Impacts of intensive dairying on soil and pasture sustainability in Taranaki

C.G. ROACH[1] and J. D. MORTON[2]
[1]*Dexcel, Whareroa Research Centre, R.D. 12, Hawera*
[2]*AgResearch, Invermay Agriculture Centre, PB 50034, Mosgiel*
chris.roach1@xtra.co.nz

Abstract

The intensification of dairying can have adverse impacts on the environment through diminished soil quality and greater loss of nutrients to water bodies. Poor soil quality can reduce the productivity and sustainability of pastoral farming systems. The effects of increased stocking rate (SR) (3, 4 and 5 cows/ha) and introducing a cut and carry system on soil, pasture and water quality were compared with a pasture fallow on an Egmont Allophanic soil in South Taranaki over three years. Soil nutrient and organic matter (OM) levels were not affected by the treatments imposed and were maintained in the ranges for adequate plant growth by the application of fertiliser (grazing) or farm dairy effluent (cut and carry). Macroporosity in the top 5 cm of soil was greater for the fallow treatment (31-37%) than the other treatments (cut and carry 20-25%; grazing 17-21%). Treading damage as indicated by soil surface roughness only increased with SR in one winter grazing when the soil was saturated. The management treatments had no significant effect on annual pasture production. Ryegrass content significantly increased with grazing and higher SRs and there was more dead material in the fallow treatment. Pasture chloride (Cl), potassium (K), nitrogen (N) and phosphorus (P) contents were significantly lower in the fallow treatment and pasture K content significantly lower in the cut and carry treatment than in the grazing treatments. The leaching loss of calcium (Ca) was significantly lower in the fallow treatment in 2003, and in 2004, the rate of magnesium (Mg) leaching increased in the grazing treatments. Nitrate-N leaching losses were low (average 5 kg/ha/yr) but in the 2004 drainage season were significantly higher in the fallow compared with the cut and carry and grazing treatments. Overall it could be concluded that the more intensive management had no adverse effect in the short term on the sustainability and quality of soil, pasture and groundwater.

Keywords: dairying, nutrient leaching, nutrients, pasture, soil macroporosity, sustainability

Introduction

In a predominantly commodity market where the inflation adjusted prices for dairy products have declined slowly over time, dairy farmers have maintained their profitability by acquiring more land or increasing production on their existing farm. One of the intensification strategies used by some farmers has been to increase SR up to 6 cows/ha on the milking platform and bring in supplements to adequately feed the animals. An estimated 40% of New Zealand's dairy production is from pasture grown on Allophanic soils in Taranaki and Waikato (LIC 2003). These ash-derived soils are naturally well structured which allows free drainage and at normal SRs of 2-3 cows/ha, provides resilience from cow treading causing soil compaction. On 10 dairy farms in the Waiokura catchment in South Taranaki, soil macroporosity ranged from 6-22% in 2001 and 2003 (Betteridge *et al*. 2005). Drewry *et al*. (2002) reported that at 5-10 cm soil depth, a unit increase in macroporosity up to 20% was associated with a 1.8% increase in pasture production. Soil physical properties of an Allophanic soil on a Waikato dairy farms were found to have declined as a result of animal treading by Singleton & Addison (1999).

High nitrate-N and ammonium-N concentrations in ground and surface water have potential detrimental effects on human health and fish survival. Leaching of dairy cow urine has been shown to be a major contributor to this contamination (Ledgard *et al*. 1999). In recent years, fundamental questions have been raised about the sustainability of intensive pastoral grazing systems and high SRs that are characteristic of many dairying regions. Therefore a trial was established to determine the short term effects of dairy cow SRs on key pasture and soil parameters compared with non-grazing systems and hence assess the sustainability of current and future farm practice.

