BETTER MANAGEMENT AND ECONOMY OF THE N RESOURCE IN GRASSLAND

RELATIVE DENITRIFICATION RATES IN SURFACE AND SUBSURFACE MINERAL SOIL LAYERS

END OF PROJECT REPORT

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SUMMARY

The project, which was carried out at Johnstown Castle, was concerned with measuring denitrification at depth in grazed grass plots receiving 362 kg fertiliser N per ha. Reports in the scientific literature had indicated that such was likely, given the conditions necessary for the denitrifying microbial reactions to take place.

In one experiment, denitrification was detected in measurable amounts to 90cm soil depth in spring-summer, using the acetylene block technique. A second more extensive experiment carried out under similar conditions within one year from March to August and from October to March looked at denitrification in greater detail to 50 cm deep.

Results showed the importance of soil water and soil ammonium (NH_4) to rate of denitrification. The rate was much greater in the 0-10 cm layer than in the lower layers in both time periods. Of the total denitrification occurring in the 0-50 cm layers in the year, which was 16.6 kg N per ha, 80% occurred at 0-10 cm with 62% occurring in the second time period, October to March.

OBJECTIVES AND METHODOLOGY

In the current European context of striving for Sustainable Production Systems (EU 5th Action Programme) it was considered relevant to gain information on and to try to understand N loss pathways, in particular denitrification, concerning which little information was readily available.

Denitrification is a process whereby certain anaerobic bacteria obtain the oxygen necessary for life from the nitrate (NO_3) ion. It is a common-place phenomenon in soils, occurring wherever there is an adequate carbon source, a supply of NO_3-N, suitable temperature, anaerobic conditions and the presence of denitrifying bacteria.

The end products of denitrification are dinitrogen (N_2) and nitrous oxide (N_2O). The latter is an important, long- ived greenhouse gas currently estimated to account for 5-10% of the potential increase in global warming. This potential, on a molecular basis, is about 250 times greater than CO_2 and the total flux includes N_2O from all possible sources, i.e., native soil N, N from recent atmospheric deposition, previous fertilisation, N from grass/crop residues, N in subsurface aquifers and from current N fertiliser practices. About 70% of the N_2O emitted from the biosphere into the atmosphere is derived from soils and the amount of N_2O emitted, on a global scale, from soils is twice the amount produced by burning fossil fuels and four times the amount evolved from the ocean.

The extent of denitrification below the surface layers is of interest since (1) it represents a loss of N from the soil and (2) it can alleviate groundwater contamination by NO_3. In this study the effect of depth (0-50 cm) on denitrification was examined in N fertilised, grazed plots.

Denitrification was measured within 2 periods of the year having contrasting soil moisture regimes.

Period I (March to August) was a time of increasing soil moisture tension; period II (October to March) was a time of soil moisture saturation. On 57 dates within the calendar year intact soil cores (3cm diameter ; 10 cm long) in successive layers, from 0 to 50 cm deep, were collected at five random locations in two grazed plots receiving 362 kg fertiliser N per ha. The soils were moderately well to imperfectly drained, of loam to sandy loam surface texture over loam texture at 50 cm deep with summer infiltration rates of 12 mm per hour.

In order to obtain soil samples, galvanised pipe 148 cm long, 32.6 cm internal diameter narrowing to a hardened steel entry port 3.2 cm internal diameter and marked at 30 cm intervals from the entry port was pushed into the soil to 30 cm deep using a Rossi loader. (Plate 1). The loader easily withdrew the pipe containing the soil core from the ground and the 30 cm long core was removed using a steel plunger. This was repeated to 50 cm using an iron sleeve to protect the pipe from the 'hammer blows' of the Rossi front-end loader. Each 30 cm soil core was divided into 3 sections of 10 cm each for incubation in the Kilner jars with four other cores (Plate 2).

Field denitrification was determined following the incubated soil core technique of Ryden et al.
In this method each set of two sets of 5 soil cores, taken per plot on each sampling date, are placed in one of two 880 ml Kilner-type food preserving glass jars into one of which is introduced 50 ml of acetylene (C_2H_2), equivalent to 5.7% of the jar volume. The acetylene is supplied to inhibit the reduction of N_2O to N_2 during denitrification. If this were not done it would be impossible to measure the extent of the process since the ambient atmosphere contains 79% N_2. Jars not supplied with C_2H_2 allow measurement of N_2O emission alone.

