Simulated nitrogen dynamics and nitrate leaching in a perennial grass ley. Plant and Soil 105, 273-281.

Bergström, L, Jarvis, N.J., 1991. Prediction of nitrate leaching losses from arable land under different fertilization intensities using the SOIL-SOILN models. Soil Use and Management 7, 79-85.

Borg, G.Ch., Jansson, P.-E., 1988. Simulation of moisture and temperature conditions in a clay arable soil. In: Königsson, L.-K. (Ed.), Computers and computer modelling within Nordic geosciences. Striae, 30:00-00, Uppsala ISBN 91-7388-062-0. ISSN 0345-0074.

Borg, G.C., Jansson, P.-E., Lindén, B., 1990. Simulated and measured nitrogen conditions in a manured and fertilised soil. Plant and Soil 121, 251-267.

Brady, N.C., 1990. The nature and properties of soils. Tenth edition. Macmillan Publishing Company, New York, USA, 621 pp.

Brooks, R.H. & Corey, A.T., 1964. Hydraulic properties of porous media. Hydrology Paper no.3, Colorado State University, Fort Collins, Colorado, 27 pp.

Claesson, S., & Steineck, S., 1991. Plant nutrient management and the environment. Special report 41. SLU, P.O. Box 7070, SE-750 07 Uppsala, Sweden. 69 pp.

Haak, E., 1993. Skiftesanpassad gödsling och växtproduktion. Field-related fertilization and crop production. Internal Report, Department of Soil Sciences, Division of Plant Nutrition, SLU, P.O. Box 7072, SE-75007 Uppsala, Sweden. (In Swedish). 43 pp.

Håkanson, L., 1995. Optimal size of predictive models. Ecological Modelling 78, 195-204.

Hansson, A.-C., Pettersson, R., Paustian, K., 1987. Shoot and root production and nitrogen uptake in barley with and without nitrogen fertilization. Journal of Agronomy & Crop Science. 158, 163-171.

Heathwaite, A.L., 1993. Nitrogen cycling in surface waters and lakes. In: Burt, T.P., Heathwaite, A.L., Trudgill, S.T. (Eds.), Nitrate: Processes, Patterns and Management. John Wiley & Sons Ltd, England, pp. 99-140.

Hessel Tjell, K., Aronsson, H., Torstensson, G., Gustafson, A., Lindén, B., Stenberg, M., Rydberg, T., 1999. Mineralkvävedynamik och växtnäringsutlakning i handels- och stallgödslade odlingssystem med och utan fånggröda. Resultat från en grovmo i södra Halland, perioden 1990-1998. Ekohydrologi 50. Division of Water Quality Management, Department of Soil Sciences, SLU, P.O. Box 7072, SE-75007, Uppsala, Sweden. (In Swedish). 42 pp.

Hoffmann, M. 1999. Assessment of leaching loss estimates and gross load of nitrogen from arable land in Sweden. Doctoral Thesis, Agraria 168, SLU, P.O. Box 7072, SE-75007 Uppsala, Sweden. 36 pp.

Hoffmann, M., Johnsson, H., 1999a. Test of a modelling system for estimating N leaching – a pilot study in a small agricultural catchment. In: Hoffmann, M., Assessment of leaching loss estimates and gross load of nitrogen from arable land in Sweden. Doctoral Thesis, Agraria 168, SLU, P.O. Box 7072, SE-75007 Uppsala, Sweden. Paper V, 19 pp.

Hoffmann, M., Johnsson, H., 1999b. A method for assessing generalised nitrogen leaching estimates for agricultural land. Environmental Modeling and Assessment, 4, 35-44.

Hoffmann, M., Johnsson, H., Gustafson, A., Grimvall, A., 2000. Leaching of nitrogen in Swedish agriculture – a historical perspective. Agriculture, Ecosystems and Environment 80, 277-290.

Jansson, P.-E., 1991. Simulation model for soil water and heat conditions. Description of the SOIL model. Report 165, Department of Soil Sciences, Division of Biogeophysics, SLU, P.O. Box 7014, SE-75007, Uppsala, Sweden. 72 pp.

Jansson, P.-E., Gustafson, G., 1987. Simulation of surface runoff and pipe discharge from an agricultural soil in nothern Sweden. In: Gustafson, G., Water Discharge and Leaching of Nitrate. Ecohydrologi 22., Division of Water Quality Management, Department of Soil Sciences, SLU, P.O. Box 7072, SE-75007, Uppsala, Sweden. 16 pp.

Jansson, P.-E., Halldin, S., 1979. Model for annual water and energy flow in a layered soil. In: Halldin, S. (Ed.), Comparison of Forest Water and Energy Exchange Models, International Society for Ecological Modelling, Copenhagen. pp. 145-163.