Materials and methods

Site and design

In spring 2002, the following five treatments were allocated to four replicate 0.1 ha grazing plots at the Whareroa Research Dairy Farm near Hawera in South Taranaki:

1 Fallow – ungrazed and uncut with no fertiliser applied.
2. Cut and carry – ungrazed with pasture mown and removed at similar times as grazing of Treatments 3-5. Farm dairy effluent was applied to replace the nutrients removed.
3-5 Grazed at the equivalent of 3, 4 and 5 Friesan/Jersey cows/ha with silage fed to cows in Treatments 4 and 5 to maintain feed intakes at a

similar level to Treatment 3. Fertiliser application of 700 kg 30% potassic superphosphate/ha was applied in October of each year to maintain soil test levels.

The trial was sited on a gently undulating Egmont Allophanic soil and the pasture was composed of predominantly ryegrass with small proportions of cocksfoot and white clover.

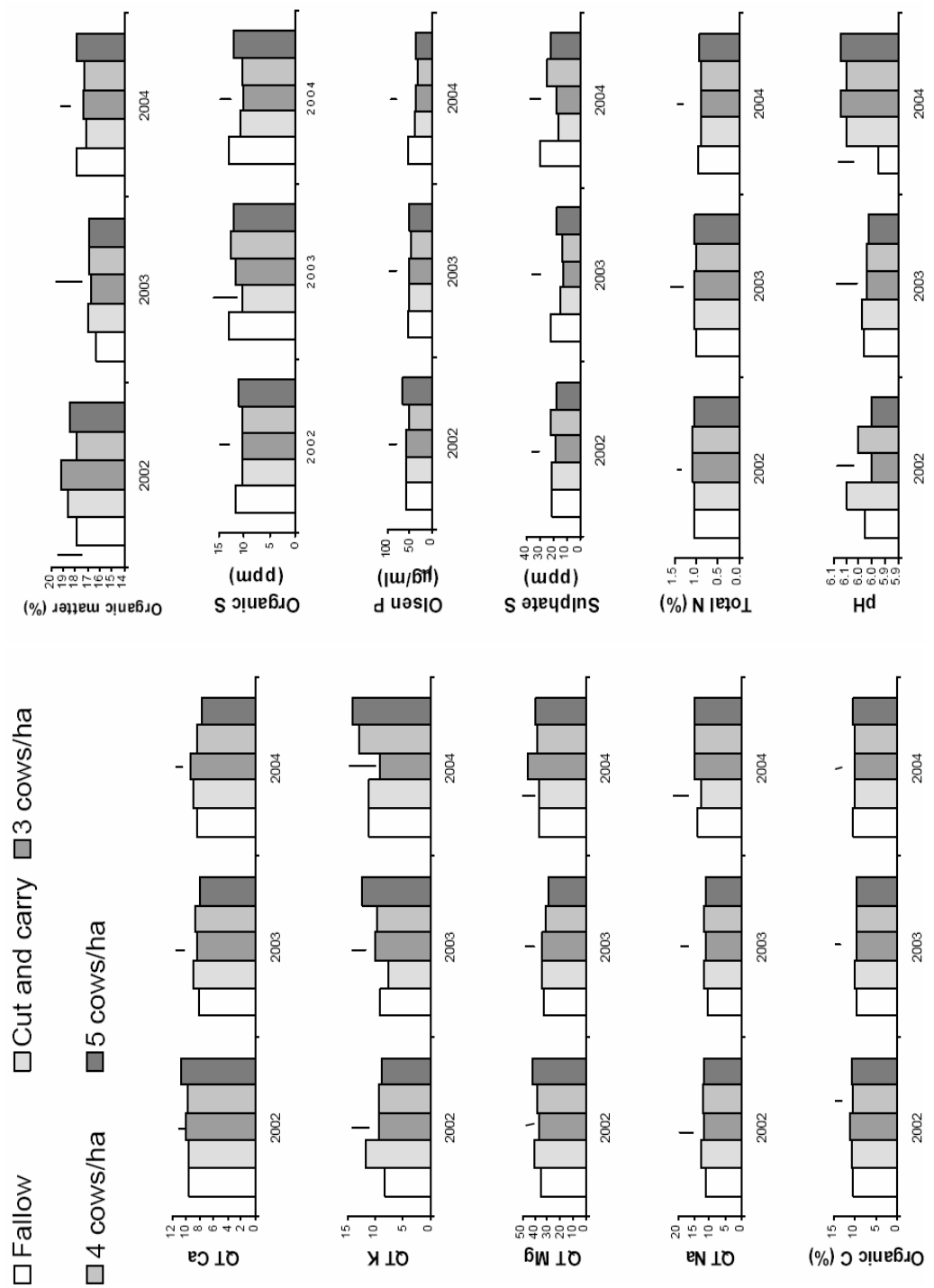

Figure 1 Effect of management treatment on soil nutrient and OM levels for each year. Bars indicate LSD (P<0.05).

Table 1 Effect of management treatment on soil macroporosity (%v/v).

Treatment	Fallow	Cut and carry	3 cows/ha	4 cows/ha	5 cows/ha	LSD (P<0.05)
2003	31.88	20.80	17.38	17.00	17.73	5.04
2004	36.95	24.60	18.43	20.35	19.95	4.27

Management

The plots in Treatments 2-5 were grazed or mown at 3-4 weekly intervals from August-May when pasture mass reached 2500-3000 kg dry matter (DM)/ha. Each plot in Treatments 3-5 was grazed by 6-50 cows (depending on rotation length) for 24 hours to leave a residual pasture mass of 1200-1600 kg DM/ha. Post-cutting pasture masses in Treatment 2 were similar to post-grazing pasture masses in Treatments 3-5.

Measurements

Soil

Twenty soil cores were sampled to a depth of 75 mm from each plot in November 2002, 2003 and 2004 and analysed for pH, Olsen P, quick test (QT) K, Mg, Ca, sodium (Na), total N, organic carbon (C), OM and sulphate-sulphur (S). In November 2003 and 2004, twenty soil cores of 50 mm diameter were sampled to a depth of 50 mm from each plot and macroporosity measured from the central third of each core (Drewry *et al*. 2002). Surface roughness as an indicator of soil treading damage was assessed from each plot pre- and post-grazing for one event in each season using the chain method (Saleh 1993).

