LEACHING LOSSES OF NITROGEN AND CARBON FROM LOW AND MEDIUM SLOPED AREAS IN SHEEP GRAZED NORTH ISLAND HILL COUNTRY

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Abstract
A recent review of carbon (C) and nitrogen (N) cycling in New Zealand hill country pastures identified critical gaps in information which restricts current ability to adequately evaluate the environmental implications of land use intensification in this environment (Hoogendoorn et al, 2010). A 3 ½ year grazing trial has been initiated to look at the impacts of grazing intensification, in two distinct topographical categories (low slopes (0 - 12°) (LS) and medium slopes (13 – 25°) (MS)), in sheep grazed hill country on: inorganic N (ammonium N and nitrate N) and dissolved organic N (DON) and C (DOC) leaching at 300 mm below the soil surface. The trial consists of 6 paddocks (0.7 ha each) with similar aspect and mix of slope classes, arranged in three blocks. Sixteen lysimeters (150 x 300 mm) were installed in each paddock; 8 in each slope class. Two grazing intensity treatments were imposed in August 2010; an extensive (8 SU/ha) and an intensive (14 SU/ha) grazing regime. Rainfall from April 1 2010 – January 12 2011 totalled 1084 mm, with approximately 60 and 80% measured as drainage from LS and MS areas respectively ($P < 0.005$). Pasture covers in early January 2011 were 1325 and 2000 kg DM/ha for the intensive and extensively grazed treatments respectively. Leaching results obtained in both the pre-differential (April 1 – August 30 2010) and differential grazing treatment period (Sept 1 – Jan 12 2011) highlight topographical differences in nutrient leaching from 300 mm below the soil surface, with no significant differences in nutrient leaching detected to date between the two grazing intensity treatments. Mean values for nitrate N leached from April 1 2010 – Jan 12 2011 were 63 and 9 kg N/ha from LS and MS areas respectively ($P < 0.001$). Leaching of DON and DOC, for the period April 1 – September 21 2010, from LS and MS areas respectively totalled 44 and 9 kg DON/ha ($P < 0.02$) and 124 and 76 kg DOC/ha ($P > 0.05$). The results reported are of the first 9 months of a 3 ½ year grazing trial, and must therefore be interpreted with caution.

Introduction

The pastoral industry in New Zealand is increasingly challenged to ensure that its impacts on the environment are understood and managed. Its future growth and prosperity is dependent on its ability to demonstrate to local communities and global consumers that its systems are sustainable. In New Zealand hill country, future farming pressures are likely to include the need to intensify grazing management on selected areas of hill country. Knowledge is still required to fully understand the biological behaviours of intensified grazing systems. Additionally, knowledge is also required to anticipate the impacts of a changing climate on the biological behaviours of these grazed hill country systems.

Concerns about climate change and water quality make it necessary to have a better understanding of the cycling of carbon (C) and nitrogen (N) within landscapes. 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 C and N within these systems. In particular, there have been very few studies on the likely effects of intensifying farming operations on the cycling of C and N on these hill country landscapes.

The implications of grazing intensification on the storage and losses of N and C in hill country soils must be understood in order to adequately understand and model C and N pools and fluxes in this environment. In a review Hoogendoorn et al. (2010) identified a number of critical gaps in information on N and C cycling in grazed hill country in New Zealand. Information on the effect of grazing management intensification on inorganic N (ammonium N and nitrate N) and organic N and C leaching in this environment are particularly lacking.

This report describes the objectives, design and protocol of a grazing trial initiated to measure the impact of grazing intensification on N and C leaching in sheep grazed hill country. Brief summaries of N and C leaching data collected in the first autumn/winter prior to the commencement of intensification treatments are provided, and are compared with leaching data from the early spring/summer period.

Objectives

The objectives of this grazing trial are to measure the impact of grazing intensification in sheep grazed summer moist hill country on leaching of inorganic N and organic N and C, from 300 mm below the soil surface, on low (0-12°) (LS) and medium (13-25°) (MS) sloped areas separately.