Jansson, P.-E., Halldin, S., 1980. Soil water and heat model. Technical description. Swedish Coniferous Forest Project. Technical report 26. Department of Soil Sciences, Division of Biogeophysics, SLU, P.O. Box 7014, SE-75007, Uppsala, Sweden. 81 pp.

Johnsson, H., Hoffmann, M., 1996. Nitrate leaching simulations. In Rekolainen, S., Leek, R. (Eds.), Regionalisation of Erosion and Nitrogen Losses from Agricultural Land in Nordic Countries. Tema Nord 1996:615, Copenhagen, Denmark, pp. 18-24.

Johnsson, H., Hoffmann, M., 1998. Nitrogen leaching from agricultural land in Sweden – Standard rates and gross loads in 1985 and 1994. Ambio 27, 481-488.

Johnsson, H., Jansson, P.-E., 1991. Water balance and soil moisture dynamics of field plots with barley and grass ley. Journal of Hydrology 129, 149-173.

Johnsson, H., Bergström, L., Jansson, P.-E., Paustian, K., 1987. Simulated nitrogen dynamics and losses in a layered agricultural soil. Agriculture Ecosystems and Environment 18, 333-356.

Johnsson, H., Klemedtsson, L., Nilsson, Å., Svensson, B.H., 1991. Simulation of field scale denitrification from soils with grass ley and barley. Plant and Soil 18, 287-302.

Johnsson, H., Larsson, M.H., Mårtensson, K., Hoffmann, M., 2002. SOILNDB: a decision support tool for assessing nitrogen leaching losses from arable land. Environmental Modelling & Software 17, 505-517.

Larsson, M., Johnsson, H., 2003. Description of an application with SOILNDB at the Mellby experimental station in south-west Sweden simulating nitrate leaching between 1984 and 1998 for 10 different management practices. Teknisk rapport 71, SLU, Division of Water Quality Management.

Lewan, E., 1993. Evaporation and discharge from arable land with cropped or bare soils during winter. Measurements and simulations. Agricultural and Forest Meteorology 64, 131-159.

Lewan, E., 1994. Effects of a catch crop on leaching of nitrogen from a sandy soil: simulations and measurements. Plant and Soil 166, 137-152.

Lindén, B., Nouno, S., 1983. Det atmosfäriska nedfallets och kvävemineraliseringens bidrag till grödornas N-försörjning (Contribution of atmospheric deposition and nitrogen mineralization to crop nitrogen supply). In: Eriksson T. (Ed.) Kväveprognos – lägesbeskrivning och inriktning framöver. Rep. No. 3, Redovisning av seminarium, Kungliga Skogs och Lantbruksakademien, Stockholm, Sweden. (In Swedish) p. 41-59.

Mattson, L., 1991. Effects of annual straw application on soils and crops. Report 180, Department of Soil Sciences, Division of Soil Fertility, SLU, P.O. Box 7014, SE-75007, Uppsala, Sweden. pp.

Mattson, L., 1994. Kärna/halm-kvot – en metodikstudie Internal Report 1994-05-03, Department of Soil Sciences, Division of Soil Fertility, SLU, P.O. Box 7014, SE-75007, Uppsala, Sweden. (In Swedish) 4 pp.

Miller, R.D., Johnson, D.D., 1964. The effect of soil moisture tension on carbon dioxide evolution, nitrification, and nitrogen mineralization. Soil Science Society of America Proceedings 28, 644-647.

Monteith, J.L., 1965. Evaporation and the atmosphere. In: Fogg, G.E., (Ed.), The state and movement of water in living organisms. 19th Symposium, Society of Experimental Biology, The company of biologists, Cambridge, pp. 205-234.

Mualem, Y., 1976. A new model for predicting the hydraulic conductivity of unsaturated porous media. Water Resoursec Research 12, 513-522.

Myrbeck, Å., 1998. Swedish agricultural and horticultural crops. Report, PM Nr 1/98 KEMI. Swedish Inspectorate for Chemicals (Kemikalieinspektionen), P.O. Box 1384, SE-17127, Solna, Sweden. 44 pp.

O'riordan, T., Bentham, G., 1993. The politics of nitrate in the UK. In: Burt, T.P., Heathwaite, A.L., Trudgill, S.T. (Eds.), Nitrate: Processes, Patterns and Management. John Wiley & Sons Ltd, England, pp. 404-429.

Owens, N.J.P., 1993. Nitrate cycling in marine waters. In: Burt, T.P., Heathwaite, A.L., Trudgill, S.T. (Eds.), Nitrate: Processes, Patterns and Management. John Wiley & Sons Ltd, England, pp. 169-209.

Penman, H.L., 1953. The physical basis of irrigation control. In: Synge, P.M. (Ed.), Report of the 13th International Horticultural Congress, 1952, The Royal Horticultural Society, London. Volume II, 913-924.