Pasture

Pre- and post grazing pasture DM mass was assessed by rising plate meter, using the standard calibration equations for dairy pastures (Thomson *et al*. 2001). Just prior to one grazing in each season, 20 pasture sub-samples were cut from each plot at grazing level and bulked so that pasture composition (% ryegrass, other grasses, white clover, weeds and dead material) could be measured. This dried sample was then used to measure the content of N, P, K, Mg, Ca, Na, S and Cl in the pasture.

Leachate

Eight ceramic cups were randomly placed at 1 m depth in each plot and leachate sampled to measure the loss of nitrate-N, ammonium-N, K, Mg, Ca, Na, S and Cl in every 40-50 mm of drainage. Drainage volume was determined by measuring drainage from seven lysimeters of 30 cm diameter and 50 cm depth containing undisturbed soil columns.

Statistical analysis

Analysis of variance was used to detect significant differences between treatments, using plots as the basis for comparison. Nitrate-N leaching rates were log transformed to reduce the variability caused by urine patches.

Results

Soil

Soil chemical and biological properties

There were no significant differences (P<0.05) between treatments that were consistent over the three years of research, or apparent trends between years (Figure 1).

Macroporosity

In both years, soil macroporosity for the fallow treatment was significantly higher (P<0.05) than the cut and carry and grazing treatments (Table 1). One year following the imposition of treatments (2003), no significant differences had developed between the cut and carry and grazing treatments. The cut and carry treatment had significantly higher macroporosity than the grazing treatments in 2004, with no significant differences between SRs. Soil macroporosity for the site, measured in spring 2002, before the treatments were imposed, was 14%.

