IMPACT OF TOPOGRAPHY ON SOIL NITRIFICATION RATE IN SHEEP GRAZED SUMMER MOIST HILL COUNTRY

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Abstract
A grazing trial was initiated in September 2010 to investigate the impact of topography (low slopes (LS, 0 - 12°), medium slopes (MS, 13 – 25°) and high slopes (HS, >25°)) and grazing intensification (8 vs. 14 SU/ha) on aspects of nitrogen cycling in sheep grazed summer moist hill country. A short term (16 h) nitrification assay was conducted on soil samples taken to a single depth in 2010 (0-100 mm) and in 2011 at two depth increments (0-100 and 100-200 mm) from each of the three topographical areas plus to a 200-300 mm depth, in LS areas only.

Our hypothesis was that short term nitrification rate (STN) would be higher in low compared to medium and high slope areas, due to more favourable conditions for nitrification in LS areas. We also hypothesised that soils from areas grazed at the greater stocking intensity would have a higher STN due to the greater availability of ammonium (NH_4^+) substrate.

In both the 2010 and 2011 studies topography had a highly significant impact on STN, with mean nitrification rate of soils from LS areas nearly 8x that from MS areas at the 0-10 cm depth increment in 2011 (0.421 vs. 0.056 µg NO_3-N gained/g dry soil/h, respectively). In that year soils from high slope areas had a very low STN (0.003 µg NO_3-N gained/g dry soil/h). In the 2011 study, grazing intensity differences in the previous 10 months did not have a significant impact on STN. Short term nitrification rate decreased markedly in soils from 100-200 mm compared to the 0-100 mm depth increment for LS and MS areas. Significant nitrification activity was also present at the 200-300 mm depth increment in LS areas (0.086 µg NO_3-N gained/g dry soil/h). Our results suggest that LS areas in grazed hill country are potential critical source areas for N loss.

Introduction
In New Zealand, pastoral farming on hill country is a major land use, and there is very little information available at a landscape level on the cycling of nitrogen (N) within these systems. In particular, there have been very few studies on the likely effects of intensifying farming operations on the cycling of N in these hill country landscapes. Knowledge is still required to fully understand the biological behaviours and sources of variability in grazed hill pasture systems. Additionally, knowledge is also required to anticipate the impacts of a changing climate on the biological behaviours of these grazed hill country systems. The sources of variability in the forms of, storage, cycling and losses of N in hill country soils must be understood in order to adequately understand and model N pools and fluxes in this environment.

Nitrate (NO_3^-) is a major source of N loss from grazing systems via leaching and denitrification. In grazed pastures soil NO_3^- is produced through a key process called nitrification, whereby ammonium (NH_4^+), primarily derived from urine deposits, is oxidised to nitrite (NO_2^-) and then to NO_3^-. The nitrification process is influenced by soil and environmental factors, namely: NH_4^+ substrate supply, soil temperature, moisture, and pH (Subbarao et al., 2006).

Aim

The aim of this study was to evaluate the effect of slope class and grazing intensity on short term soil nitrification rates at 2 or 3 soil depth increments.

Materials and methods

Study site

The trial site is located in the southern Hawke's Bay at the AgResearch Ballantrae Research Station (40°19'S, 175°50'E) at an altitude of between 150 and 200 m.s.l. The area contains a mix of slope classes (0 – 35°) and is predominantly of southwest aspect. Average annual rainfall in the area is 1270 mm; historically the highest rainfall months are July (mid winter) and October (mid spring) and the driest months are January (mid summer) and March (early autumn).

Grazing treatments and soil characteristics

The study was conducted within an experimental area designed to study the cycling of carbon and N in a hill country pastoral system grazed by sheep at two levels of grazing intensity. The two grazing intensity treatments; extensive (Ext) and intensive (Int), were instigated in September 2010. The Ext treatment is predominantly set stocked with breeding ewes rearing single lambs and carries an average annual stocking rate of 8 ewe stock unit equivalents/ha (SU/ha). The Int treatment is a mixture of set stocking with breeding ewes rearing twin lambs and rotational grazing with sheep according time of year and pasture cover, with an average annual stocking rate of 14 SU/ha. To ensure that the differentiation between grazing intensities is maintained, the minimum and maximum target pasture cover varies with treatment and time of year. The Ext treatment pasture cover ranges from 1200 kg DM/ha in winter to a maximum of 2800 kg DM/ha in summer. The Int treatment has a minimum herbage mass of 1200 kg DM/ha in winter, but is restricted to a maximum herbage mass of 2000 kg DM/ha in summer. There are 3 replicate 0.5 ha paddocks of each treatment. The soil of the study area is an imperfectly drained silt loam with parent material of patchy loess over massive mudstone and siltstone. The soil textures range from silty clay loam to clay loam. Some site soil characteristics are given in Table 1 below.

Table 1 Soil pH, Olsen P, organic carbon, total nitrogen and C:N ratio at each slope class (0-100 mm)

Slope Class	pH	Olsen P (µg/mL)	Organic Carbon (%)	Total Nitrogen (%)	C:N ratio
Low slope (0-12°)	5.5	25.7	5.4	0.5	10.9
Medium slope (13-25°)	5.3	8.7	4.6	0.4	12.8
High Slope (>25°)	5.3	8.3	4.1	0.3	13.8

Soil sampling
Soil samples were taken in 3 slope class areas within each paddock: namely low slopes (1-12°) (LS), medium slopes (13-25°) (MS) and high slopes (>25°) (HS). The initial measurements, taken August 2010 prior to imposition of the grazing treatments, were conducted for one depth increment (0-100 mm). The measurements taken in June 2011 sampled three depth increments (0-100, 100-200 and 200-300 mm respectively). Three soil cores (25 mm diameter) were taken at 3 sites each per slope class in each paddock. In both 2010 and 2011, the 3 soil cores were bulked per site and depth increment at each slope class in each paddock.