Rawls, W.J., Brakensiek, D.L., Saxton, K.E., 1982. Estimation of soil water properties. Transactions of the ASAE. 1316-1320.

Stanford, G., Epstein, E., 1974. Nitrogen mineralization-water relations in soil. Soil Science Society of America Proceedings 38, 103-107.

Steineck, S., Gustafson, G., Andersson, A., Tersmeden, M., Bergström, J., 1999. Animal manure – content of nutrients and trace elements. Rapport 4974. Naturvårdsverket, SE-106 48 Stockholm, Sweden. (In Swedish with English summary) 28 pp.

Swedish Environmental Protection Agency, 1997. Källor till kväveutsläpp: underlagsrapport. Rapport 4736. Naturvårdsverket, SE-106 48 Stockholm, Sweden. (In Swedish) 132 pp.

Torstensson, G., Johnsson., H., 1996. Simulation of water and nirogen dynamics in a five year leaching experiment with varying fertilisation and manure treatments. Report 29. Department of Soil Sciences, SLU, P.O. Box 7014, SE-75007, Uppsala, Sweden. 62 pp.

Torstensson, G., Aronsson, H., Lindén, B., 1996. Winter crops as green cover crops - nirogen uptake capacity and effects on nitrogen leaching. Technical Report 22., Division of Water Quality Management, Department of Soil Sciences, SLU, P.O. Box 7072, SE-75007, Uppsala, Sweden. 7 pp.

APPENDIX I

Table A1. Selections used in SOILNDB for the technical switches in the SOIL model

ADDSIM	OFF	AVERAGED	ON	AVERAGEG	ON
AVERAGET	ON	AVERAGEX	ON	CHAPAR	ON
DDAILY	ON	DRIVPG	1	INSTATE	OFF
LISALLV	ON	OUTFORN	OFF	OUTSTATE	OFF
VALIDPG	OFF	VISALLOUT	OFF		

Table A2. Selections used in SOILNDB for the model specific switches in the SOIL model

ATIRRIG	OFF	CRACK	OFF	EVAPOTR	3
FRINTERA	ON	FRLIMINF	1	FRLIMUF	ON
FRLOADP	ON	FRPREFL	OFF	FRSWELL	OFF
GWFLOW	OFF/ON	HEATEQ	ON	HEATPUMP	0
HEATWF	ON	INHEAT	OFF	INTERCEPT	ON
INWATER	1	PLANTDEV	OFF	ROOTDIST	3
ROUGHNESS	0	RSCALC	0	SALT	OFF
SNOW	ON	SUREBAL	0	UNITG	ON
WATEREQ	ON	WUPTAKE	2		

Table A3. Selections used in SOILNDB for the technical switches in the SOILN model

ADDSIM	OFF	AVERAGED	ON	AVERAGEG	ON	AVERAGET	ON
AVERAGEX	ON	CHAPAR	ON	DRIVPG	ON	INSTATE	ON
LISALLV	ON	OUTFORN	OFF	OUTSTATE	OFF	VALIDPG	OFF

Table A4. Selections used in SOILNDB for the model specific switches in the SOILN model