Surface roughness

There was a significant increase (P<0.05) in surface roughness pre- and post-grazing (change) from 3 compared with 5 cows/ha in spring 2003, from 3 compared with 5 cows/ha in winter 2004 and from 4 compared with 3 and 5 cows/ha in spring 2004 (Table 2).

Pasture

Pasture production

There were no significant differences in annual pasture production (P<0.05) between any of the management treatments (Table 3).

Pasture composition

Ryegrass content showed a significant decrease (P<0.05) in the fallow treatment compared with all others and in the cut and carry treatment compared with the 4 and 5 cows/ha grazing treatments (Figure 2). In 2003/2004, the fallow and cut and carry treatments had a significantly greater content of other grasses compared with all the grazing treatments and in 2004/2005 compared with 5 cows/ha. The fallow treatment had a

Figure 2 Effect of management treatment on pasture composition in each year ((A) 2002/2003, (B) 2003/2004, (C) 2004/2005). Bars indicate LSD (P<0.05).

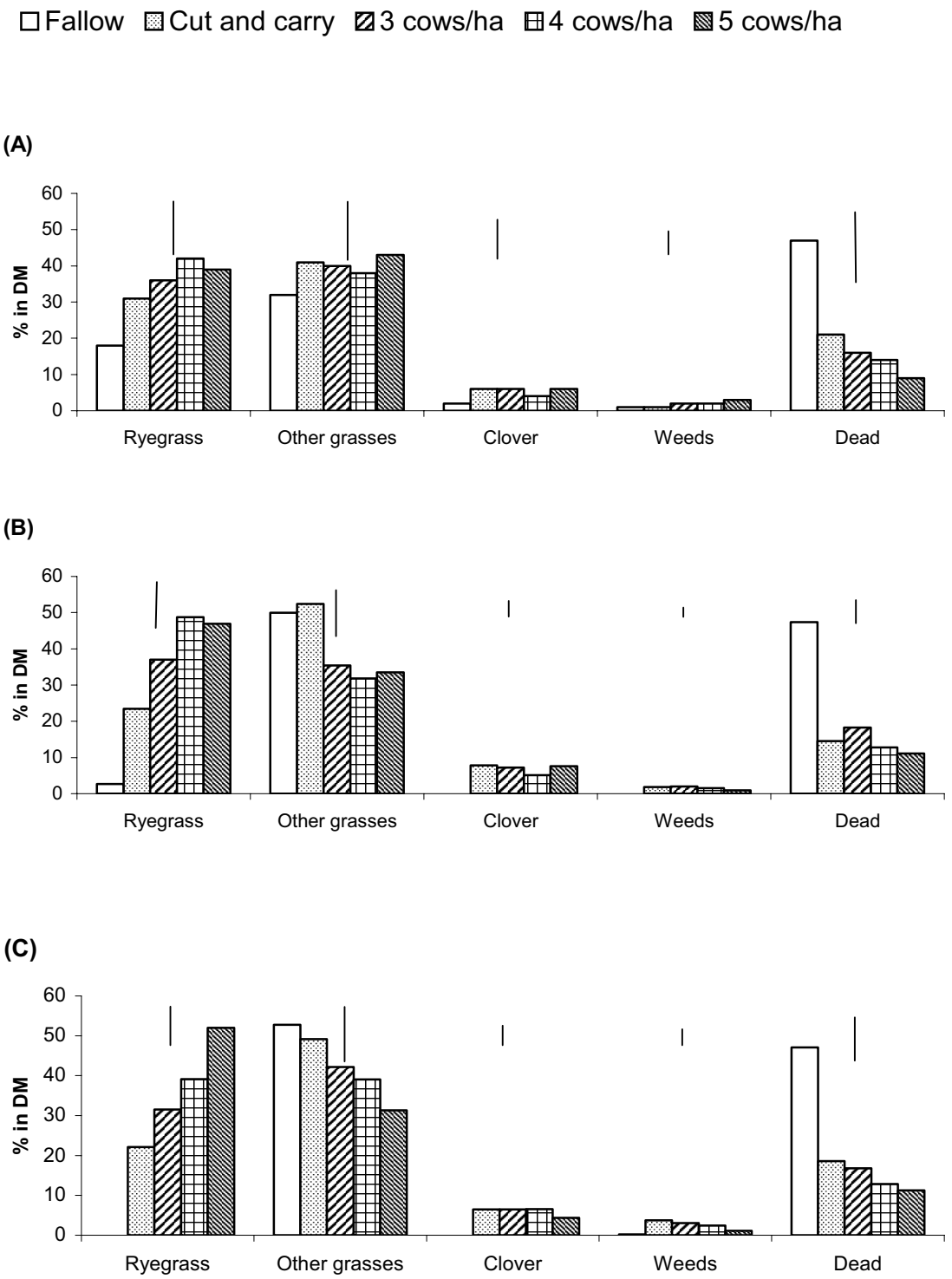

Table 2 Effect of management treatment on soil surface roughness (0-10 increasing scale).

Treatment		Fallow	Cut and carry	3 cows/ha	4 cows/ha	5 cows/ha	LSD (P<0.05)
Season	Grazing						
Spring 2002	Pre-	1.93	1.00	1.35	1.25	1.05	0.69
	Post-			1.83	1.43	1.85	0.73
	Change			0.48	0.18	0.80	1.23
Summer 2002/2003	Pre-	1.80	0.95	1.43	1.23	1.18	0.52
	Post-			1.78	1.70	1.75	0.62
	Change			0.35	0.47	0.57	0.85
Autumn 2003	Pre-	1.74	0.85	1.45	1.37	1.27	0.49
