Leaching of organic nitrogen and carbon after cultivating grass-clover pastures

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Organic nitrogen (org. N) and carbon (org. C) can be lost in considerable amounts by leaching, and that the leaching depends upon crop and management. At low leaching of nitrate as for example under a well-developed catch crop relatively more org. N is leached than at high levels of nitrate leaching under a bare soil treatment. An opposite situation was found for leaching of org. C, which was higher under a catch crop than under a bare soil (Vinther et al., 2004). An outline of the research leading to these conclusions is presented below.

Experiment setup with five field treatments

The experimental sites were located on a private dairy farm in the southern part of Denmark, where a 3rd and a 5th year grass-clover pasture was ploughed in the spring 2003. A field trial for studying different strategies for reducing N-leaching was then established on each of the two cultivated pastures - field A and B - located c. 500 m from the farm and next to the farm, respectively.

After ploughing the pastures in the end of March 2003 the two trials were established with five different treatments (Table 1). Treatments 1-3 were unfertilised, and in treatment 4 and 5 cattle slurry (120 kg NH_4-N ha^{-1}) was incorporated three days before sowing spring barley in all five treatments. In treatment 1 and 4 the barley was harvested early as a green crop for silage, allowing the undersown catch crop (Italian ryegrass) to be fully developed before the winter season. In treatment 2 the barley was harvested at maturity, which restricted growth of the undersown catch crop (Perennial ryegrass). In treatment 3 and 5, which were without catch crops, the barley was harvested at maturity, and the soil was kept free from vegetation by two times rotary cultivation during the autumn. All plots measuring 3 x 16 m were prepared in four replicates in a random block design.

Installation of suction cups and water analysis

Shortly after sowing of spring barley ceramic suction cups were installed at a depth of 100 cm, and during the entire period from May 2003 to May 2004 samples were taken at weekly or bi-weekly intervals, and analysed for total N and nitrate (NO_3-N. Assuming that the content of ammonium (NH_4-N) was negligible, mobile organic N (MON) was calculated as the difference between total N and NO_3- N. Total N was determined in untreated samples, and therefore the organic N measured represents the fraction of MON, which was able to pass the 1-µm pores of the suction cups. Additionally, samples from treatment 1 and 5 were analysed for mobile organic carbon (MOC).

Percolation at one meter was calculated using the water balance model Evacrop and the leaching subsequently estimated using mean N or C concentration between two sampling dates multiplied with runoff during that period.

Relationships between organic N and nitrate N

Compared to the concentration of NO_3-N in the soil water, which was in the range from 0 to 120 mg N L^{-1}, the concentration of MON (Figure 1) was considerably more constant ranging from 1.2 to 9.4 mg N L^{-1}. The highest concentrations of MON were measured in the bare soil treatment, whereas concentrations in catch crop treatments were between 1.2 and 3.2 mg N L^{-1}.

Leaching of organic N and C

The accumulated percolation was 595 and 645 mm in the catch crop and bare soil treatments, respectively, resulting in annual leaching of MON (Figure 2) in the range from about 10 kg N ha^{-1} in catch crop treatments to about 30 kg N ha^{-1} in the bare soil treatment in field B. The amount of MON leached corresponded to between 6 and 77% of total N leached, as shown by inserted values.

The leaching of MOC (Figure 3) showed opposite trends compared to leaching of MON with higher values in the catch crop treatments (296 - 310 kg MOC ha^{-1}) than in bare soil treatments (174 - 217 kg MOC ha^{-1}). However, as for MON, the leaching of MOC tended to be higher in field B than A.

Environmental perspectives

Although the measured amounts of organic carbon only represent a minor quantity (<0.5%) of the carbon pool in the soil, this mobile fraction may be of importance for the microbial biomass and activity in deeper soil layers. For example, a considerable potential to denitrify at depth has been demonstrated under grasslands (Jarvis and Hatch, 1994), and Vinther et al. (1999) showed a clear positive correlation between soluble carbon and numbers of denitrifiers in macropore channels at 2-3 meters depth, which indicate a potential for denitrification under water saturated conditions (Jørgensen et al., 2004). Thus, from an environmental point of view, leaching of organic matter may have beneficial effects by increasing the potential for denitrification.