DENDIST	0	DRIVCROP	0	DRIVEXT	0	DRIVMANA	0
GROWTH	OFF	GWFLOW	OFF/ON	MANURE	ON	ROOTDIST	3
SPECIAL	OFF	TEMPR	ON				

APPENDIX II

List of symbols

Symbol	Parameter definition	Value	Unit in source	Equation number	Source	Name in SOILNDB	Name in SOIL/SOILN
	SOIL-soil hydrology and plotpf						
k_s	saturated hydraulic conductivity	Table 4	cm hr^{-1}	1,6	autopar.mdb	SATC	SATC
k_{sm}	saturated hydraulic conductivity including macropores	Table 4	cm hr^{-1}	7	autopar.mdb	SATCT	SATCT
λ	pore size distribution index	Table 4	—	4, 6	autopar.mdb	LAMBDA	LAMBDA
θ_r	residual water content	Table 4	vol %	4	autopar.mdb	RES	RES
θ_s	porosity	Table 4	vol %	4, 5, 7	autopar.mdb	PORO	PORO
ψ_a	air entry pressure	Table 4	cm water	4, 6	autopar.mdb	PSIE	PSIE
θ_w	water content at wilting point (at pF 4.2)	Table 4	vol %	3	autopar.mdb	WILT	WILT
ψ_x	upper limit for use of the Brooks & Corey expression	Table 4	cm water	3, 4	autopar.mdb	XPSI	XPSI
A_{0T}	empirical coefficient	0.54	—	—	autopar.mdb	A0T	A0T
A_{1T}	empirical coefficient	0.025	—	—	autopar.mdb	A1T	A1T
n_{var}	tortuosity factor in the Mualem equation	1; 5	—	6	autopar.mdb	NVAR	NVAR
ψ	calculated soil water tension	—	cm water	3, 4, 6, 7	—	—	—
θ	calculated water content	—	vol %	3 - 5	—	—	—
ψ_{wilt}	soil water tension at wilting point	15000	cm water	3, 6	—	—	—
θ_x	calculated water content at ψ_x	—	vol %	3	—	—	—
ψ_m	threshold tension for the use of the Brooks & Corey expression	—	cm water	4 - 7	—	—	—
ψ_0	lower range in the linear expression in the retention function	0	cm water	5, 7	—	—	—
k_w	calculated unsaturated hydraulic conductivity	—	cm hr^{-1}	6, 7	—	—	—
	upper depth of the soil layer, used in 'soilp.dat'	—	cm	—	autopar.mdb	UDEP	UDEP
	lower depth of the soil layer, used in 'soilp.dat'	—	cm	—	autopar.mdb	LDEP	LDEP
	replicate number of soil profile, used in 'soilp.dat'	—	—	—	autopar.mdb	UNUM	UNUM
	profile number, used in 'soilp.dat'	—	—	—	autopar.mdb	UPROF	UPROF
q_{pipe}	Saturated flow to tile drains	—	mm	1			
A_{rel}	Ratio between vertical area and horizontal area	—	—	1			

z_{pipe}	Depth of tile drains	0.9	m	1	Indata	DDRAIN	DDRAIN
z_{gw}	Depth of water table		m	1	calculated		
L	Distance between tile drains	10	m	1	Indata	DDIST	DDIST
q_{gr}	Horizontal groundwater flow		mm day^{-1}	2	calculated		
$q1$	Potential maximum flowrate	0	mm day^{-1}	2	Indata	GWFLOW	GWFLOW
z_1	Depth were flow ceases		m	2			
	SOIL – evapotransp.						
$t_{\mathrm{day}}(\mathrm{i})$	day number for specification of temporal variation within year	Table 7	julian day		autopar.mdb	daynum(i)	DAYNUM(i)
$d_{\mathrm{h}}(t_{\mathrm{day}}(\mathrm{i}))$	displacement height	Table 8	m		autopar.mdb	displv(i)	DISPLV(i)
$l_{\mathrm{ai}}(t_{\mathrm{day}}(\mathrm{i}))$	leaf area index	Table 8	—			laiv(i)	LAIV(i)
$z_0(t_{\mathrm{day}}(\mathrm{i}))$	roughness length	Table 9	m		autopar.mdb	roughv(i)	ROUGHV(i)
$r_{\mathrm{s}}(t_{\mathrm{day}}(\mathrm{i}))$	surface resistance	Table 9	s m^{-1}		autopar.mdb	rsv(i)	RSV(i)
r_{sint}	surface resistance for intercepted water	5,0	s m^{-1}		autopar.mdb	intrs	INTRS
a_{r}	albedo of vegetation and soil	20	—		autopar.mdb	albedo	ALBEDO
$c_{\mathrm{form}}(t_{\mathrm{day(i)}})$	shape coefficient	1	—		autopar.mdb	cform(i)	CFORM
i_{LAI}	interception storage capacity of canopy	0.2	mm LAI^{-1}		autopar.mdb	intlai	INTLAI
d_{lat} (s)	latitude of site				climate.mdb	latitud	LATID
	SOIL –water uptake						
r_{frac}	root fraction	0.05	—		SOIL	RFRACLOW	RFRACLOW
$z_{\mathrm{r(i)}}$	root depth (at different dates defined by $t_{\mathrm{root(i)}}$)	Table 10, Table 11	m		autopar.mdb VB-code	rootdep(i)_soil nrootdep2	ROOTDEP(i)
$t_{\mathrm{root(i)}}$	dates defining root development stages	Table 11	julian day		VB-code	rootti(i)	ROOTT(i)
f_{umov}	degree of compensatory uptake of water	0.5	—		SOIL	UPMOV	UPMOV
t_1	temperature coefficient	0.8	—		autopar.mdb	wupate	WUPATE
t_2	temperature coefficient	0.4	—		autopar.mdb	wupbte	WUPBTE
ψ_{c}	critical soil water tension where reduction of transpiration begins	Table 6	cm water		autopar.mdb	wupcri	WUPCRI
p_1	parameter in water tension respons function for transpiration	0.2	day mm^{-1}		autopar.mdb	wupf	WUPF
p_2	parameter in water tension respons function for transpiration	0	—		autopar.mdb	wupfb	WUPFB
	SOIL – soil evapaporation						
r_{alai}	aerodynamic resist.	50	s m^{-1}		autopar.mdb	ralai	RALAI
k_{rn}	extinction coefficient	0.5	LAI^{-1}		autopar.mdb	rntlai	RNTLAI
r_{ψ}	empirical coefficient used to calculate soil surface resistance	All but sand 100, sand 200	s m^{-1}		autopar.mdb	psirs	PSIRS