	Post-			1.42	1.57	1.52	0.37
	Change			-0.03	0.20	0.25	0.53
Winter 2003	Pre-	2.50	0.99	2.59	2.64	2.74	0.52
	Post-			3.32	3.55	3.58	0.32
	Change			0.93	0.91	0.84	0.43
Spring 2003	Pre-	2.72	3.26	4.29	4.25	4.97	0.52
	Post-			4.80	4.71	4.95	0.64
	Change			0.51	0.46	-0.02	0.52
Summer 2003/2004	Pre-	2.10	0.798	1.25	1.29	1.38	0.16
	Post-			1.55	1.53	1.65	0.35
	Change			0.30	0.24	0.27	0.28
Autumn 2004	Pre-	1.74	0.92	1.38	1.42	1.39	0.48
	Post-			1.52	1.55	1.58	0.55
	Change			0.14	0.13	0.19	0.65
Winter 2004	Pre-	2.58	1.18	2.55	2.55	2.82	0.60
	Post-			6.67	8.52	10.18	1.89
	Change			4.12	5.97	7.34	2.29
Spring 2004	Pre-	1.78	1.03	1.92	1.92	1.88	0.41
	Post-			3.07	3.00	3.22	0.22
	Change			1.15	2.08	1.34	0.47
Summer 2004/2005	Pre-	1.58	0.97	1.64	1.73	1.73	0.49
	Post-			1.45	1.45	1.32	0.27
	Change			-0.20	-0.28	-0.41	0.33

Table 3 Effect of management treatment on annual pasture production (kg DM/ha).

Treatment	Cut and carry	3 cows/ha	4 cows/ha	5 cows/ha	LSD (P<0.05)
2002/2003	10747	10793	10576	11083	2162
2003/2004	14241	13796	14419	14540	1670
2004/2005	11891	12230	11604	11774	1968

significantly greater content of dead material than the other treatments in all three years.

Pasture mineral content

The pasture in the fallow treatment had a significantly lower content of Cl, K, N and P (P<0.05) than the other treatments in most seasons (Figure 3). The grazing treatments had a significantly higher K content than the cut and carry treatment in all seasons except spring.

