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URINE NITROGEN IN HILL COUNTRY PASTURE SOILS

**A thesis presented in partial fulfilment of the requirements for a
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ABSTRACT

In New Zealand the traditional way of building up nitrogen (N) fertility in pastures has been to apply phosphorus (P) fertilisers to provide adequate soil fertility for legume growth, which then provides N through biological N fixation. However, the marked responsiveness of hill pastures to N fertiliser indicates that this traditional approach may be placing a serious constraint on hill country production. At the same time, there is concern that the resulting elevated soil P levels may pose some environmental risk.

Although the importance of soil N availability to hill country pasture production has long been recognised, there is surprisingly little information available on N cycling in hill country pastures. This is because the limited research funding available has been directed mainly at determining the requirements for P and sulfur (S) fertilisers, which have constituted the bulk of fertiliser expenditure in hill country. In order to develop best practice in the use of fertiliser N in hill country, information is required on N flows in the soil-plant-animal system on the contrasting topographic land units that comprise hill pastures. The role of grazing animals and particularly the N transformations associated with urine patches are very important components of these N cycles.

In this study, two field experiments were conducted at contrasting locations in North Island hill country pastures to investigate the fate of urine N. These field experiments were then followed by a laboratory incubation experiment that sought to clarify the effect of soil properties on subsequent transformations of urine N. The experimental results were then used, together with data from the literature, to model the N cycle for hill country pasture. In addition, to assess the N availability in hill pastures, an *in situ* N measurement technique using ion exchange resin membrane spikes was developed and evaluated.

The first preliminary field experiment was carried out at the AgResearch Grassland hill country research site in Waipawa, North Island, New Zealand from 09 June 1999 to 29 October 1999. The major soil type was Waipawa Stony Silt Loam (Pallic Soil). Three synthetic urine treatments (0, 200, 400 kg N/ha) were applied in a randomised complete block design and the experiment was repeated in a flat campsite and a steep site. At 1

day after urine application (DAUA), the increase in the soil mineral N pool was close to or greater than the quantity of added urine N. The dominant form of mineral N throughout the experiment was $\text{NH}_4^+\text{-N}$. This suggested that nitrification rates were low and that leaching losses of $\text{NO}_3^-\text{-N}$ would therefore be low. Only 18-27% of the urine N was recovered by the pasture. Estimates of the loss of urine N by ammonia volatilisation were large, ranging from 21-34% of added urine N. At the end of the experiment (142 DAUA), 34 -50% of added urine N appeared to have been immobilized into complex organic matter.

The second field experiment was carried out at Ballantrae AgResearch hill country research station from 14 July 2000 to 12 December 2000. The soil was Ngamoko Silt Loam (Brown Soil). Three different rates (0, 280, 560 kg urine N/ha) of synthetic urine were applied as treatments and the experiment was repeated as a randomised complete block design on a flat campsite and a steep slope. Shortly after application, recovery of urine N as soil mineral N was greater than 100% (113-141%) in the flat site. This increase in mineral N corresponded to a decrease in mineralisable N, suggesting organic matter mineralisation after urine application. During the first month after urine application, $\text{NH}_4^+\text{-N}$ was the dominant form of mineral N, but during the second month, $\text{NO}_3^-\text{-N}$ was the dominant mineral N form. At the end of the experiment (88 DAUA), urine N recovery as mineral N was very low, ranging from 0-3%. The rate of nitrification after urine application was higher in flat campsites than in steep slopes. Soil $\text{NO}_3^-\text{-N}$ levels in the 0-10 cm soil depth in urine-treated plots at both sites decreased considerably between 30 and 45 DAUA. A simple model developed in Microsoft Excel suggested that substantial leaching of urine N (9-33% of added urine N) was likely to have taken place. Urine N recovery by herbage in this experiment was low (1-14% of added urine N). Estimates of the loss of urine N through volatilisation were large, ranging from 24-51% of added urine N. At the end of the experiment the amounts of urine N estimated to have been immobilised into the soil organic matter ranged from 8-57% of that added.

A laboratory incubation experiment was conducted using four soils collected from the flat and steep sites of the field experiments at Waipawa and Ballantrae together with three other soils collected from lowland sites (Kairanga silt loam, Karapoti silt loam and Manawatu sandy loam (Fluvial Recent Soils)) that had received substantial quantities of

excretal N over several years. Field moist soil, equivalent to a weight of 100 g of dry soil, was placed in each of 36 small plastic cups for each soil type. Urine was collected from four cows during milking two weeks before the experiment. Urine was applied to 18 cups of each soil at the rate of 6 mL of urine/100 g dry soil (40 mg urine N/100 g dry soil). The remaining 18 cups were used as controls. No solution was added to the control cups.