Both jars containing the 5 soil cores are placed in 10 cm deep excavated holes in soil at ambient temperature. After 24 hours incubation a 10 ml gas sample is removed from each jar, 7 ml of which is placed in a previously evacuated 7 ml vial. The vial is used as a reservoir from which gas samples are taken for analysis. Nitrous oxide is determined on the gas samples using a Pye-Unicam GCV gas chromatograph having a 3m column using Porapak Q as the stationary phase and a 63Ni electron capture detector under the following conditions: injector temperature 70˚ C, oven temperature 110° C, detector temperature 300˚ C. The flow rate of the Argon carrier is 30 ml per minute.

Plate 1: Soil sampler in position prior to being pushed into soil

Plate 2: Close-up of soil core extruded from sampler

RESULTS AND DISCUSSION

Soil temperatures were >4°C, the minimum required for denitrification to take place in grassland, at 10 and 30 cm throughout the year apart from a short period in late December-early January. Soil moisture conditions were more favourable for denitrification in period II than period I as shown by the high electrical conductivity at 15 cm and higher soil moisture levels at the other depths from late October to March. In period I, the effect of rainfall was quickly reflected in the soil moisture content of the 15 cm layer as seen in electrical conductivity (Figure 1); this layer was saturated in period II and electrical conductivity was not very much affected by rain.

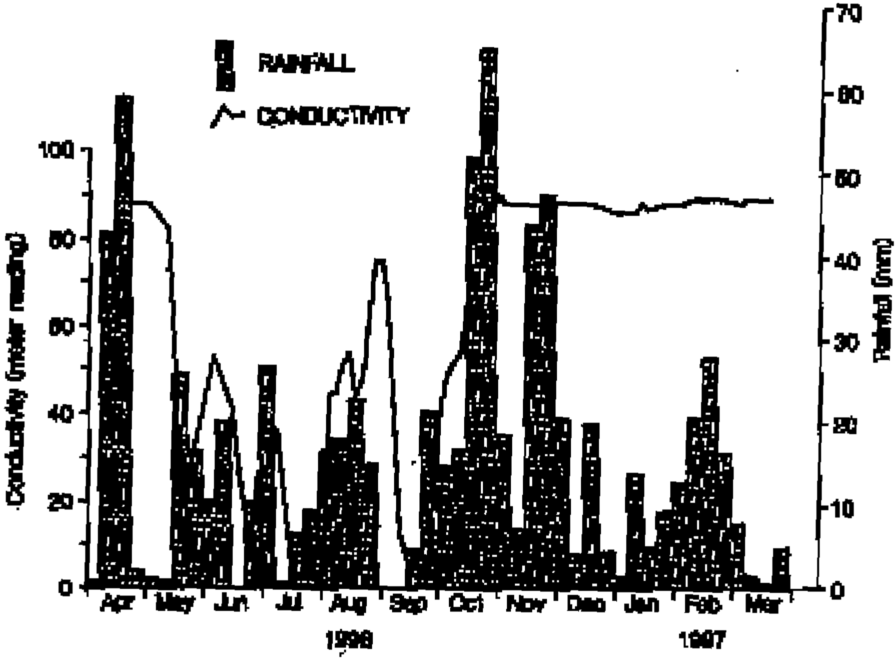

Figure 1: Weekly rainfall and electrical conductivity of 15 cm layer (mean of 2 plots) April 1996 - March 1997.

Multiple regression models of denitrification, fitted by backward elimination of the variables soil water, NO_3-N, NH_4-N, total soil mineral N for each depth in periods I, II illustrated the importance of soil water, NH_4-N in period 1 and NH_4-N in period II at particular soil depths. For periods I, II the significant models were as shown in Table 1. All variables left in the models were significant at the 0.05 level.

Table 1: Multiple regression models (P<0.05) derived by backward elimination procedure for dependant variable denitrification.