Leachate

In 2003, apart from the greater loss of Ca from the fallow treatment, there were no significant differences in nutrient leaching loads (P<0.05) between treatments (Table 4). In 2003 and 2004, the load of Cl leached was significantly greater from the fallow than the cut and carry treatment and the 4 cows/ha grazing treatment respectively. The load of Mg leached was also significantly greater from the grazing treatments and the load of nitrate-N leached was significantly greater from the fallow treatment in 2004.

Discussion

Although this paper only reports on the short term, three year changes, the results provide an assurance that there is no immediate rapid decline in the quality of soil, pasture and water when the commonly practised dairy system (3 cows/ha, all grass) is intensified.

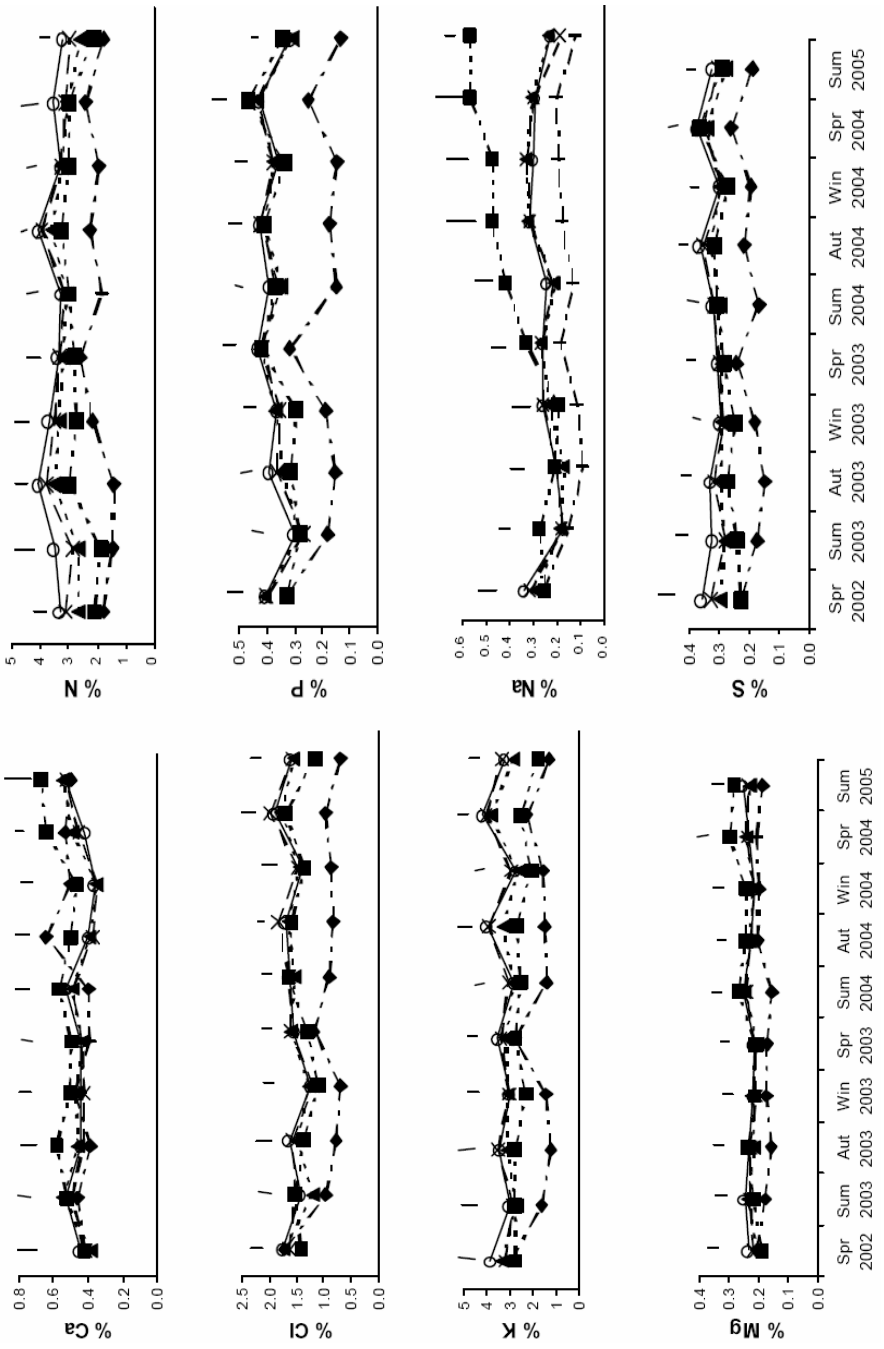

Figure 3 Effect of management treatment on pasture mineral content for each season. Bars indicate LSD (P<0.05).

Soil nutrient levels required for maintenance of pasture production in the grazing treatments were maintained in the adequate range (Roberts & Morton 1999) by the application of fertiliser and those in the cut and carry treatment by the application of farm dairy effluent. The input of nutrients in silage and the greater return of animal excreta to the higher stocked treatments may be expected to slowly increase soil nutrient levels in the longer term while the even return of effluent to the cut and carry treatment compared to the uneven return in excreta may have the same effect. The lack of change in soil organic matter and organic C and S was expected because of the presumed steady state condition of the soil. Soil macroporosity was greater in the fallow treatment and in

Table 4 Effect of management treatment on nutrient leaching losses (kg/ha).

Treatment	Fallow	Cut and carry	3 cows/ha	4 cows/ha	5 cows/ha	LSD (P<0.05)
2003						
Ca	83.03	74.48	63.81	49.93	49.86	20.49
Cl	217.66	185.47	169.28	157.74	153.39	52.45
K	6.39	23.70	6.04	20.52	9.28	22.80
Mg	17.24	15.00	22.93	16.87	21.23	4.20