In contrast to the field experiments, there was little evidence of an initial priming effect, with mineral N levels 3 DAUA ranging from 64-81% of added urine N. Nitrification rates were highly variable (0.3 to 18.3 $\mu\text{g NO}_3^- \text{-N/g soil/day}$) across the seven soils. All lowland soils had higher nitrification rates than hill soils, while those soils collected from campsites had higher nitrification rates than soils collected from steep slopes. Although nitrification could account for most of the disappearance of soil $\text{NH}_4^+ \text{-N}$ from 3-45 DAUA, it was evident that mineralisable N and soil microbial biomass N also increased after urine application.

A simulation model of a hill country N cycle developed in Microsoft Excel confirmed the importance of urine N in hill country pastures. The model indicated that N outputs in animal products, together with losses through ammonia volatilisation and leaching from urine patches were likely to exceed the N inputs to hill pastures by legume N fixation, non symbiotic fixation and atmospheric deposition. This may be the reason for the observed high N responsiveness in hill country pastures. Pasture utilisation and excretal distribution in the paddock were the most important factors influencing the overall N balance in the paddock. More work is required to obtain information on these parameters in hill country pastures.

The *in situ* N measurement technique using ion exchange resin membrane spikes proved to be a useful approach to monitoring the continuous changes in soil mineral N in the field experiments as well as in the incubation experiment. Resin spikes were able to detect apparently real differences in the availability of soil N - even when the standard 2 M KCl extraction could detect no differences. The potential of resin spikes to detect spatial variability in soil N status was also demonstrated.

A simple model developed in Visual Basic in Microsoft Excel to simulate the N adsorption by resin spike in soils demonstrated that soil moisture, soil temperature, soil N concentration and the time the resin spike is in the soil are all major determinants of the amount of N adsorbed to resin in soil.

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TABLE OF CONTENTS

ABSTRACT	II
ACKNOWLEDGEMENT.....	VI
TABLE OF CONTENTS	VII
LIST OF TABLES	XIII
LIST OF FIGURES.....	XVI
LIST OF PLATES.....	XXIV

CHAPTER 1

INTRODUCTION

INTRODUCTION	1
---------------------------	----------

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction	4
2.2 New Zealand hill country	4
2.2.1 Topography	5
2.2.2 Soil	5
2.2.3 Pasture composition	6
2.2.4 Nitrogen use in hill country.....	7
2.3 Nitrogen balances in different topographic units of hill country.....	8
2.3.1 Pasture N uptake.....	11
2.3.2 N fixation.....	11
2.3.3 Non-symbiotic N fixation and atmospheric deposition.....	13
2.3.4 Pasture utilisation	13
2.3.5 N remaining in pasture litter.....	14
2.3.6 N in animal products	14
2.3.7 Dung and urine N	14
2.3.8 Above ground N balance in hill country	16
2.4 Summary of literature review	18

CHAPTER 3

FIELD INVESTIGATION OF THE FATE OF URINE NITROGEN ON A SUMMER DRY HILL COUNTRY PASTURE

3.1	Introduction	20
3.2	Literature review	21
3.2.1	Nitrogen cycling through animals	21
3.2.2	Urine N	21
3.2.3	N transformations in the urine patch	22
3.2.3.1	Urea hydrolysis	24
3.2.3.2	Ammonia volatilisation	25
3.2.3.3	Nitrification	28
3.2.3.4	Leaching	34
3.2.3.5	Denitrification	37
3.2.3.6	Mineralisation and immobilisation	37
3.2.3.7	Plant uptake	40
3.2.3.8	Fixation to clay minerals	41
3.3	Materials and methods	41
3.3.1	Field site	41
3.3.2	Field trial design	42
3.3.3	Treatments	42
3.3.4	Soil and plant sampling	43
3.3.5	Ammonia volatilisation	45
3.3.6	Statistical analysis	46
3.4	Results	46
3.4.1	Rainfall	46
3.4.2	Statistical data interpretation	47
3.4.3	Mineral nitrogen	47
3.4.4	Ammonium	50
3.4.5	Nitrate	51
3.4.6	Mineralisable N	52
3.4.7	Pasture response	54
3.4.8	Ammonia volatilisation	58
3.5	Discussion	59
3.5.1	Urine N recovery	59
3.5.2	Mineral N	62
3.5.3	Nitrification and leaching	64
3.5.4	Pasture response	65
3.5.5	Ammonia volatilisation	66
3.5.6	Mineralisation and immobilization	66

3.5.7	Comparison of urine N transformations at two sites	68
3.6	Conclusions	68

CHAPTER 4

DEVELOPMENT OF ION EXCHANGE RESIN MEMBRANE SPIKES FOR CONTINUOUS MONITORING OF AVAILABLE SOIL NITROGEN IN HILL COUNTRY PASTURE