SOIL - temperature

T_{ini}	initial soil temperature	8	°C	VB-code	ITEMPS	ITEMPS
y_{cycle}	length of cycle of analytical air temperature	365	days	VB-code	YCH	YCH
t_{ph}	phase shift of analytical air tempemperature	18	days	VB-code	YPHAS	YPHAS
T_{amean}	mean value in the analytical air temperature function	8	°C	VB-code	YTAM	YTAM
T_{aamp}	amplitude in the analytical air temperature function	10	°C	VB-code	YTAMP	YTAMP

SOIL -Frost

fc_i	decrease of unsat. hydraulic conductivity due to freezing	Table 6	—	autopar.mdb	fcond	FCOND
d_1	fraction of wilting point remaing as unfrozen water at –5°C	Table 6	—	autopar.mdb	fwfrac	FWFRAC
d_2	coefficient in the freezing point depression function	Table 6	—	autopar.mdb	fdf	FDF

SOIL -Snow

T_{max}	rain temp. threshold	2	°C	VB-code	PRLIM	PRLIM
T_{min}	snow temperature threshold	-2	°C	VB-code	PSLIM	PSLIM
S_1	radiation melt factor for old snow	2.5	—	VB-code	SAGEM1	SAGEM1
S_2	snow age coefficient in radiation melt respons on snow	0.1	—	VB-code	SAGEM2	SAGEM2
P_{samin}	limit for snow age updating	5	mm day^{-1}	VB-code	SAGEZP	SAGEZP
Q_{samin}	thermal quality limit for snow age updating	0.9	—	VB-code	SAGEZQ	SAGEZQ
S_{dl}	liquid water coefficient in snow density function	100	kg m^{-3}	VB-code	SD1OL	SD1OL
S_{dw}	water equivalent coefficient in snow density funct.	0.9	m^{-1}	VB-code	SD2OM	SD2OM
ρ_{smin}	snow density of newly formed snow	100	kg m^{-3}	VB-code	SDENS	SDENS
S_{wlmin}	threshold liquid water storage of snow	3	kg m^{-2}	VB-code	SLWL0	SLWL0
m_f	refreezing efficiency coefficient in snow melt function	0.1	m	VB-code	SMAFR	SMAFR
m_{Rmin}	minimum value of global radiation influence in snow melt funct.	1e-007	mm J^{-1}	VB-code	SMRIS	SMRIS
m_T	temperature coefficient in snow melt function	3	mm day^{-1} °C^{-1}	VB-code	SMTEM	SMTEM
f_{ret}	retention capacity of snow	0.07	—	VB-code	SRET	SRET
s_k	thermal conductivity coefficient for snow	2.86e-006	Wm^4 kg^{-2}	VB-code	STCON	STCON

	SOIL – other						
ψ_{ini}	initial soil tension	100	cm water		VB-code	IPOT	IPOT
T_{ini}	initial soil temperature	?			?	?	IPOT
n^o	number of layers	5/6	—		VB-code	NUMLAY	NUMLAY
$z(l)$	layer thickness	Table 3	m	16, 17, 18	VB-code	thick(i)	THICK(i)
$c_{rain\ (s)}$	correction coefficient for rain precipitation	1.18	—	—	climate.mdb	preca0	PRECA0
$c_{snow\ (s)}$	addition correction coefficient for snow precipitation	0.20	—	—	climate.mdb	preca1	PRECA1
	thickness of layers 1 to 5 used in ‘soilp.dat’	0	—	—	VB-code	UTHICK(i)	UTHICK(i)
	multiplicative factor for all layer thicknes	1	—	—	VB-code	VC	VC
	technical: division factor in time step integration calculation	2	—	—	VB-code	XADIV	XADIV
	lower limit to calculate convective heat flow	10	—	—	VB-code	XINFLI	XINFLI
	technical: recalculation frequency	2	—	—	VB-code	XLOOP	XLOOP
	technical: number of layers for recalculation frequency	4	—	—	VB-code	XNLEV	XNLEV
		(20)		—	VB-code	STPMAX 20	STPMAX
		(50)		—	VB-code	STXTGD 50	STXTGD
	SOILN-Plant N uptake and management						
u_{a1}	N uptake parameter for main uptake period for all crops but ley	—	$g\ m^{-2}\ yr^{-1}$	22	VB-code	upa1(i)	UPA(i)
u_{a2}	N uptake parameter for catch crop	—	$g\ m^{-2}\ yr^{-1}$		indata	upa2	UPA(i)
u_{a3}	N uptake parameter for winter crops during the autumn period	Table 16	$g\ m^{-2}\ yr^{-1}$	23	autopar.mdb	upa3	UPA(i)
u_{b1}	coefficient in plant N uptake function	Table 16	$g\ m^{-2}\ yr^{-1}$	22	autopar.mdb	upb1	UPB(i)
u_{b2}	coefficient in plant N uptake function for catch crops during the autumn period	Table 17	$g\ m^{-2}\ yr^{-1}$		autopar.mdb	c_upb2	UPB(i)
u_{b3}	coefficient in plant N uptake function for winter crops during the autumn period	Table 16	$g\ m^{-2}\ yr^{-1}$	23	autopar.mdb	upb3	UPB(i)
u_{c1}	coefficient in plant N uptake function	Table 16	d^{-1}	22	autopar.mdb	upc1	UPC(i)
u_{c2}	coefficient in plant N uptake function for catch crops during the autumn period	Table 17	d^{-1}		autopar.mdb	c_upc2	UPC(i)
u_{c3}	coefficient in plant N uptake function for winter crops during the autumn period	Table 16	d^{-1}		autopar.mdb	upc3	UPC(i)
$u_{a(i)L}$	N uptake parameter for the first and second uptake period for ley	—	$g\ m^{-2}\ yr^{-1}$	25	VB-code	upa1(i)	UPA(i)