Na	54.60	54.86	60.79	62.48	54.25	17.64
S	34.84	41.44	39.60	39.42	38.08	7.39
Nitrate-N	1.63	9.38	13.31	3.19	1.74	13.06
Org + ammon-N	5.59	7.97	4.66	5.20	4.06	2.62
2004						
Ca	92.25	65.16	73.65	74.95	83.77	22.50
Cl	174.84	82.66	155.13	182.37	202.96	47.77
K	13.30	22.56	7.71	28.19	17.11	27.88
Mg	16.42	14.63	26.38	26.24	34.29	6.34
Na	91.96	57.98	75.16	87.91	84.89	20.68
S	58.50	56.50	48.50	46.75	45.75	12.06
Nitrate-N	13.87	1.21	4.27	2.12	4.81	9.19
Org + ammon-N	6.30	4.08	4.63	4.30	4.88	2.13

the cut and carry treatment at the second measurement because of the absence of treading by animals and was not affected by SR because the cows generally grazed the pastures when the soils were not saturated. Furthermore ash-derived soils being very well drained, tend to dry out rapidly after rainfall events and are generally resilient to treading damage. The exception to this was in the winter 2004 grazing where there was more treading damage as SR increased from grazing wet soils as indicated by the change in soil surface roughness during grazing. Soil macroporosity was in the upper range of that measured on commercial farms in a nearby catchment in South Taranaki (Betteridge *et al*. 2005).

Because none of the parameters that influence pasture production were greatly affected by the management treatments, the lack of difference in pasture production was not surprising. The increase in ryegrass content with SR indicated either that there was greater efficiency of N cycling and/or the cutting regime adversely affected the growth of ryegrass. The lower mineral content of the pasture in the fallow treatment could be attributed to the greater maturity of the plants (Wallace 1961). Less efficient cycling of N in the cut and carry treatment was not supported by the measurements of N content in pasture but there was an indication from lower pasture K content of less efficient cycling of K. Pasture mineral contents were all in the optimum ranges for pasture production (Cornforth & Sinclair 1984) commensurate with the high soil nutrient status.