4.1	Introduction	70
4.2	Literature review	71
4.2.1	Ion exchange resins	71
4.2.2	Diffusion.....	74
4.2.3	Ion exchange resin use in recent soil research	75
4.3	Development of the ion exchange resin membrane spike.....	77
4.3.1	Experiment 1: Preliminary assessment of the ability of resin strips to adsorb mineral N from Soil.....	77
4.3.2	Experiment 2: Assessment of variability with resin spikes.....	78
4.3.3	Experiment 3: Optimization of resin spike construction.....	79
4.3.4	Experiment 4: Optimization of resin spike construction II.....	80
4.3.5	Experiment 5: Evaluation of resin spike variability in soil.....	81
4.4	N adsorption to resin membranes.....	82
4.4.1	N adsorption to resin spikes over time	87
4.4.1.1	Experiment 1: N adsorption from solution.....	87
4.4.1.2	Experiment 2: N adsorption from soil.....	88
4.5	Resin spikes performance in field	91
4.5.1	Field experiment 1.....	91
4.5.2	Field experiment 2.....	93
4.6	Modelling of <i>in situ</i> N adsorption to resin membrane spikes.....	96
4.6.1	Introduction	96
4.6.2	Basic equations for solute diffusion in soil	96
4.6.3	Model development.....	100
4.6.4	Model output	105
4.6.4.1	The effect of time of burial on N adsorption by a resin spike in soil....	105
4.6.4.2	Effect of soil moisture on N adsorption by resin spikes	109
4.6.4.3	Effect of initial soil N concentration	111

4.6.4.4	Effect of temperature on N adsorption by resin spike in soil	111
4.6	Recommended procedure	112
4.8	Discussion	114

CHAPTER 5

FIELD INVESTIGATION OF NITROGEN DYNAMICS UNDER URINE PATCHES IN NORTH ISLAND HILL COUNTRY PASTURE

5.1	Introduction	118
5.2	Materials and methods.....	119
5.2.1	Site description	119
5.2.2	Field layout and soil sampling	119
5.2.3	Treatments	120
5.2.4	Soil sampling	121
5.2.5	Ammonia volatilisation	121
5.2.6	Soil mineral and mineralisable nitrogen.....	121
5.2.7	Dissolved organic carbon and dissolved organic nitrogen	122
5.2.8	Resin-adsorbed nitrogen.....	122
5.2.9	Plant dry matter production and pasture nitrogen uptake.	122
5.2.10	Statistical analysis	123
5.3	Results	123
5.3.1	Climate	123
5.3.2	Statistical interpretation.....	125
5.3.3	Mineral nitrogen	125
5.3.4	Ammonium.....	128
5.3.5	Nitrate	131
5.3.6	Performance of resin spikes	133
5.3.6.1	Relationships between 2 M KCl -extractable N and resin-adsorbed N.....	135
5.3.7	Mineralisable N	137
5.3.8	Pasture response	141
5.3.9	Ammonia volatilisation	144
5.3.10	Leaching.....	146
5.3.10.1	Leaching model development	146
5.3.10.2	Leaching model output.....	150
5.3.11	Nitrification	154
5.4	Discussion	158

5.4.1	Urine N recovery	158
5.4.2	Mineral N	161
5.4.3	Priming effect	162
5.4.4	Ammonia volatilisation	164
5.4.5	Nitrification	165
5.4.6	Leaching	165
5.4.7	Pasture response	167
5.4.8	Denitrification	168
5.4.9	Immobilisation	168
5.5	Conclusions	169

CHAPTER 6

LABORATORY INCUBATION STUDY OF NITROGEN TRANSFORMATIONS IN HILL COUNTRY AND LOWLAND PASTURE SOILS AFTER APPLICATION OF URINE

6.1	Introduction	170
6.2	Materials and methods.....	171
6.2.1	Soils used for the incubation	171
6.2.2	Experimental procedure	171
6.2.3	Chemical analysis.....	173
6.2.3.1	Mineral nitrogen (NH_4^+ -N and NO_3^- -N)	173
6.2.3.2	Total dissolved nitrogen	173
6.2.3.3	Dissolved organic carbon	173
6.2.3.4	Microbial carbon	174
6.2.3.5	Microbial nitrogen.....	174
6.2.3.6	Total carbon and total nitrogen in soil	174
6.2.3.7	Hot water soluble carbon.....	174
6.2.3.8	Clay fixed nitrogen.....	174
6.2.4	Statistical Analysis	175
6.3	Results	175
6.3.1	Organic matter quality of tested soils.....	175
6.3.2	Mineral N	182
6.3.3	Ammonium.....	184
6.3.4	Nitrate.....	187
6.3.5	Mineralisable N	189
6.3.6	Dissolved organic carbon (DOC)	191
6.3.7	Soil microbial biomass (SMB).....	191
6.4	Discussion	194
6.4.1	Nitrification	198