Materials and methods

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).

The trial site was cleared from native forest early in the 20th century, sown with a mixture of grasses and legumes and subsequently grazed by sheep and beef cattle. Grazing management has been typical of that for hill country in this area, with an average stocking rate of 8-10 ewe equivalents/ha. Average annual NHA is approximately 8-9 tonnes DM/ha. The pasture plant species are a mix of “high fertility responsive grasses” namely: perennial ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata)*, yorkshire fog (*Holcus lanatus*), and *Poa* spp, and “low fertility tolerant grasses” namely: browntop (*Agrostis tenuis*), sweet vernal (*Anthoxanthum oderatum*), crested dogstail (*Cynosurus cristatus*), and chewings fescue (*Festuca rubra L* subsp. *commutata*). The legume content of the pasture is low (~ 5 to 10%) and is predominantly white clover (*Trifolium repens*). The trial site was established, fenced and instrumented between October 2009 and March 2010. From October 2009 till end August 2010 the trial area was under a common grazing management typical for a North Island summer moist hill country property with a stocking rate of 8-10 ewe equivalents/ha. Collection of pre-treatment application leaching and soil measurements occurred from April 1 2010 – August 20 2010, and the differential grazing treatments were imposed on 20 August 2010. The trial, with the differential grazing treatments in place, will continue until 1 September 2013.

The soil at the trial site is an imperfectly drained silt loam with the parent material described as being patchy loess over massive mudstone and siltstone. Soil textures range from silty clay loam to clay loam. The Land Use Capability Class at the site is 6e2; i.e. "moderately steep to strongly rolling fertile mudstone and siltstone hill country with a moderate potential for shallow earthflow and soil slip erosion" (Lynn 2009).

A metrological station, located in similar hill country approximately 1 km from the trial area, records hourly measurement of rainfall and solar radiation, hourly mean ambient air and 10 cm soil temperatures, soil moisture (to 15 cm) and wind speed and direction.

The two grazing treatments: - a control or relatively extensive grazing treatment (E) with a target stocking rate of 8 stock units/ha, and - an intensive grazing treatment (I) with a target stocking rate of 14 stock units/ha. The trial is set out as a randomised complete block design with three replicate blocks. Each of the three replicate blocks contain two 0.7 ha paddocks. The two grazing treatments (E & I) were assigned at random to the two paddocks in each block. Initial soil chemical properties were obtained in June 2010, 2 months before grazing intensification treatments commenced, and are presented in Table 1 below.

Table 1. Initial soil chemical properties at 0-100 mm soil depth; by block and slope class. For each value in the table, n = 6 soil samples; each sample being a bulk of four soil cores (25 mm x 100 mm).

Block	Slope Class	pH	Olsen P (µg/mL)	Organic C (%)	Total N (%)	C:N ratio
1	LS	5.5	21	5.3	0.47	11.3
	MS	5.3	9	4.8	0.33	14.4
2	LS	5.6	21	5.1	0.48	10.6
	MS	5.3	11	4.6	0.39	11.9
3	LS	5.5	35	5.9	0.54	11.0
	MS	5.3	6	4.5	0.37	12.1

Grazing management for the two grazing intensity treatments is implemented according to predetermined treatment-specific target pasture covers for each month of the year. To this end, separate target pasture cover curves for each grazing intensity treatment have been developed. In spring/early summer the extensive grazing treatment is allowed to go above target covers somewhat but the minimum cover must be very close to the target, whereas for the intensive grazing treatment, pasture cover is allowed to go below the target cover somewhat but not above. The two grazing intensities are achieved by continually adjusting animal numbers in each paddock to attain the desired pasture covers designated by the particular grazing intensity treatment assigned to that paddock. For both grazing intensity treatments the paddocks are set stocked with ewes and lambs from lambing to weaning (approx. mid- late August till mid-late December), and are rotationally grazed with dry sheep for the remainder of the year.