Depth (cm)	Model	F test	R2
	Period I		
0 - 10	Dentrification = -95.37 + 0.0009 NH_4-N + 4.46 H_2O	***	0.63
10 - 20	Dentrification = -0.8178 + 0.1459 H_2O	***	0.53
30 - 40	Dentrification = -0.0424 + 0.0001 NH_4-N + 0.0588 H_2O	***	0.46
40 - 50	Dentrification = 0.1953 + 0.0615 H_2O	**	0.34
	Period II		
20 - 30	Dentrification = 3.1450 + 0.0002 NH_4-N	*	0.14
30 - 40	Dentrification = 2.2159 + 0.0013 NH_4-N	***	0.36

Table 2: Calculated cumulated Dentrification (kg/ha) for periods I, II.

Depth (cm)	0-10	10-20	20-30	30-40	40-50	0-50
Period I	5.52	0.24	0.20	0.15	0.17	6.28
Period II	7.70	0.79	0.56	0.61	0.62	10.28
Total	13.22	1.03	0.76	0.76	0.79	16.56

Table 2 shows the total denitrification for periods I, II obtained through integrating time by rate intervals for those periods and allowing for different apparent specific gravity values for the layers.

There are 72 days from August to October not included in the calculation.

The predominant effect of the top 10 cm layer on periodic and total denitrification is clear. Levels of denitrification taking place in the lower layers were low for both periods. Denitrification in the surface layer was 88% and 75% of the total for periods I, II; overall it was 80%.

The results, while showing some denitrification activity at depth in the soil profile, agree with the findings of other researchers which point to the overwhelming effect of the surface layer. Jordan, studying denitrification potential in the 0-40 cm zone, found that 67 and 94% occurred at 0-10 cm in two Northern Ireland soils. Ryden et al. found that denitrification in grassland soil occurred mainly in the surface 20cm while studies carried out by Watson et al. indicated that the 0-5 cm layer accounted for up to 90% of the total loss from the 0-15 cm depth of N fertilised, grazed grassland.

In contrast to these results, Dowdell et al. found the highest soil profile concentrations of N_2O at 90 cm deep in a clay soil when studying soil atmospheric gases in England. Burford and Millington, using cans to sample the soil atmosphere, detected N_2O in all layers to 90 cm deep in a sandy loam, which agrees with an earlier aspect of the work being reported here.

CONCLUSION

The results (Figures 2, 3) indicate that, with the exception of peaks caused by fertiliser applications, it is likely that N_2O emissions under grazing will be higher during autumn-winter than in spring-summer. The soil studied is similar in drainage characteristics and silt plus clay content of its upper, middle and lower layers to the major soils of Associations 13, 14, 15, 28, and 30-37 (General Soil Map of Ireland) (Gardiner and Radford). With similar rainfall and N inputs, these soils which constitute 35% of all Associations and represent 236,728 ha,