6.4.2	Relationships between resin-adsorbed N and 0.5M K ₂ SO ₄ - extractable N	204
6.5	Conclusion.....	207

CHAPTER 7

MODELLING THE NITROGEN CYCLE IN SHEEP GRAZED NORTH ISLAND HILL COUNTRY PASTURE

7.1	Introduction	209
7.2	Model inputs and development	209
7.3	Model outputs	214
7.4	Sensitivity of the model to different conditions	220
7.4.1	Impact of excretal distribution	221
7.4.2	Impact of pasture utilisation	222
7.4.3	Impact of soil fertility, as affected by P fertiliser addition.....	226
7.5	Improvement of efficiency of hill country N cycle	229

CHAPTER 8

SUMMARY AND IMPLICATIONS FOR FUTURE RESEARCH.....	232
---	-----

REFERENCES	241
------------------	-----

APPENDIX 1	261
------------------	-----

APPENDIX 2	263
------------------	-----

APPENDIX 3	271
------------------	-----

APPENDIX 4	274
------------------	-----

LIST OF TABLES

CHAPTER 2

Table 2.1	Calculation of amount of dung and urine N derived from on each slope category in the notional 1 ha paddock.....	15
Table 2.2	N balance on different land slopes within a notional sheep-grazed hill pasture. (Values are based on Fig. 2.1 and Fig. 2.2).....	16
Table 2.3	N inputs and N surplus in the notional 1 ha hill country paddock. Data on N inputs per ha and N surplus per ha are from Table 2.2 and proportions of land in each slope category are from Table 2.1 and Gillingham (1978).....	17

CHAPTER 3

Table 3.1	The partition of urinary nitrogen (Doak, 1952).	21
Table 3.2	Constituents of the synthetic urine solution (pH= 7.8).	43
Table 3.3.	Treatments used in the experiment.	43
Table 3.4	Apparent recovery of urine N as mineral N and mineralisable N after urine application (kg N/ha/7.5 cm depth) in the soil profile (0-15 cm) i.e. all values are treatment minus control. * = did not measure.....	49
Table 3.5	Mineralisable N levels (kg N/ha) in control soils at different depths. Values are the average of soils sampled 27, 100 and 142 DAUA.	53
Table 3.6	Pasture DM production and N uptake as effected by urine application.....	58
Table 3.7	Effect of urine treatments on ammonia volatilization.....	59
Table 3.8	Apparent fate of urine NH_4^+ -N from 1-27 DAUA (A) and 27-100 DAUA (B). All quantities are expressed as kg N/ha.	64
Table 3.9	Soil fertility indices of the two sites.....	68

CHAPTER 4

Table 4.1	Resin-adsorbed N ($\mu\text{g-N}/5 \text{ cm}^2/3 \text{ days}$) from two different pasture plots.....	78
Table 4.2	Resin-adsorbed N ($\mu\text{g-N}/5 \text{ cm}^2/\text{day}$) from NH_4NO_3 solution containing $10 \mu\text{g/mL NH}_4^+$ -N and $10 \mu\text{g/mL NO}_3^-$ -N.	79

Table 4.3	Adsorption of N ($\mu\text{g-N}/5\text{ cm}^2/\text{day}$) by glued spikes and fresh resin membranes from 25 mL samples of NH_4NO_3 solution containing $10\text{ }\mu\text{g NH}_4^+\text{-N/mL}$ and $10\text{ }\mu\text{g NO}_3^-\text{-N/mL}$ over a day.	79
Table 4.4	N adsorption ($\mu\text{g-N}/5\text{ cm}^2/\text{day}$) to resin spikes immersed in NH_4NO_3 solution containing $10\text{ }\mu\text{g/mL NH}_4^+\text{-N}$ and $10\text{ }\mu\text{g/mL NO}_3^-\text{-N}$ for a day. .	80
Table 4.5	N adsorption to resin spike from homogeneous soil ($\mu\text{g-N}/5\text{ cm}^2/7\text{ days}$).	81
Table 4.6	Estimation of resin-adsorbed $\text{NO}_3^-\text{-N}$ from NH_4NO_3 solution containing different initial quantities of $\text{NO}_3^-\text{-N}$	85
Table 4.7	Estimation of resin-adsorbed $\text{NH}_4^+\text{-N}$ from NH_4NO_3 solutions containing different initial quantities of $\text{NH}_4^+\text{-N}$	86
Table 4.8	Soil $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ assessed by 2 M KCl extraction and resin adsorption, together with pasture N uptake over 12 days at 2 sites. Means with common letters are not significantly different ($P<0.05$) within a column at each site.	92
Table 4.9	Levels of mineral N in two soils as measured by 2 M KCl extraction and resin spikes. Measurements were made over a 7 day period in the field and also after incubation for 7 days in the laboratory.	95

