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Short communication

Dissolved organic nitrogen in contrasting agricultural ecosystems

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Abstract

Dissolved organic nitrogen (DON) is increasingly being recognized as a major component of the terrestrial nitrogen cycle, however, the factors that regulate its behaviour in soil remain poorly understood. The aim of this study was to investigate the impact of agricultural land use on the amount of DON in soil. At 94 sites, representing seven contrasting agricultural land use types, we extracted soil solution during the growing season. DON was high in all land use types constituting $57 \pm 8\%$ of the total dissolved N (TDN) pool and generally followed the series

citrus > vegetable > forest = arable > grassland = wetland > heathland.

The TDN pool was dominated by DON in less intensive agricultural systems. In relative contrast to DON, the amount of dissolved inorganic N (DIN) varied widely upon land use with intensive agricultural systems being dominated by NO_3^- and low input systems dominated by NH_4^+. We conclude that DON represents a significant N pool in all agroecosystems but its concentration is less sensitive to land use system than DIN.

Keywords: Agricultural system; Ammonium; Dissolved organic carbon; Fertilizer; Land management; Moorland; Nitrate; Soil solution; Woodland

Dissolved organic nitrogen (DON) has been hypothesized to constitute a major component of both terrestrial and marine N cycles (Antia et al., 1991; Chapin, 1995; Nashölm et al., 2000; Neff et al., 2002). To quantify the functional role of dissolved organic nitrogen (DON) in terrestrial ecosystems we need to understand its behaviour at a range of spatial scales. This includes fine spatial scale competition for DON between plants roots and soil microorganisms in the rhizosphere through to the flow of DON at the landscape scale. Within freshwater environments, DON concentrations appear to be at least partially regulated by land use type (Russell et al., 1998; Willett et al., 2004). The impact of agricultural land use systems on the concentrations of DON in soil remains understudied although there are some studies to suggest that differences can be expected to occur (Murphy et al., 2000; Chantigny, 2003). Our primary aim was therefore to quantify the relative amounts of dissolved organic C and N and soluble inorganic N in contrasting agricultural land use systems and to establish if relationships existed between these parameters.

Seven contrasting agricultural land use systems were selected for the study and included: intensive citrus orchards (orange; *Citrus sinensis* at 600–800 stems ha^{-1}; $n=5$), intensive vegetable production (Cabbage; *Brassica oleracea*; $n=5$), intensive arable (wheat and barley; $n=9$), monoculture forestry [deciduous (*Fagus sylvatica*) and coniferous (*Picea sitchensis*, *Pinus sylvestris, Abies cephalonica*); $n=23$], high and low intensive grassland ($n=27$), low intensive wetland ($n=5$) and low intensive grazed heathland ($n=20$). Intensive is defined here as land receiving regular NPK fertilizers and producing high yields. All the wetlands were dominated by *Juncus effusus* and the heathlands by *Calluna vulgaris* and *Vaccinium myrtillis*. The grasslands included a range of mixed species of which the most prevalent were *Lolium perenne*, *Holcus lanatus*, *Poa annua*, *Poa pratensis*, *Trifolium repens* and

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Table 1
Characteristics of the land uses investigated in this study

	Major vegetation	Fertilizer	Drainage	Grazing	No. of sites
Citrus	Oranges	Inorganic NPK and/or FYM	Freely draining	No	5
Vegetable	Cabbage	Inorganic NPK and/or FYM	Freely draining	No	5
Arable	Wheat and barley	Inorganic NPK	Freely draining	No	9
Forest	Mature pines, spruce, beech and oak	No	Freely draining	No	23
Grassland	Mixed annuals	Variable from very high inorganic NPK and/or FYM to none	Freely draining	Sheep, cows of high to moderate intensity	27
Heathland	Dwarf shrubs such as heather and *Vaccinium*	No	Moderate draining	Sheep of low intensity	20
Wetland	Reeds and grasses	No	Poorly draining	No	5

Medicago sativa. All sites were sampled at least 30 d after fertilizer application (Table 1).