Short term nitrification rate (STN)
Five grams of fresh soil was shaken with 50 ml of 1 mM ammonium sulphate ($(NH_4)_2SO_4$) for 1 hour, centrifuged for 2 minutes and a 10 ml sample of solution was taken. Phenyl mercuric acetate (PMA) was added to the 10 mL sample to give a final concentration of 5 µg PMA/ml. The 10 mL sample was then centrifuged for 10 minutes and filtered through Whatman #42 filter paper. The remainder of the solution was shaken for a further 16 hrs, and then PMA added, centrifuged and filtered as above. Both time 1h (T1) and time 17 h (T17) samples were analysed for nitrate-N concentration using a FIAstar5000 auto analyser (acc. to ISO13395). Short term nitrification rate was calculated by taking the difference in NO_3-N concentration between T1 and T17 and is expressed as µg NO_3-N gain/g dry soil/h.

Results
The STN was significantly different (P<0.001) between slope classes in both 2010 and 2011. In August 2010, when measurements were done on the 0-100 mm soil depth increment only, mean STN from LS areas were nearly 20x that of MS areas and 35x that of HS areas (Table 2). In June 2011, mean STN for the 0-100 mm depth increment from LS areas was nearly 8x that of MS areas, soils from HS areas had a very low STN (Table 3). No significant difference in STN was detected between the Ext and Int treatments in June 2011, 10 months after the differential grazing intensity treatments had been instigated. In the 2011 study, depth of soil was also found to have a significant effect on STN (P<0.001) (Table 3). For the LS areas the 0-100 mm STN was nearly 3x that of the 100-200 mm depth increment and 5x that of the 200-300 mm depth increment.

Table 2 Short term nitrification rates in August 2010

	µg NO_3-N gain/g dry soil/h	s.e.m.
Low slope	0.622	0.142
Medium slope	0.030	0.011
High slope	0.018	0.003
Probability		
Slope class effect	<0.001	

Table 3 Short term nitrification rates in June 2011

Slope class	Depth increment (mm)	µg NO_3-N gain/g dry soil/h	s.e.m.
Low slope (0-12°)	0 - 100	0.421	0.069
	100 - 200	0.156	0.034
	200 - 300	0.085	0.028
Medium slope (13-25°)	0 - 100	0.056	0.025
	100 - 200	0.017	0.007
	200 - 300	Not done	
High Slope (>25°)	0 - 100	0.003	0.001
	100 - 200	0.007	0.002
	200 - 300	Not done	
Probability			
Slope class	<0.001		
Depth	<0.001		

Discussion

Our results suggest that STN is markedly influenced by topography (as defined by slope class) and soil depth. However, differences in grazing intensity in the 8 months prior to the 2011 sampling did not have a significant impact on STN.

Short term nitrification rate is an indication of the potential of soil to oxidise the less mobile NH_4^+ ion to the more mobile NO_3^- ion. Both forms of inorganic N are able to be taken up by plants, but NH_4^+ is a more biologically efficient source of N for plants (Salsac et al., 1987). Thus the conversion to NO_3^- in the soil offers no great advantage to plants in terms of N availability. However, NO_3^- represents a greater risk of loss from the soil as NO_3^- can be lost either directly through leaching, or via denitrification.

Our study suggests that soils in areas of low slope are likely to have the highest potential for nitrification activity, compared to medium and high slope areas. For the low slopes to have established this greater potential there must be some differences in factors that contribute to a soil's potential for nitrification activity. For nitrification to take place there needs to be a population of nitrifying bacteria present in the soil. The greater and the more consistent the supply of substrate (i.e. NH_4^+), the more likely a substantial population of nitrifiers will be present.

If the amount of nitrogen in the form of NH_4^+ is low, then the amount available for maintaining a population of nitrifying bacteria after plant and soil ecosystem demands for NH_4-N are met, is also likely to be very low. Thus, differences in the supply of $NH4^+$ to the soil is likely have a major influence on STN in a grazing system.

In grazed hill pastures this difference in substrate supply will be largely driven by the pattern of excreta deposition from gazing animals. A nutrient transfer model for grazed hill country was developed by Saggar et al. (1990) which attributed much greater returns of dung and urine to low than medium and high sloped areas. In support of this earlier work, Betteridge et al. (2012) established that cattle are more likely to deposit urine and dung in a relatively small portion of a paddock and that these areas are normally low slope areas. With this information it should be possible to identify areas that are more likely to exhibit relatively high STN as found on the low slopes in this study.

A review by Subbarao et al. (2012) reported on a growing body of evidence that some plant species, including grasses, are able to inhibit the process of nitrification. If this is found to apply to some hill pasture species, this attribute may help keep soil inorganic N present in the NH_4^+ form when N supply is low.

In order to understand and adequately model the behaviour and losses of N in our grazed hill country it is important that we develop a better understanding of the drivers behind these behaviours and losses. Our study has identified that both topography and soil depth influence STN and this warrants further investigation.

Acknowledgements

We wish to thank the Ballantrae farm staff John Napier and Brad Gordon for their essential contribution to managing this trial resource. We also wish to acknowledge the technical assistance of Barry Rolle and Shona Brock in the conducting the nitrification rate assay. This research was conducted as part of the FRST- Rural Futures programme (C10X0809).

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