CHAPTER 5

Table 5.1	Treatments used in the experiment at Ballantrae AgResearch hill country research station investigating the fate of simulated urine N applied to hill country pasture.	120
Table 5.1A	Constituents of the synthetic urine solution ($\text{pH}=7.8$).	120
Table 5.2	Average meteorological conditions for 1970-1995 at Ballantrae AgResearch Hill country research station (wind speed data was only available for 1994).	124
Table 5.3	Net mineral N (extracted by 2 M KCl) in the soil profile (0-30 cm) (i.e. treatment minus control values).	127
Table 5.4	Mineralisable N levels (kg/ha) in control soils at different depths. Values are the average of soils from sampling times at 3, 12 and 27 DAUA.	138
Table 5.5	Pasture DM production, herbage N concentration and N uptake following urine application.	144
Table 5.6	Quantities of NH_3 trapped by samplers and estimated losses of NH_3 by volatilisation.	145

Table 5.7	Amounts of urine N lost through NH_3 volatilisation and overall recovery of added urine N at 3 DAUA. # = data from Table 5.3	145
Table 5.8	Example of leaching calculation by the model. Data extracted from leaching model of the F560 treatment.....	149
Table 5.9	Estimated leaching losses from urine treatments by the two models.	151
Table 5.10	Example of nitrification calculation. Calculations up to day 8 are presented for the F560 treatment plots.	155

CHAPTER 6

Table 6.1	Apparent fate of urine N at 3 DAUA. * (rate of urine N was 400 μg N/g soil) i.e. values are treatment minus control).....	194
Table 6.2	Quantitative comparison of NH_4^+ -N decrease and NO_3^- -N increase in urine treated soils from 3-45 DAUA. (All values are in μg N/g soil).	198
Table 6.3	Nitrification rates during first 15 DAUA in the experimental soils.....	199

CHAPTER 7

Table 7.1	Data used to evaluate the model. G= measured data of Gillingham (1978), B= measured data of Blennerhassett (2002), T= Findings from this thesis.	214
Table 7.2	Modelled N balances for individual slope categories and for the overall paddocks taking into account that campsites, easy slopes and steep slopes occupy 12.2%, 45.5% and 42.3% of the paddock area respectively.	217
Table 7.3	Data used to evaluate the model on a paddock with a high level of P fertility. G = measured data of Gillingham (1978), B = measured data of (Blennerhassett (2002), T = Findings from this thesis.	226

CHAPTER 8

Table 8.1	Comparison between sustainable levels of pasture production with current N inputs and theoretical maximum pasture production in different slope categories of hill country	239
-----------	--	-----

LIST OF FIGURES

CHAPTER 2

Fig. 2.1	Above-ground N balances for hill country with a north facing aspect. All values are kg N/ha/yr.....	9
Fig. 2.2	Above-ground N balances for hill country with a south facing aspect. All values are kg N/ha/yr.....	10

CHAPTER 3

Fig. 3.1	Percentage urine N recovery in urine patches. Data extracted from Ball <i>et al.</i> , 1979 (Palmerston North) and Carran <i>et al.</i> , 1982 (Gore).....	23
Fig. 3.2	Four general patterns of nitrification observed by Steel <i>et al.</i> (1980) when soils are perfused with .005M (NH ₄) ₂ SO ₄	32
Fig. 3.3	Relationships between INA (Initial Nitrification Activity) and total N (%) and C/N ratio of soil. The data are extracted from soils that showed the Type 1 and Type 2 nitrification patterns of Steel <i>et al.</i> (1980).	33
Fig. 3.4	Relationships between INA (Initial Nitrification Activity) and total N (%) and C/N ratio of soil. All the data presented in Steel <i>et al.</i> (1980) were used for the relationships.	33
Fig. 3.5	Daily rainfall during the experimental period.....	46
Fig. 3.6	Effect of urine application on soil (0-15 cm) mineral N level. * = significant treatment differences were observed within a sampling at the same site. NS = no significant treatment differences were observed within a sampling at the same site.....	48
Fig. 3.7	Effect of urine treatments on soil (0-15 cm) NH ₄ ⁺ -N. * = significant treatment differences were observed within the sampling time. NS = no significant treatment differences were observed within the sampling time.	50
Fig. 3.8	Effect of urine treatments on soil (0-15 cm) NO ₃ ⁻ -N. * = significant treatment differences were observed within the sampling time. NS = no significant treatment differences were observed within the sampling time.	52

Fig. 3.9	Effects of urine treatments on soil (0-7.5cm) mineralisable N levels at 27, 100, 142 DAUA. Treatments with common lower case letters do not differ ($P<0.05$) within a sampling day at the same site. Treatments at the same site with common upper case letters do not differ at ($P<0.05$) between sampling days.....	53
Fig. 3.10	Effect of urine treatments on pasture DM accumulation. Total DM accumulations at the same site with common upper case letters do not differ at the $P<0.05$ level. Treatments at the same site and at the same harvest with common lower case letters do not differ at the $P<0.05$ level.....	56
Fig. 3.11	Effect of urine treatments on pasture N accumulation. Total pasture N accumulations at the same site with common upper case letters do not differ at the $P<0.05$ level. Treatments at the same site and at the same harvest with common lower case letters do not differ at $P<0.05$ level.	57
Fig. 3.12	Effect of urine treatments on ammonia volatilisation. Treatments with common letters within a site do not differ at the $P<0.05$ level.....	58
Fig. 3.13	Total urine N recovery (%) during the experiment.	60
Fig. 3.14	Urine N recovery during the experiment.	61