Sites were selected throughout England and Wales (n= 70) and Greece (n=24) to enable a coverage of agroecosystems. At all 94 sites, soil was collected from the surface horizon (0–15 cm). At each location, a representative area with uniform vegetation coverage was visually identified and three individual samples of soil were taken at triangulated points 2 m apart (i.e. n=3 per site). The soil was placed in gas-permeable plastic bags and stored at 4 °C until analysis. Soil solution was removed from each replicate sample of soil within 24 h of collection by the centrifugal-drainage procedure described in Giesler and Lundström (1993). Particulate organic matter (POM) was removed from the collected soil solutions by high speed centrifuging at 16,000g for 15 min. The removal of POM by centrifugation yielded DON and DOC concentrations almost identical to those which have been 0.2 μm filtered (data not presented). The collected soil solutions were stored frozen at −20 °C to await analysis. DOC and total dissolved N (TDN) in solution were determined with a Shimadzu TOC-TN analyzer (Shimadzu Corp., Kyoto, Japan). The TOC-TN analyzer injects 50 μl of soil solution or soil extract into a combustion furnace held at 725 °C after which the CO_2 produced is detected by an infra-red gas analyzer and the NO_x via a chemiluminescence detector. The limit of detection for both DOC and TDN was 0.05 μg ml^{-1}. NH_4^+ in the soil solutions was determined colorimetrically by the salicylate-nitroprusside method of Mulvaney (1996) on a Skalar autoanalyzer (Skalar Ltd, York, UK; detection limit 0.01 μg ml^{-1}). NO_3^- was determined colorimetrically using the same Skalar autoanalyzer in which NO_3^- was first reduced to NO_2^- with a Cd–Cu column followed by the reaction of the NO_2^- produced with *N*-1-napthylethylenediamine to produce a chromophore (detection limit 0.01 μg ml^{-1}). DON was calculated as the difference between the TDN reading and the combined NH_4^+ and NO_3^- reading (DIN). To determine the significance of land use on soil solution concentrations statistical analysis was performed on site mean values by ANOVA with Dunnett multiple comparison testing, while t-tests were used to compare country effects (UK versus Greece). Linear regression analysis was used to identify relationships between soil solutes. Statistical analysis was performed using the computer packages Sigmaplot 4.01 (SPSS, Inc., Chicago, ILL) and Minitab 14 (Minitab, Inc., State College, PA).

The relative amount of dissolved inorganic and organic N in each of the agricultural ecosystems studied is shown in Fig. 1. Generally, significant amounts of DON were found in soils from all land uses. On average, DON constituted 57±8% of the TDN pool across all land use types, with the maximum contribution seen in wetlands (94±1% of TDN) and being least under citrus (32±9% of TDN). ANOVA revealed that land use had a significant impact on the concentration of DON in soil solution ($P<0.001$) and generally followed the series

$$\text{citrus} > \text{vegetable} > \text{forest} = \text{arable} > \text{wetland}$$
$$= \text{grassland} > \text{heathland}.$$

A significant positive relationship was observed between the amount of DON in solution and the amount of NO_3^- when all sites were considered ($P<0.001$; $n=94$) or when individual land use categories were considered ($P<0.01$; $n=7$). At a land use level, no significant relationship was apparent between the concentration of DON and NH_4^+ ($P>0.05$; $n=7$) although significant positive relationships between DON and NH_4^+ were apparent in some land use types (e.g. grassland, $P<0.001$). Where the same land use type was sampled in both Greece and the UK (arable, forest and grassland) no significant difference in the relative amount of DON as a proportion of the TDN pool was observed ($P>0.05$). Only in grasslands was a significant difference in the concentration of DON observed between UK and Greek sites with concentrations being approximately 2-fold higher in the Greek soils ($P<0.001$). This might be expected because of the different grassland species in the two countries. No significant difference in DON concentration was observed between high and low intensity grasslands ($P>0.05$; data not presented).

ANOVA revealed that land use had a significant impact on the concentration of DOC in soil solution ($P<0.001$) and followed the general series

$$\text{forest} > \text{citrus} = \text{vegetable} > \text{wetland} > \text{heathland}$$
$$= \text{grassland} = \text{arable}.$$