N_{L3up}	potential N uptake of ley after the last harvest each year or if no harvest is specified	Table 17	g m^{-2} yr^{-1}	24	autopar.mdb	upa	UPA(i)
u_{aiL}	N uptake parameter for undersown ley	7	g m^{-2}		VB-code	upa2(i-1)	UPA(i)
$u_{b(i)L}$	coefficient in plant N uptake function, ley	0.3	g m^{-2} yr^{-1}	25	autopar.mdb	upb1(i)	UPB(i)
u_{biL}	coefficient in plant N uptake function, undersown ley	0.3	g m^{-2} yr^{-1}		autopar.mdb	i_upb	UPB(i)
$u_{c(i)L}$	coefficient in plant N uptake function, ley	0.045; 0.09;0.09	d^{-1}	25	autopar.mdb	upc1	UPC(i)
$u_{c(i)L}$	coefficient in plant N uptake function, ley	0.06;0.09	d^{-1}	25	autopar.mdb	upc2	UPC(i)
$u_{c(i)L}$	coefficient in plant N uptake function, ley	0.09	d^{-1}	25	autopar.mdb	upc3	UPC(i)
u_{ciL}	coefficient in plant N uptake function, undersown ley	0.08	d^{-1}	25	autopar.mdb	i_upc	UPC(i)
u_{au}	pot. N uptake of insown ley in the autumn after harvest of the main crop	11	g m^{-2} yr^{-1}		autopar.mdb	i_upa	UPA(i)
$u_{st(i)}$	start of plant uptake period, spring crops	—	julian day		VB-code	s_tdp(i)+12	UPST(i)
$u_{st(i)}$(s)	start of plant uptake period, winter crops (w.c.) and ley	100 (w.c.) 95 (ley)	julian day		climate.mdb	w_(i)_upst1 ley_upst1	UPST(i)
$u_{st(i)}$	start of plant uptake period, undersown ley and catch crops		julian day		VB-code	upst1, upst2(i)	UPST(i)
$t_{sk(i)}$	harvest date, all crops but ley	—	julian day		indata	sk_tdp(i)	UPET(i)
$u_{et(i)}$	end of plant uptake period, catch crops	365	julian day		VB-code? autopar.mdb	upet3 i_upet c_upet2	UPET(i)
$u_{et(i)}$(s)	end of plant uptake period, winter crops (w.c.) and ley	364 (w.c.) 334 (ley)	julian day		climate.mdb	w_(i)_upet3 ley_upet3 ley_i_upet3	UPET(i)
f_{ma}	fraction of N available for plant uptake	0.08	d^{-1}		autopar.mdb	upma	UPMA
f_{harv}	harvested fraction of plant N	—	—	29, 30	calculated	harhp1(i)	HARHP(i)
f_{harvL}	harvested fraction of plant N, ley and catch crops (c.c.)	0.5 ley 0 (c.c.)	—	24, 25	autopar.mdb	harhp(i); ploughing of ley harhp(i) c_harhp2	HARHP(i)
f_s	above ground residue fraction of plant N at harvest	—	—	30	calculated	HARAR	HARAR(i)
f_{sL}	above ground residue fraction of plant N at harvest and at the end of the uptake period, ley and catch crops	Table 17	—		autopar.mdb	harar(i); ploghing of ley harar(i); i_harar c_harar2	HARAR(i);
f_{lr}	regulating plant death during winter, for winter crops	1	—	23	autopar.mdb	harlr3	HARLR(i)