CHAPTER 4

Fig. 4.1	Polymerization synthesis of a styrene sulfonic acid cation exchange resin (Harland, 1994).	73
Fig. 4.2	Relationship between diffusion impedance factor and moisture content. (Logistic curve fit for the data in Fig. 4.1 of Tinker and Nye (2000).).....	75
Fig. 4.3	N adsorption to resin spikes from different concentrations of NH_4NO_3 solution. Each point represents the average of three replicates.	83
Fig. 4.4	Estimated and measured resin-adsorbed NO_3^- -N from NH_4NO_3 solutions containing different initial quantities of NO_3^- -N.....	85
Fig. 4.5	Estimated and measured resin-adsorbed NH_4^+ -N from NH_4NO_3 solutions containing different initial concentrations of NH_4^+ -N. n = Selectivity coefficient of K^+	87
Fig. 4.6	N adsorption by resin spikes with time from NH_4NO_3 solution containing $10 \mu\text{g NH}_4^+$ -N/mL and $10 \mu\text{g NO}_3^-$ -N/mL	88
Fig. 4.7	NH_4^+ -N levels during the incubation as measured by the 2 M KCl - extractable and Resin methods.	89

Fig. 4.8	NO_3^- -N levels during the incubation as measured by 2 M KCl -extractable and Resin methods.....	90
Fig. 4.9	Notional box of soil.....	97
Fig. 4.10	Modelled experimental soil cube with resin spike inserted, viewed from above. The anion exchange resin membrane is facing cells (10,9), (10,10), (10,11), and (10,12) and the cation exchange resin facing the cells (11,9), (11,10), (11,11) and (11,12).....	100
Fig. 4.11	Electrical conductivity of different NH_4NO_3 concentrations at 20° C.....	102
Fig. 4.12	Measured and modelled NO_3^- -N adsorption to resin spikes with time....	106
Fig. 4.13	Modelled NO_3^- -N concentration ($\mu\text{g}/\text{cm}^3$ soil solution) in each soil compartment (0.25 x 0.25 x 5 cm) 1 day after placement of the resin spike in soil. The asymmetrical depletion pattern is caused by the placement of the anion resin strip on the side of the spike apparently closest to the top of page. (This diagram shows only half of the system).....	107
Fig. 4.14	Soil NO_3^- -N ($\mu\text{g}/\text{cell}$) distribution in each soil compartment (0.25x 0.25x1cm) 1 day after placement of the resin spike in soil. The resin spike is placed at 2-3 cm on the X axis and at 2.5 cm on the Y axis. The asymmetrical depletion pattern is caused by the placement of the anion resin strip on the side of the spike apparently closest to the reader.	107
Fig. 4.15	Modelled NO_3^- -N concentration ($\mu\text{g}/\text{cm}^3$ soil solution) in each soil compartment (0.25 x 0.25 x 5 cm) 7 days after placement of the resin spike in soil (This diagram shows only half of the system).	108
Fig. 4.16	Soil NO_3^- -N ($\mu\text{g}/\text{cell}$) distribution in each soil compartment (0.25x 0.25x1cm) 7 days after placement of the resin spike in soil. The resin spike is placed at 2-3 cm on the X axis and at 2.5 cm on the Y axis.....	108
Fig. 4.17	Modelled effect of soil moisture content on NO_3^- -N adsorption by resin spikes with time after burial. W = gravimetric moisture content. ...	109
Fig. 4.18	Effect of soil moisture on soil NO_3^- -N ($\mu\text{g}/\text{cell}$) distribution 7 days after placement of the resin spike in soil. The resin spike is placed at 2-3 cm on the X axis and at 2.5 cm on the Y axis. The asymmetrical depletion pattern is caused by the placement of the resin strip on the side of the spike 'apparently closest' to the reader.....	110
Fig. 4.19	Modelled effect of initial soil NO_3^- -N concentration ($\mu\text{g NO}_3^-$ -N/ g soil) on NO_3^- -N adsorption by resin spikes with time after burial. The gravimetric moisture content is 0.26 (w/w).....	111

Fig. 4.20	Modelled effect of temperature on N adsorption by resin spikes with time. The moisture content of the soil is 0.26 (w/w).....	112
Fig. 4.21	Schematic diagram of resin spike.....	113
Fig. 4.22	Schematic diagram of processes controlling the available soil N.	115