Nutrient leaching measurements

Lysimeters, adapted for use in hill country, are used to measure N and C leaching from LS and MS areas. Sixteen mini-lysimeters (150 mm x 300 mm) have been installed in each 0.7

ha paddock, with eight lysimeters on LS areas and 8 lysimeters on MS areas in each paddock. Thus there are a total of 96 lysimeters at the trial site; 48 lysimeters each on LS and MS areas.

Measurement of drainage volume and nutrient concentration occur after approximately each 100 mm rainfall or at monthly intervals, whichever occurs first. At each collection the volume of water drained per lysimeter is recorded, and a subsample of leachate taken for analysis for nitrate N and ammonium N. Leachate samples from the eight lysimeters in each slope class in each paddock are bulked according to volume and the bulked sample analysed for dissolved organic N (DON) and dissolved organic C (DOC).

Results

The early-mid autumn period was relatively dry, with 130 mm of rain in the 2 ½ months from March 1 up to mid-May. Drainage measurements began on April 1, with no significant drainage occurring until the latter part of May. Over the 9 month period from April 1 2010 82% of rainfall was measured as drainage from MS areas, compared with 59% of rainfall being measured as drainage from LS areas (Figure 1).

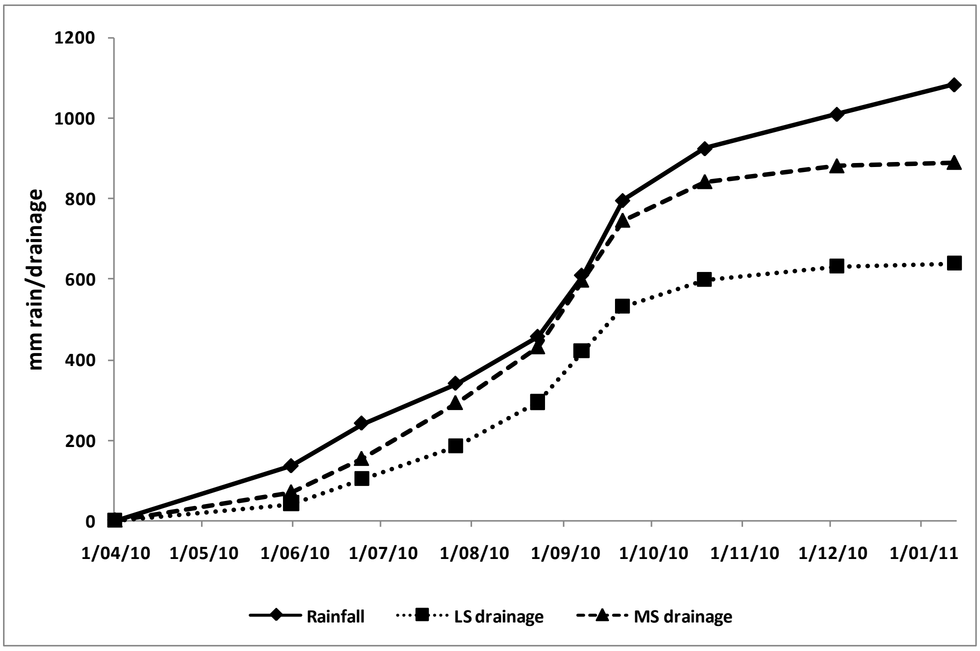

Figure1. Rainfall and mean drainage (mm) measured over the period April 1 2010 to January 12 2011 from low slope (LS) and medium slope (MS) areas.

At this early stage of implementation of the two differential grazing treatments, the concentration and amount of each nutrient leached did not differ significantly between the two grazing intensification two. There was however significant differences between slope class in both the concentration and amount of nutrients leached. Thus the early results which we report here are presented only by slope class. We also present data from the period of April-August separately to that of the September-January period, illustrating the difference in concentration and amount of each nutrient leached between the autumn/winter period and the spring/summer period.