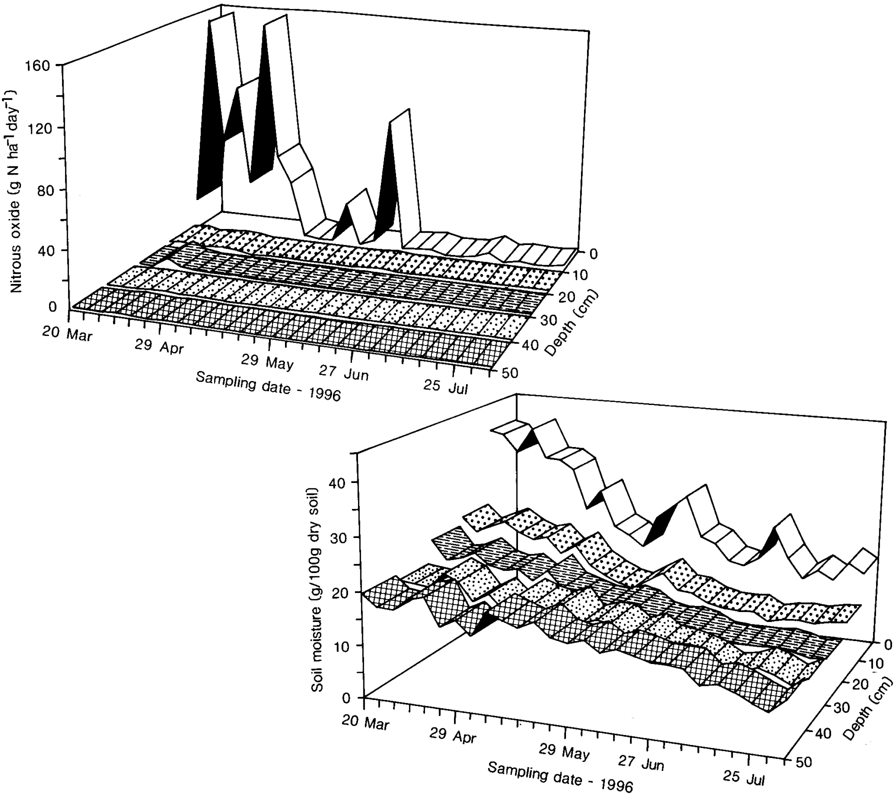

Figure 2: Effect of soil depth and date on dentrification and soil moisture in Period I (mean of two plots)

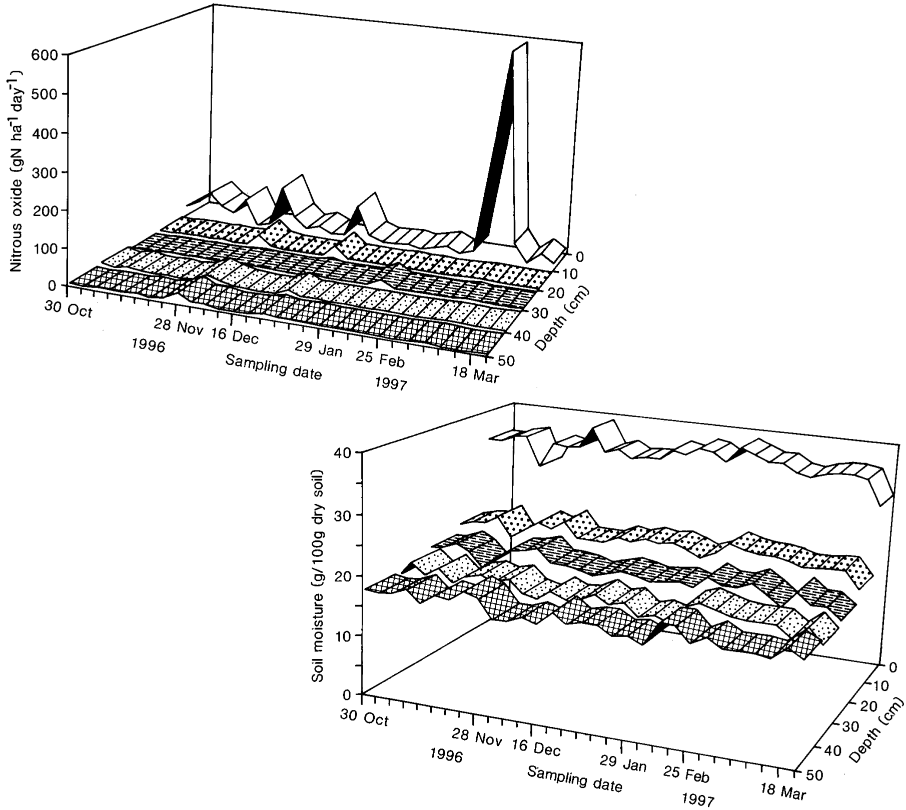

Figure 3: Effect of soil depth and date on dentrification and soil moisture in Period II (mean of two plots)

are likely to behave in a similar fashion and denitrify to only a limited extent (~20% of total) in the subsurface layers. Those soils having somewhat better drainage and shallower depth, constituting ~10% of the soil Associations, would be expected to show even less denitrification in the deeper layers while the 21% gleyed soils could be expected to show greater denitrification thus inducing lower leaching of NO_3-N.

The practical application of this work is in the realm of assisting those preparing national balance sheets and towards increasing our understanding of the extent and nature of the processes involved. Aspects of the work were included in the recently published 'Limitation and

Reduction of CO_2 and other Greenhouse Gas Emissions in Ireland' (Dept of the Environment and Local Government).

One of the gases arising from denitrification, N_2O, is reported as a global warming and ozone destructive gas. Since 1850, human activities have increased atmospheric concentrations of CO2 by 25%; emissions of N_2O have increased to a lesser extent i.e., 9% in the 140 years to 1990. Any increase in knowledge regarding harmful emissions is an aid to combating the negative effects of these gases on the global atmosphere.

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