CHAPTER 5

Fig. 5.1	Rainfall during the experimental period (14/7/2000-19/10/2000).	124
Fig. 5.2	Air and soil temperature during the experimental period (14/7/2000-19/10/2000).....	125
Fig. 5.3	Effect of urine application on soil (0-30cm) mineral N levels.	126
Fig. 5.4	Effect of urine application on soil NH_4^+ -N levels (0-10 cm) as determined by 2 M KCl extraction and resin adsorption methods.	129
Fig. 5.5	Quantities of 2 M KCl extractable NH_4^+ -N and NO_3^- -N in the 0-30 cm soil depth during the experimental period. Note. Change in scale between control and treated plots.	130
Fig. 5.6	Effect of urine application on soil NO_3^- -N levels (0-10 cm) as determined by 2 M KCl -extraction and resin-absorption methods.	132
Fig. 5.7	Effect of urine treatments on resin-adsorbed NO_3^- -N at 55 to 97 DAUA.....	134
Fig. 5.8	Relationship between resin-adsorbed N and 2 M KCl extractable N when both steep and flat site data are used.	136
Fig. 5.9	Relationships between (A) resin adsorbed NO_3^- -N and 2 M KCl -extractable NO_3^- -N. (B) Resin-adsorbed NH_4^+ -N and 2 M KCl adsorbed NH_4^+ -N.	137
Fig. 5.10	Effects of urine treatments on soil (0-10 cm) mineralisable N levels at 3, 12, 27 days after urine application. Treatments with common upper case letters do not differ at $P<0.05$ level within a sampling day. Treatments with common lower case letters do not differ at $P<0.05$ level between sampling days of the same treatment.	139
Fig. 5.11	Effect of urine application on soil mineralisable and mineral N levels (0-10 cm depth) at 3, 12 and 27 days after urine application (DAUA). ...	140
Fig. 5.12	Relationship between increase in soil mineral N and decrease in soil mineralisable N from 3 to 12 and from 12 to 27 DAUA.....	141

Fig. 5.13	Effect of urine treatments on pasture DM accumulation at the flat and steep sites. Dry matter yields with common letters between treatments within same cut and same site do not differ at $P<0.05$. Total DM accumulation with common lowercase letters between treatments within same site do not differ at $P<0.05$	142
Fig. 5.14	Effect of urine treatments on herbage N accumulation. Herbage N accumulations with common uppercase letters between treatments within the same cut and site do not differ at $P<0.05$. Total herbage N accumulations with common lowercase letters between treatments within same site do not differ at $P<0.05$	143
Fig. 5.15	Effect of urine treatments on ammonia volatilisation during the first 6 days after urine application. Values with common upper case letters between treatments within same site do not differ at $P<0.05$	144
Fig. 5.16	Estimated and measured 2 M KCl -extractable NO_3^- -N in the 0-10 cm soil depth during the experimental period. Arrows indicate measured 2 M KCl -extractable NO_3^- N. Other marked data points (•) are estimated 2 M KCl -extractable NO_3^- -N values from the relationship with resin adsorbed NO_3^- -N illustrated in Fig. 5.8.	149
Fig. 5.17	Estimated quantities of soil NO_3^- -N (g/m^2) in the 10-20 cm and 20-30 cm depths from the two models during the experimental period. .	152
Fig. 5.18	Estimated cumulative leaching of NO_3^- -N (g/m^2) from 10-20 cm and 20-30 cm soil depths from urine treatments from the two models during the experimental period.	153
Fig. 5.19	Schematic diagram to illustrate nitrification rate calculation.	154
Fig. 5.20	Cumulative daily nitrification during the experimental period.	156
Fig. 5.21	Frequency distribution of daily nitrification rates calculated at each site for the period up to 45 DAUA.	158
Fig. 5.22	Urine N recovery during the experimental period. The dotted line indicates the application rate.	159
Fig. 5.23	Urine N recoveries (%) during the experimental period, estimated as the sum of soil mineral N, NH_3 volatilisation, plant uptake and leaching of NO_3^- -N.	160
Fig. 5.24	Resin adsorbed NH_4^+ -N (A) and NO_3^- -N (B) levels during the experimental period in control treatments at both sites.	162