Leachate concentrations of ammonium N, nitrate N, DON and DOC were highest initially and decreased with each successive collection period. Leachate from LS areas had much higher concentrations of both forms of inorganic N and organic N and C than that from MS areas (Table 2).

Table 2. Mean concentrations of nitrate N, ammonium N and dissolved organic N (DON) (mg N/L) and dissolved organic C (DOC) (mg DOC/L) in the April – August period and in the September – January period, for low slope (LS) and medium slope (MS) areas separately.

	LS		MS	
	April-Aug	Sept-Jan	April-Aug	Sept-Jan
Nitrate N (mg N/L)	17.5	6.5	1.6	0.7
Ammonium N (mg N/L)	10.5	6.0	2.7	0.5
DON (mg DON/L)	8.5	5.4	2.3	0.3
DOC (mg DOC/L)	41.1	26.2	15.8	8.5

The mean amounts of both ammonium N and nitrate N leached from lysimeters in LS areas were higher than those from lysimeters in MS areas (Figure 2). Mean nitrate losses from LS areas were six times greater than that from MS areas ($P<0.001$) and mean ammonium N losses from LS areas were three times greater than that from MS areas ($P<0.001$) (Figure 2). In LS areas, mean nitrate N losses were twice that of mean ammonium N losses (63 and 28 kg N/ha, respectively), whereas the mean amounts of nitrate N leached were similar to that of ammonium N for MS areas (9 kg N/ha for both forms of mineral N respectively) (Figure 2).

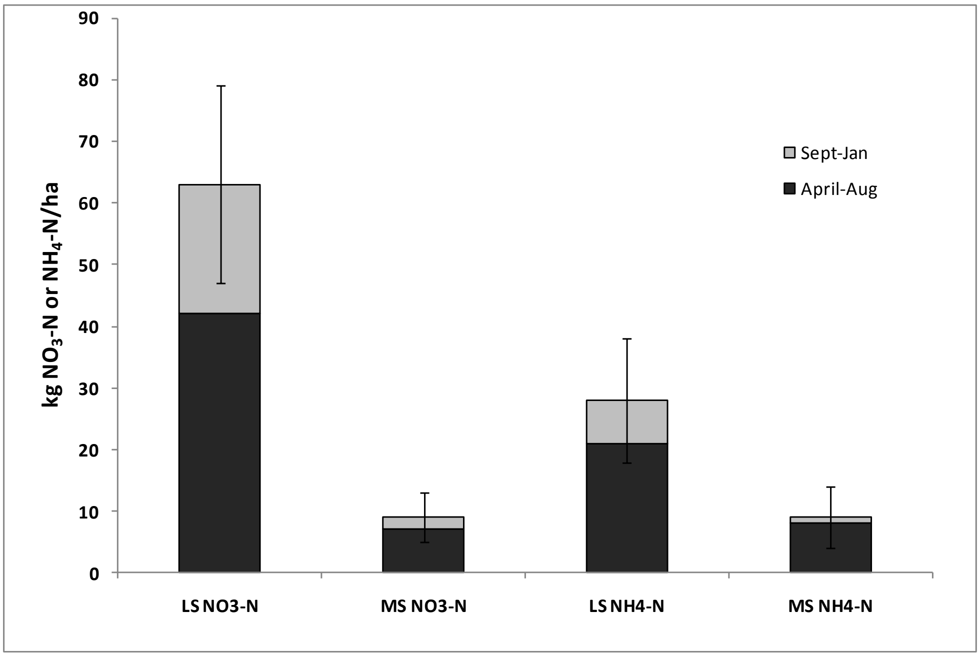

Figure 2. Mean amounts of nitrate N (NO_3-N) and ammonium N (NH_4-N) leached over the autumn/winter (April-Aug) (black portion of each bar) and spring/summer (Sept-Jan) (grey portion of each bar) periods for low slope (LS) and medium slope (MS) areas. For each bar and time period n=48. Error bars indicate the SE of the mean for the total amount leached from April 2010 – January 2011.