Apart from Mg, results did not support the hypothesis of greater leaching losses as SR increased, but in this case the increase in stocking rate was not associated with an increase in N fertiliser application. Leaching losses of nitrate-N were much lower than in other studies on Allophanic soils (Ledgard *et al.* 1999) but the period of leachate measurement was too short for drainage to be completed and definite conclusions be derived from the results.

Conclusions

Changes in management from the standard 3 cows/ha grazed all year round to higher SRs had no effect on the soil, pasture and leachate parameters measured over a 3-year period. Removing the effect of grazing animals in a cut and carry system and hence potentially improving soil physical properties and decreasing leaching losses from excreta patches also had no measurable effect. A pasture fallow treatment decreased the effect of soil compaction compared with animal treading.

ACKNOWLEDGEMENTS

Bruce Thorrold and Ants Roberts for initiating the project, Whareroa Research Centre farm staff for managing stock and Barbara Dow for statistical analysis. Funding was provided by the Dairy Industry, FertResearch and Taranaki Regional Council.

REFERENCES

Betteridge, K.; Wilcock, R.; Costall, D.; Shearman, D.; Roach, C.G. 2005. Impacts of dairy intensification on stream-water quality in a South Taranaki catchment. In *Developments in fertiliser application technologies and nutrient management.* (Eds L.D. Currie and J.A. Hanly). Occasional Report No. 18. Fertilizer and Lime Research Centre, Massey University, Palmerston North. pp 141-150.

Cornforth, I.S.; Sinclair A.G. 1984. Fertiliser recommendations for pastures and crops in New

Zealand. Ministry of Agriculture and Fisheries, Wellington.

Drewry, J.J.; Littlejohn, R.P.; Paton, R.J.; Singleton, P.L.; Boyes, M.; Judge, A.; Monaghan, R.M.; Smith, L.C. 2002. Dairy pasture yield responses to macroporosity and soil physical properties, and variability of large and small samples. In: *Dairy farm soil management.* (Eds L D Currie and P Loganathan). Occasional report No. 15. Fertilizer and Lime Research Centre, Palmerston North. pp 61-78.

Ledgard, S.F.; Penno, J.W.; Sprosen, M.S. 1999. Nitrogen inputs and losses from clover/grass pastures grazed by dairy cows, as affected by nitrogen fertilizer application. *Journal of Agricultural Science, Cambridge 132*: 215-225.

LIC 2003. *New Zealand Dairy Statistics 2001-2002*. Livestock Improvement Corporation, Hamilton,

Roberts, A.H.C.; Morton, J.D. 1999. Fertiliser use and soil fertility on dairy farms. DRC/FertResearch/ AgResearch. 38 pp.

Saleh, A. 1993. Soil roughness measurement: chain method. *Journal of Soil and Water Conservation 48*: 527-529.

Singleton, P.L.; Addison, B. 1999. Effects of cattle treading on physical properties of three soils used for dairy farming in the Waikato, North Island, New Zealand. *Australian Journal of Soil Research 37*: 891-902.

Thomson, N.A.; Upsdell, M.P.; Hooper, R.; Henderson, H.V.; Blackwell, M.B.; McCallum, D.A.; Hainsworth, R.J.; MacDonald, M.A.; Wildermoth, D.D.; Bishop-Hurley, G.J.; Penno, J.W. 2001. Development and evaluation of a standardised means for estimating herbage mass of dairy pastures using the rising plate meter. *Proceedings of the New Zealand Grassland Association 63*: 149-157.

Wallace, T. 1961. The diagnosis of mineral deficiencies in plants. Her Majesty's Stationary Office, London, UK.