f_{reslr}	fraction of living root-N remaining after harvest	0	—	30	autopar.mdb	harlr1 C_harlr2	harlr1
$C/N_{hres(y,c)}$	C/N ratio of above ground residues	—	—	31	calculated	cnares(i)	CNARES
C/N_{rootI}	C/N ratio of roots	20	—		calculated	cnroot	CNROOT
r_{fracN}	root fraction	0.001	—		autopar.mdb	rfraclow	RFRACLOW
f_{umov}	degree of compensatory uptake of N	1	—		autopar.mdb	upmov	UPMOV
$t_{root(i)}$	dates defining root development stages	table 10	julian day		VB-code	nrootti(i)	ROOTT(i)
	SOILN-mineralisation and immobilisation						
r_o	C-N ratio of microorganisms and humified products	10	—	16, 17	autopar.mdb	cnorg	CNORG
f_{efe}	effic. in intern. synth. of micro. biomass and metabolites in faces	0.5	—		autopar.mdb	feceff	FECEFF
f_{chf}	faeces carbon humification fraction	0.6	—		autopar.mdb	fechf	FECHF
k_f	rate constant for faces decomposition	0.035	d^{-1}		autopar.mdb	feck	FECK
k_h	rate constant for humus mineralisation	0.00006	d^{-1}		autopar.mdb	humk	HUMK
f_e	effic. in intern. synth. of micro. biomass and metabolites in litter	0.5	—		autopar.mdb	liteff	LITEFF
f_h	litter carbon humification fraction	0.2	—		autopar.mdb	lithf	LITHF
k_l	rate constant for litter decomposition	0.055	d^{-1}		autopar.mdb	litk	LITK
k_n	specific nitrification rate	0.2	d^{-1}		autopar.mdb	nitk	NITK
n_q	NO_3-N:NH_4-N ratio in nitrification function	6	—		autopar.mdb	nitr	NITR
	ploughdepth	0.25	m		VB-code	PLOUGHDEP	PLOUGHDEP
	date for ploughing	—	julian day		VB-code	j_tdp(i)	PLOUGHDAY
	SOILN-soil moisture respons						
$\Delta\theta 1$	water cont. related to soil moisture respons on biological activity	Table 13	%		autopar.mdb	mos1	MOS(1)
$\Delta\theta 2$	water cont. related to soil moisture respons on biological activity	Table 13	%		autopar.mdb	mos2	MOS(2)
xm	empirical const. in soil moist funct.	Table 13	—		autopar.mdb	mosm	MOSM
e_s	coef. defining the relative effect of moist. when the soil is satur.	Table 13	—		autopar.mdb	mossa	MOSSA

	SOILN-denitrification						
$\theta_d(z)$	water content range in funct. for soil moist effect on denitrificat.	17	vol %		autopar.mdb	mosden	MOSDEN
d	empirical constant	2	—		autopar.mdb	dend	DEND
c_s	half-saturation constant, gives the effect of nitrate concentration	10	mg N l^{-1}		autopar.mdb	denhs	DENHS
d_{frac}	fraction of potential denitrification in soil layers	Table 3	—		VB-code	DFRAC(i)	DFRAC(i)
k_d	potential rate of denitrification	0.1	gN m^{-2} d^{-1}		autopar.mdb	denpot	DENPOT
	SOILN-soil temperature respons						
t_b	temp. at which the temp. effect in the Q_{10}-function equals 1	20	°C		autopar.mdb	tembas	TEMBAS
Q_{10}	respons to a 10°C temperature change on biological activity	2	—		autopar.mdb	temq10	TEMQ10
	SOILN-manure						
CN_{fec}	C-N ratio of faeces in manure	Table 1			input data to SOILNDB; autopar.mdb	C-N ratio	CNFEC
t	date of manure application	—	julian day	20	input data to SOILNDB	MANET(i) MANST(i)	MANET(i) MANST(i)
N_{faeces}	amount N in faeces in manure	—	gN m^{-2}	19	VB-code	xmanfn(i)	MANFN(i)
N_{amm}	amount N in ammonium in manure	—	gN m^{-2}	20	VB-code	xmannh(i)	MANNH
	amount N in bedding in manure	0	gN m^{-2}		VB-code	MANLN(i)	MANLN(i)
	C-N ratio of bedding in manure	40	—		VB-code	CNBED	CNBED
	mixing depth of applied manure in to the soil	0.1	m		VB-code	MANDEPTH	MANDEPTH
	SOILNDB-manure						
$c_{ammN}(m)$	concentration of NH_4-N in manure	Table 1	kg N ton^{-1}	20	input; autopar.mdb	Ammonium content	—
$c_{orgN}(m)$	concentration of organic N in manure	Table 1	kg N ton^{-1}	19	input; autopar.mdb	Organic N-content	—
F_{sloss}	volatilisation loss of NH_3	Table 2	%	20	input; autopar.mdb		—
m	type of manure	Table 1	—	19, 20	input; autopar.mdb		—
M	applied amount of manure	—	ton	19, 20	input	st_giva(i)	—
a	application technique of manure	—	—	20	input; autopar.mdb		—