Mean amounts of both DON and DOC leached were higher from lysimeters in LS compared to from lysimeters in MS areas (*P*< 0.02 for DON and 0.05 for DOC) (Figure 3). In this first year of leachate collection, three times more DOC than DON was leached from the LS areas. In contrast, the amount of DOC leached from MS areas was more than ten times the amount of DON leached. Over the nine month period of leachate collection lysimeters in both LS and MS areas leached approximately twice as much inorganic N than organic N.

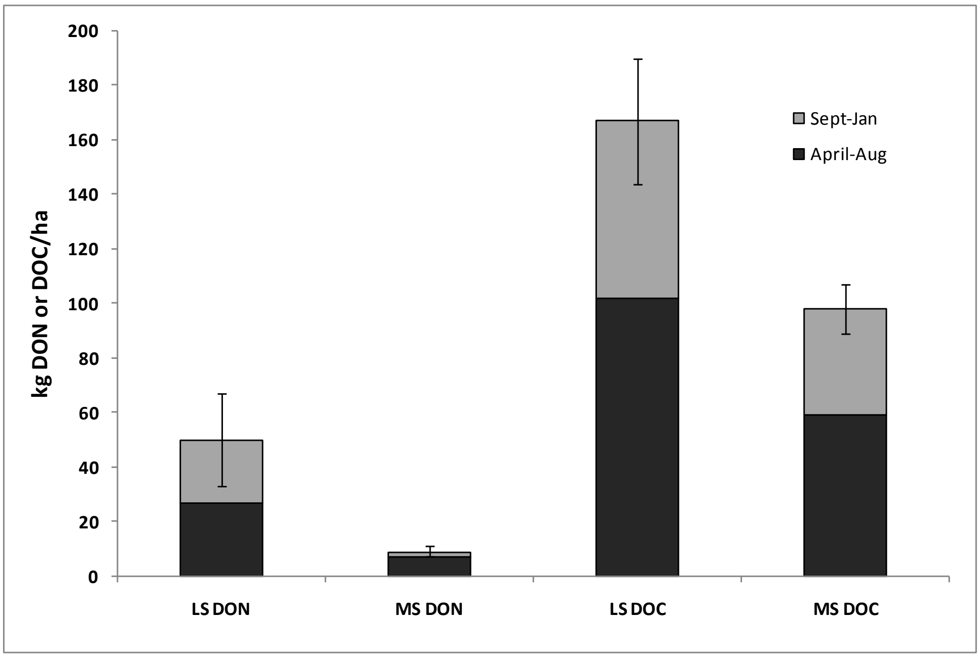

Figure 3. Mean amounts of dissolved organic N (DON) and dissolved organic C (DOC) leached over the autumn/winter (April-Aug) (black portion of each bar) and spring/summer (Sept-Jan) (grey portion of each bar) periods for low slope (LS) and medium slope (MS) areas. For each bar and time period n=6. Error bars indicate the SE of the mean for the total amount leached from April 2010 – January 2011.

Summary

This report describes a grazing trial initiated in sheep grazed summer moist hill country in the southern North Island of New Zealand. The objectives of the trial are to measure the impact of grazing intensification on inorganic N and organic N and C leaching. The report describes the trial protocol, basic trial site information, and presents initial results of N and C leaching over the first nine months of the trial.

Results obtained in the first nine months of the trial (April 1 2010 – January 12 2010) highlight topographical differences in nutrient leaching from 300 mm below the soil surface. The results presented in this report are from a single nine month period of leaching measurements and caution should be used when interpreting the results in this initial report. Extrapolating the results of the relatively short term measurements presented in this report to that of the wider context of hill country in New Zealand are discouraged.

In time, the information generated from this trial will improve understanding of the impacts of grazing intensification on the storage and losses of N and C in grazed hill country, and will inform the development of biophysical models for simulating the impact of management intensification in grazed hill country.

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