Leaching of nitrate has been a subject for extensive research for many years, whereas reports about the leaching of organic and total N are limited (Murphy et al., 2000). In forest ecosystems with minimal input of fertiliser N, the contribution of MON to the leaching of total N may be significant (Michalzik and Matzner, 1999; Campbell et al., 2000), which also is the case in unfertilised agricultural soils (Murphy et al., 2000; Jones et al., 2004). We found that the amount of organic N leached corresponded to more than three times that of nitrate N in unfertilised soils, whereas in fertilised soils the organic N constituted from 7 to 164% of total N leached. These results indicate that the leaching of organic N in agricultural soils can be significant, and should be taken into account in N-balance calculations.

References

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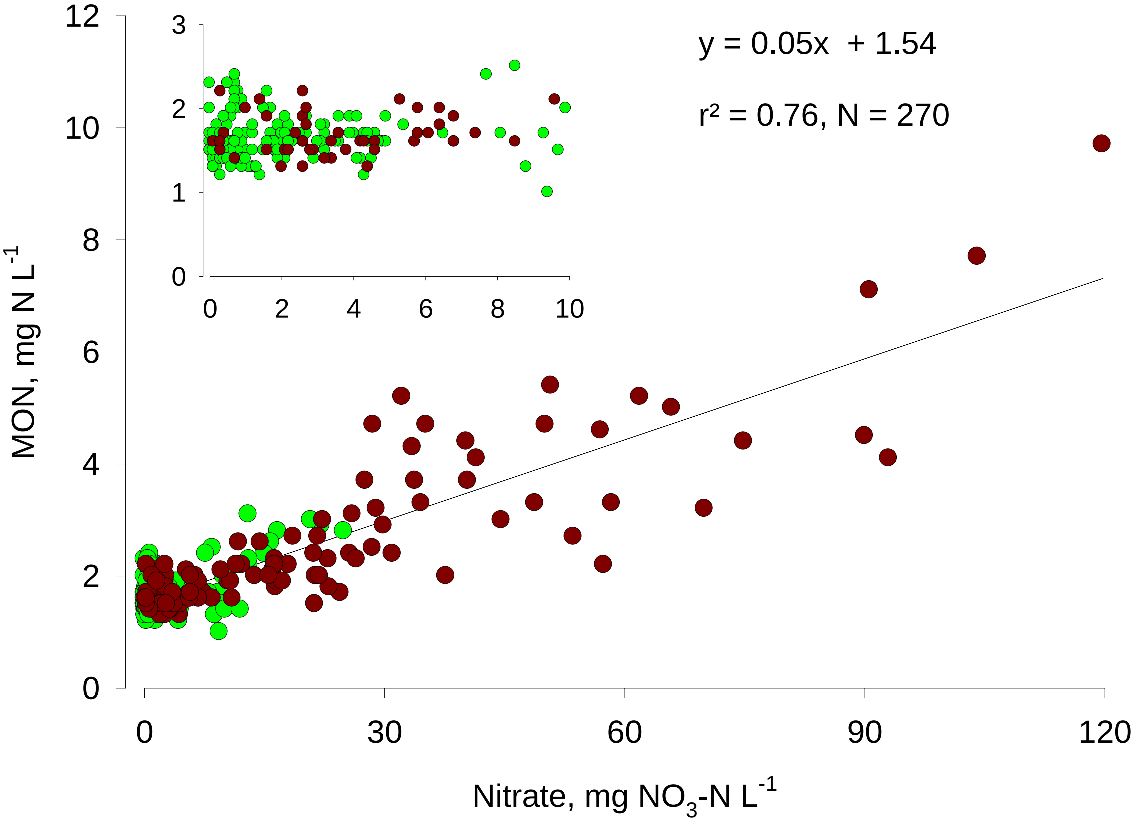
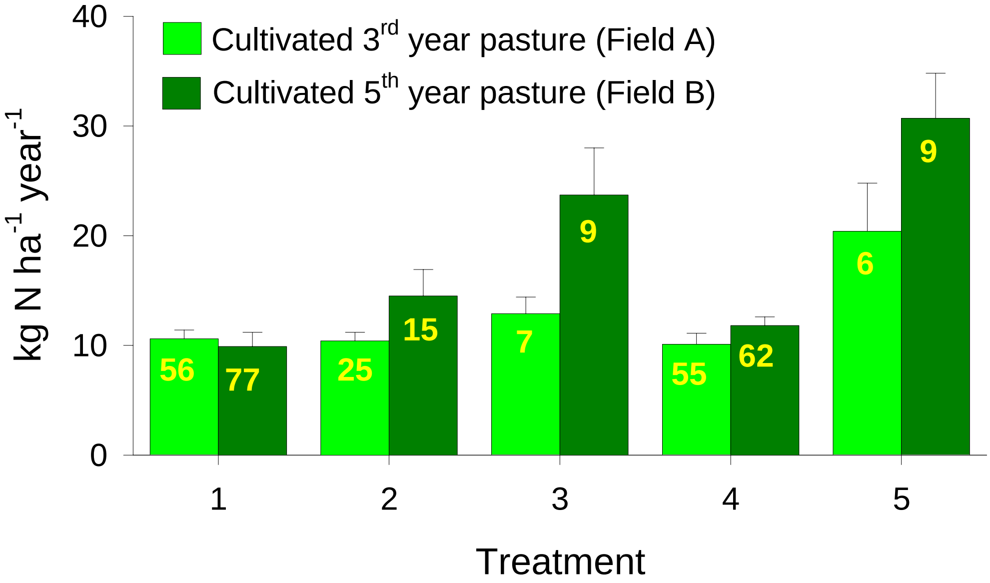
Table 1. Cropping sequence during the period from March 2003 to April 2004 in the five treatments. G-c means grass-clover and nitrogen (N) was NH_4-N in cattle slurry.

