Net N-mineralisation related to soil organic matter pools

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ABSTRACT

Soil organic matter and its turnover rate are key parameters for agricultural management practice as well as for environmental issues. In a field experiment comparing organic (compost) and mineral fertilisation and combinations of both the amount of inorganic nitrogen in the soil and the nitrogen uptake by the plants were measured. Considering these data and the fertilisation practice the net N-mineralisation during the vegetation periods 1996–2001 was estimated for six fertilisation treatments. Simultaneously the nitrogen dynamics in the soil were calculated using the STOTRASIM model, which takes into account four soil organic matter pools of different turnover rate. A close relation was found between the amount of a slow decomposable fraction and the net N-mineralisation during the vegetation period.

Keywords: soil nitrogen; N mineralisation; pool size; modelling

The decomposition of soil organic matter and therefore the mineralisation rate of nutrients from this pool is essential for plant nutrition as well as for the management of the quality of surface water and groundwater. In undisturbed systems, soil organic matter can be considered to attain a steady state level governed by the soil forming factors and their interaction. Where soils are used for agricultural production, these equilibria are not maintained. The establishment of a new steady state during cultivation will depend on soil type, crop rotations and the management of residues, organic inputs and soil (Jarvis et al. 1996). Soil organic matter contains a large reservoir of nutrients and is commonly divided into a number of pools, into which materials behaving similarly are grouped. These are linked by a number of interacting, competing, and sometimes antagonistic processes. Experiments in the field as well as in the laboratory (Hassink 1995, Curtin and Wen 1999, Honeycutt 1999) investigated soil organic matter fractions and their decomposition rates and many approaches are recommended for modelling these dynamics (de Willigen et al. 1991, Rickman et al. 2001).

MATERIAL AND METHODS

In the frame of a project investigating the impact of organic farming on the environment, nitrogen fluxes in the soil have been assessed not only by investigations in a field experiment but also by efforts for modelling. Results from the measurements in the field allow to check the assumed dynamic of nitrogen mineralisation in the model approach.

Field experiment

An arable field experiment investigating nutrient dynamics in soil and nitrate leaching to the groundwater with different regimes of fertilisation is in operation near Vienna since 1992. The fertilisation treatments cover fertilisation with compost from source separated organic household waste (C1, C2, C3), mineral fertilisation (N1, N2, N3), combinations of both (N1C1, N1C2, N1C3, N2C1, N3C1) and an untreated control (O) in six replications in a Latin rectangle. This study presents data from one plot of each of the treatments C2, C3, N2, N3, N1C3 and N3C1 from the years 1996–2001. During this period, biowaste compost (from source-separated organic waste and yard trimmings) was applied at rates of 3, 7 and 10 t/ha/year on average (C1, C2, C3). The minerally fertilised treatments received average rates of 20, 30 and 40 kg N/ha/year plus 34 kg/ha P_2O_5 and 60 kg/ha K_2O (N1, N2, N3). The treatments with combined fertilisation did not receive mineral phosphorus or potassium fertiliser (Erhart et al. 2002).

Except for the fertilisation, the trial was managed according to the European Union (EU) regulation 2092/91 on organic farming with customary farm machinery. The crop rotation 1996–2001 included oats, spelt, potatoes, winter wheat, winter barley and winter rye. In the field trial, compost from the composting plant of the City of Vienna was used. The compost raw material consisted of source-separated organic waste, which included organic household waste and yard trimmings at a 2:3 ratio. The compost was produced in an open windrow process with regular turning using front-end loader and windrow turner.

The amount of inorganic nitrogen in the soil (NO_3-N + NH_4-N for the depth of 0–90 cm) was measured periodically in each plot and the yield and the nitrogen uptake by the plants were determined annually. For the six plots investigated in detail the net-N-mineralisation during the vegetation periods 1996–2001 is calculated using the following equation assuming that inorganic N-input from the atmosphere is compensated by gaseous losses (Table 1).