SOILNDB-plant uptake and harvest

N_{harv}	target N yield	—	kg ha^{-1}	26, 27, 29	VB-code	malskord(i)	—
N_{harvL}	target N yield for ley	—	kg ha^{-1}	28	VB-code	malskord(i)	—
N_{totup}	target N uptake	—	g m^{-2}	21 – 25, 29	VB-code	U	—
S_1	target harvest yield of all crops excluding ley	—	kg ha^{-1}	21, 23, 26, 27	input	sk_avk1(i)	
$S_{L(i)}$	target ley yield for first and second harvest	—	kg ha^{-1}	24, 25, 28	input	sk_avk1(i)	
c_{N1}, c_{N3}	nitrogen concentration in the harvested product	Table 15	%	21, 23-28	autopar.mdb	grain N content	—
c_{N2}	nitrogen concentration in above ground residues	Table 15	%	21, 23, 27, 31	autopar.mdb	residues N content	—
C_{C2}	carbon concentration in plant biomass	0.4		31	autopar.mdb	residues_C_content	—
wc_2	water content in above ground residues	Table 15	%	31	autopar.mdb	water content for residues N content values	—
f_a	ratio of above ground residues to grain biomass	Table 15	—	21, 23	autopar.mdb	residues: grain ratio	—
f_b	straw/grain ratio	Table 15	—	27	autopar.mdb	straw:grain ratio	—
f_r	fraction of N in roots of total plant N	Table 15	—	21, 23, 30	autopar.mdb	rootN:plantN fraction	—
$t_{s(i)}$	sowing date	—	julian day		indata to SOILNDB	s_tdp(i)	
t_{up}	length of the uptake period	—	days	22, 25	VB-code	t	—
y	year	—	—	21, 23-29, 31	indata to SOILNDB	—	—
c	crop type	—	—	21, 23, 27, 29, 31	indata to SOILNDB	—	—

SOILN-initial conditions

—	initial content of NO3-N for each soil layer	Table 3	g m^{-2}		VB-code	no3(i)	NO3(i)
—	initial content of NH4-N for each soil layer	Table 3	g m^{-2}		VB-code	nh4(i)	NH4(i)
$N_{lom}(l)$	initial content of litter N for each soil layer	—	g m^{-2}	16	VB-code	nlit(i)	NLIT(i)
$N_{hom}(l)$	initial content of humus N for each soil layer	—	g m^{-2}	17	VB-code	nh(i)	NH(i)
$C_{lom}(l)$	initial content of litter C for each soil layer	—	g m^{-2}	18	VB-code	cl(i)	CL(i)
—	initial content of C in faeces	0	g m^{-2}	—	VB-code	CF(i)	CF(i)
—	initial content of N in faces	0	g m^{-2}	—	VB-code	NF(i)	NF(i)
—	initial accumulcted denitrification	0	g m^{-2}	—	VB-code	DENIT	DENIT
—	initial accumulcted N leaching	0	g m^{-2}	—	VB-code	DLOSST	DLOSST
—	initial content of N in plant	0	g m^{-2}	—	VB-code	PLANT	PLANT
—	initial content of N in fertilizer pool	0	g m^{-2}	—	VB-code	FERT	FERT
—	initial content of N in above ground residues	0	g m^{-2}	—	VB-code	LITABOVE	LITABOVE

	SOILNDB-initial conditions						
r_{lh}	litter-humus ratio	0.005		16 - 18	autopar.mdb	ini_lit_hum_ratio	—
		0.1			autopar.mdb	sub_SOM_Content	
$c_{\mathrm{Com(l)}}$	fraction of C in soil organic matter	0.58		18	autopar.mdb	SOM_C_Content	
		10			autopar.mdb	SOM_CN_Ratio	CNORG???
ρ(l)	dry bulk density for the top soil (0-25 cm)	1.35	g cm^{-3}	16 - 18	autopar.mdb	db_dens_top	
ρ(l)	dry bulk density for the sub soil (25-150 cm)	1.45	g cm^{-3}	16 - 18	autopar.mdb	db_dens_sub	
SOM(l)	soil organic matter content	—	%	16 - 18	input data to SOILNDB	top_SOM_Content	
SOM(l)	soil organic matter content	—	%	16 - 18	input data to SOILNDB	sub_SOM_Content	