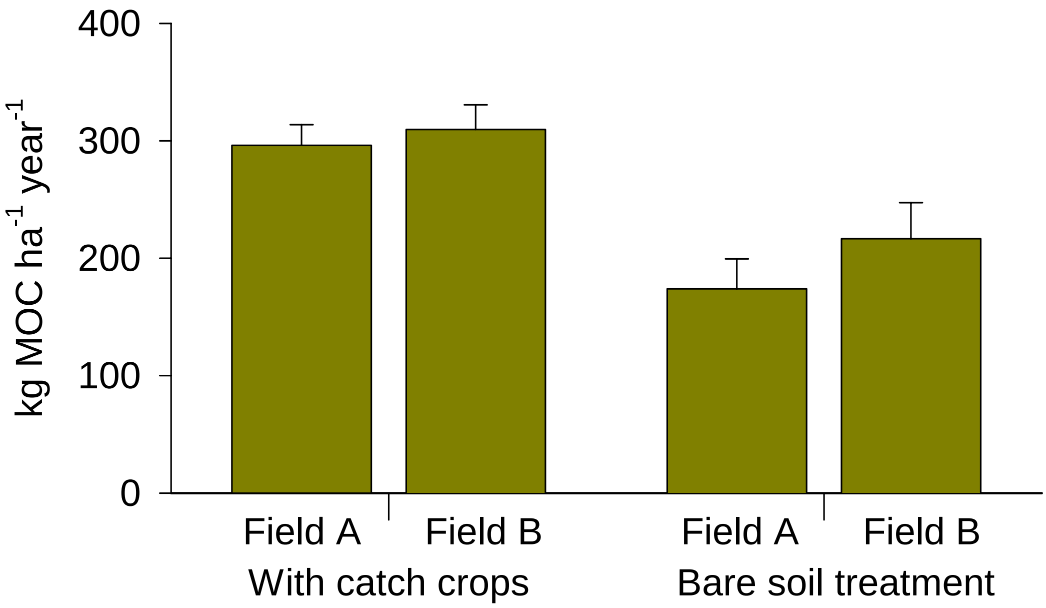
Treat-ment	Kg N ha^{-1}	2003										2004			
		M	A	M	J	J	A	S	O	N	D	J	F	M	A
1	0	G-c	Spring barley		Catch crop (Italian ryegrass)										
2	0	G-c	Spring barley				Catch crop (perennial rye-grass)								
3	0	G-c	Spring barley				Bare soil								
4	120	G-c	Spring barley		Catch crop (Italian ryegrass)										
5	120	G-c	Spring barley				Bare soil								



y = 0.05x + 1.54
r² = 0.76, N = 270
MON, mg N L-1
Nitrate, mg NO3-N L-1
0
2
4
6
8
10
12
0
30
60
90
120
0
1
2
3
0
2
4
6
8
10



40
30
20
10
0
Cultivated 3rd year pasture (Field A)
Cultivated 5th year pasture (Field B)
kg N ha-1 year-1
56
77
25
15
7
9
55
62
6
9
1
2
3
4
5
Treatment



400
300
200
100
0
kg MOC ha-1 year-1
Field A
Field B
Field A
Field B
With catch crops
Bare soil treatment