CHAPTER 6

Fig. 6.1	Soil carbon related organic matter properties studied during the experiment.	177
Fig. 6.2	Nitrogen related organic matter properties studied during the experiment.	178
Fig. 6.3	Soil carbon to nitrogen ratios in experimental soil.....	179
Fig. 6.4	Relationships between organic matter quality parameters.	181
Fig. 6.5	Effect of urine application on 0.5M K ₂ SO ₄ -extractable soil mineral N. (The statistical analysis of the data in this figure is included in Appendix 3).	183
Fig. 6.6	Percentage of urine N recovered as soil mineral N at the beginning (3 DAUA) and end (45 DAUA) of the experiment.	184
Fig. 6.7	Effect of urine application on soil 0.5M K ₂ SO ₄ -extractable NH ₄ ⁺ -N. (The statistical analysis of data in this figure is included in Appendix 3).	185
Fig. 6.8	Effect of urine application on resin-adsorbed NH ₄ ⁺ -N. (The statistical analysis of data in this figure is included in Appendix 3).	186
Fig. 6.9	Effect of urine application on 0.5 M K ₂ SO ₄ -extractable soil NO ₃ ⁻ -N. (The statistical analysis of data in this figure is included in Appendix 3).	188
Fig. 6.10	Effect of urine application on resin-adsorbed NO ₃ ⁻ -N over time. (The statistical analysis of data in this figure is included in Appendix 3.)	189
Fig. 6.11	Effect of urine application on soil mineralisable N with time. (The statistical analysis of data in this figure is included in Appendix 3).	190
Fig. 6.12	Effect of urine application on soil DOC levels. (The statistical analysis of data in this figure is included in the Appendix 3)	192
Fig. 6.13	Effect of urine application on soil microbial biomass N with time. (The statistical analysis of data in this figure is included in Appendix 3)	193
Fig. 6.14	The distribution of NH ₄ ⁺ -N and NO ₃ ⁻ -N in urine treated soils with time after urine application.....	197
Fig. 6.15	Comparison of nitrification of urine N and control soil N.	200
Fig. 6.16	Relationship between C/N ratio and nitrification rate.	202

Fig. 6.17	Relationship between nitrification rate and the ratio of labile organic C to TC.	203
Fig. 6.18	Relationship between nitrification rate and soil pH of the experimental soils.	204
Fig. 6.19	Relationship between resin-adsorbed N and 0.5M K ₂ SO ₄ -extractable N	205
Fig. 6.20	Relationships between resin-adsorbed N and 0.5M K ₂ SO ₄ -extractable N in different soils.....	206

CHAPTER 7

Fig. 7.1	Modelled N cycle in a hill country paddock with northerly aspect (12.2% campsite, 45.5% easy slope, 42.3% steep slope). All values kg N/ha/yr.	215
Fig. 7.2	Modelled N cycle in a hill country paddock with southerly aspect (12.2% campsite, 45.5% easy slope, 42.3% steep slope). All values are kg N/ha/yr.	216
Fig. 7.3	Modelled N balance for two hill country paddocks with contrasting proportions of steep, easy and flat land. All values are kg N/ha/yr. F = N input by legume N fixation, non symbiotic fixation and atmospheric deposition, AT = Animal transfer, AP = Animal products, AV = Ammonia volatilisation, L = Leaching, P.U. = Pasture utilisation, Excretal N = Percentage of excretal N deposited on each slope category in that paddock.	223
Fig. 7.4	N Balances for hill country paddocks with different excretal distributions. Values are kg N/ha/yr. Pasture DM production, proportion of clover in herbage and N concentration in herbage were as for the north aspect paddock in Table 7.1 A. F = N input by legume N fixation, non symbiotic fixation and atmospheric deposition, AT= Animal transfer, AP = Animal products, AV = Ammonia volatilisation, L = Leaching, P.U. = Pasture utilisation, Excretal N = percentage of excretal N deposited on each slope category in that paddock.....	224
Fig.7.5	N Balances for hill country paddocks with different pasture utilisations. Values are kg N/ha/yr. Pasture DM production, proportion of clover in herbage and N concentration in herbage were as for the north aspect paddock in Table 7.1 A. F = N input by legume N fixation, non symbiotic fixation and atmospheric deposition, AT = Animal transfer, AP = Animal products, AV = Ammonia volatilisation, L = Leaching, P.U. = Pasture utilisation, Excretal N = percentage of excretal N deposited on each slope category in that paddock.....	225

Fig. 7.6 N Balances for north aspect hill country paddocks under low P and high P conditions. Values are kg N/ha/yr. F = N input by legume N fixation, non symbiotic fixation and atmospheric deposition, AT = Animal transfer, AP = Animal products, AV = Ammonia volatilisation, L = Leaching, P.U. = Pasture utilisation, Excretal N = percentage of excretal N deposited on each slope category in that paddock.....227

Fig. 7.7 N Balances for south aspect hill country paddocks. Values are kg N/ha/yr. F = N input by legume N fixation, non symbiotic fixation and atmospheric deposition, AT = Animal transfer, AP = Animal products, AV = Ammonia volatilisation, L = Leaching, P.U. = Pasture utilisation, Excretal N = percentage of excretal N deposited on each slope category in that paddock.....228

LIST OF PLATES

Plate 3.1 Ammonia volatilisation measurement using chamber methods (Ball *et al.*, 1979; Theobald, 1983).....27

Plate 3.2 Ammonia volatilisation measurement using passive samplers (Carran *et al.*, 2000).....27