Table 1. Data for the calculation of the net-N-mineralisation; total amounts for the vegetation periods 1996–2001

Plot	ΣN_d	ΣN_p	ΣN_f	ΣNet-N_m
	kg N/ha			
N2	–33	558	180	345
N3	–59	554	240	255
C2	–28	576	4	544
C3	–1	639	6	633
N1C3	–30	659	94	535
N3C1	–63	734	242	429

$$\text{Net-}N_m = N_d + N_p + N_l - N_f$$

where:

Net-N_m = net-nitrogen-mineralisation (kg N/ha)

N_d = difference in inorganic nitrogen in the soil (0–90 cm) between autumn and spring ($N_{min\text{-}au} - N_{min\text{-}sp}$, kg N/ha)

N_p = inorganic nitrogen uptake by plants (kg N/ha)

N_l = inorganic nitrogen leached (kg N/ha), negligible for the vegetation period because of the water balance

N_f = inorganic nitrogen fertilisation through mineral fertiliser and compost-NO_3 and -NH_4 (kg N/ha)

Modelling

The water fluxes in the soil and plant growth are calculated with the deterministic simulation model SIMWASER (Stenitzer 1988) and the nitrogen dynamics in the soil and accordingly the losses of nitrate to the groundwater are calculated with STOTRASIM (Feichtinger 1998). The models describe one-dimensional, vertical flow of water and nitrate-nitrogen within a soil profile, neglecting interflow and preferential flow.

SIMWASER simulates the water balance for a soil profile and the crop yield of any number of crop rotations and years on a daily basis, provided that daily weather records are available. The water balance and the growth of plants are interrelated by the physiological interaction of assimilation and transpiration. Potential assimilation and therefore potential plant growth occurs as long as the water supply towards the stomata can meet the potential transpiration loss. The potential growth rate is specific to each crop and depends mainly on air temperature and global radiation. The potential plant production rate and the proportion of actual transpiration to the potential one calculate actual plant growth. The potential evapotranspiration is calculated according to the Penman-Monteith-for-

Table 2. Data for the estimation of N_{SOS}

Plot	Soil texture (g/100 g)			Soil organic matter*	N_{SOS} (0–30)
	sand (63–2000 μm)	silt (2–63 μm)	clay (< 2 μm)	0–30 cm (g/100 g)	kg N/ha
N2	15	62	23	3.0	3763
N3	17	59	24	2.7	3170
C2	14	63	23	3.0	3643
C3	17	59	24	4.2	6095
N1C3	17	59	24	3.6	5149
N3C1	17	59	24	3.1	3853

*determination by wet combustion according ÖNORM L 1081

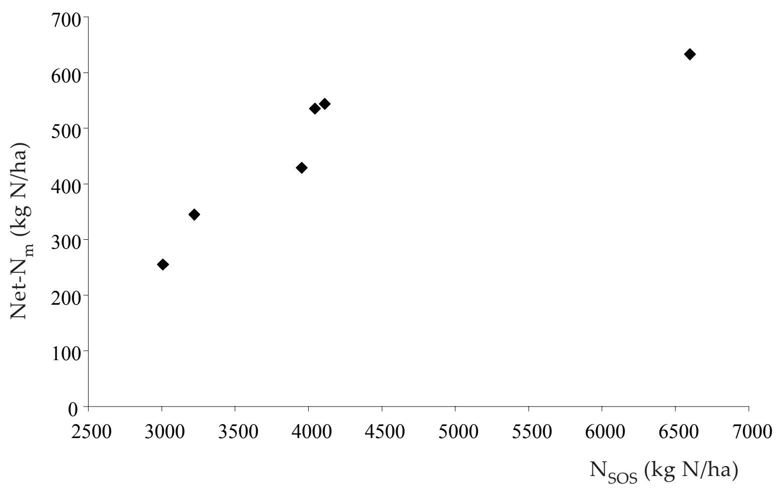

Figure 1. Relation between net-N-mineralisation (Net-N_m) and N_{SOS}, a decomposable part of soil organic matter

mula (Szeicz et al. 1969, Thom et Oliver 1977) and the potential transpiration is deduced from the potential evapotranspiration. The actual transpiration is the amount of water, which can be withdrawn by the roots from the soil and is less equal to the potential transpiration. Precipitation and irrigation are an input and evaporation and transpiration are an output at the soil surface. Interception is also taken into account. Water fluxes in the soil are calculated according to DARCY's law. Taking into account the soil physical properties either capillary rise or seepage will be the result.

STOTRASIM calculates the daily nitrogen balance for a soil profile. The inputs (fertilisation, precipitation, irrigation, assimilation from the air by legumes, capillary rise) and losses (volatilisation, denitrification, leaching), the nitrogen uptake of the vegetation, the nitrogen turnover (mineralisation, immobilisation) and the nitrate transport in the soil are taken into account.

Nitrogen turnover in the soil is calculated for an inorganic N-fraction (NH_4-N, NO_3-N) and four organic N-pools. Besides primary (fresh) organic substances (FOS = plant residues, organic fertiliser, compost etc.) three soil organic matter-pools with different turnover rates (fast decomposable/AOS, slow decomposable/SOS, inert/IOS) are considered. The AOS-pool is calculated as a function of a specific pore volume (Rühlmann et al. 2001) and the inert organic fraction (IOS) is initialised in dependence of the fine-grained mineral soil particles (Rühlmann 1999). SOS results from the humus content of the soil minus AOS and IOS. Based on a potential turnover rate for each pool the processes are controlled by the soil temperature and the soil moisture. Details on the nitrogen uptake by the plants, the assimilation of nitrogen from the air by legumes, the volatilisation of ammonia, the denitrification and the transport of nitrate-nitrogen within the soil are outlined in Feichtinger (1998).

Modelling the nitrogen dynamics in the soil is in progress for the six plots investigated in detail. The calculated amount of nitrogen in the SOS-fraction (N_{SOS}) of the upper soil layer (0–30 cm) is based on soil texture, the organic matter content and the above mentioned assumptions (Table 2).

Finally N_{SOS} as a source of nitrogen release is related to the net-mineralisation of nitrogen (Net-N_m) for each plot.

RESULTS AND DISCUSSION

The calculated amount of N_{SOS} in the soil (0–30 cm depth) and the calculated net-N-mineralisation during the vegetation periods 1996–2001 in total are related for these six plots of the field experiment, which have been investigated in detail (Figure 1).

For the case presented the mean net-N-mineralisation can be predicted well by N_{SOS}. It seems, that the assumption used in the model for partitioning the soil organic matter into different pools of release time comes close to the facts.

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ABSTRAKT

Čistá mineralizace dusíku ve vztahu k různým frakcím půdní organické hmoty

Půdní organická hmota a intenzita její přeměny jsou mimořádně důležité jak pro zemědělskou praxi, tak pro ochranu životního prostředí. V polním pokusu byl porovnáván účinek organického (kompost) a minerálního hnojení a jejich kombinace na obsah minerálního dusíku v půdě a jeho příjem rostlinami. Na základě výsledků pokusu a praktických zkušeností byla vypočítána čistá mineralizace dusíku v šesti různých kombinacích hnojení v období 1996 až 2001. Současně byla simulována dynamika dusíku v půdě s využitím modelu STOTRASIM, který obsahuje čtyři složky půdní organické hmoty, jejichž mineralizační rychlosti se liší. Byl nalezen těsný vztah mezi množstvím pomalu rozložitelné složky půdní organické hmoty a čistou mineralizací dusíku v průběhu vegetačního období.

Klíčová slova: půdní dusík; mineralizace dusíku; složky půdní organické hmoty; modelování

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