The effect of withholding winter grazing from summer cropped paddocks in Hawke's Bay on soil quality

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Abstract

Soil structure degradation is a major issue facing cropping farmers. Many mitigation techniques apply to management over the cropping season, but little has been done on the regenerative phase of the crop cycle, the winter grass period. A three-year experiment in Hawke's Bay compared soil quality and subsequent crop yields in plots either winter grazed with sheep or with stock excluded. Incorporation of greater levels of pasture biomass in the ungrazed plots did not affect soil nutrient status or subsequent crops. Soil bulk density and aggregate stability improved where stock was excluded but this benefit was negated by spring cultivation. The most immediate impact of grazing stock over the winter was an increased soil mineral N level and therefore a greater risk of N leaching.

Additional key words: soil management, nitrate leaching, cover crops, treading

Introduction

Land use on the Heretaunga Plains of Hawke's Bay has a history of increased intensification. Currently the predominant land use is permanent horticulture (orchards and vineyards) and cropping (vegetable and arable). Many paddocks on the Heretaunga Plains have now been cropped for over 30 years, and there are very few uncultivated pasture paddocks.

Soil structure degradation is a major issue facing cropping farmers. Recent studies (e.g. Reid *et. al*., 2001) showed how soil degradation can cost growers in term of crop yield and therefore income. Most suggestions for improving soil structure apply to management over the cropping season, but little work has been done on the regenerative phase of the cropping cycle, the winter grass period.

Detrimental effects of winter grazing are visually evident as loss of vegetation cover, burial of plants and damage to plant roots, ponding of water on the soil surface and gleying in the 0-5 cm soil depth. In a cropping situation, some of these effects may be offset by cultivation the following spring. The long-term effects of winter grazing in a cropping cycle on soil quality are unknown.

This project investigated the effects of winter grazing of summer cropped paddocks on soil quality and subsequent crop yields over three years.

Materials and Methods

A three-year experiment was established in May 2000 in a paddock (soil type Meeanee silt loam formed on lagoon deposits), which, was used for long term (> 15 years) commercial summer crop production in Hawke's Bay. The paddock had been recently re-grassed following a summer crop with annual ryegrass (*Lolium multiflorum* Lam.) (c.v.

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Moata). Two treatments were applied to ten plots (each 30 m x 30 m), in a randomised block design with five replicates. Treatments were applied to the same plots for three consecutive winters. The treatments were:

1. Winter grazed (by lambs at a set-stocking rate of 16 SU ha^{-1})
2. Grazing withheld (by fencing off the plots from stock).

Following removal of the stock in early spring 2000, the paddock was cultivated (disc, plough and power harrowed) for a summer crop. After harvest of the summer crop in autumn 2001, the paddock was cultivated and re-grassed with annual ryegrass for grazing over winter 2001. A similar crop sequence was used the following year.

Soil measurements

A range of soil measurements was taken from each plot at the start and end of each winter. Twenty five soil cores (2.5 cm diameter, 15 cm depth) were collected $plot^{-1}$, combined and tested for:

- Soil nutrient status (pH, Olsen P, exchangeable cations as tested by a commercial laboratory using the methods of Blakemore *et. al.*, 1987) and potentially mineralisable N (Keeney and Bremner, 1966)
- Organic carbon and nitrogen (N) by LECO (Sheldrick, 1986)
- Microbial biomass carbon (Vance *et al.*, 1987)
  Five large cores (8 cm diameter, 15 cm depth) were collected $plot^{-1}$ and tested for
- Aggregate stability (Kemper and Rosenau, 1986)
- Soil bulk density (Blake and Hartge, 1986) cores were split into 0-5 cm, 5-10 cm and 10-15 cm depths for samples collected at the end of winter 2002 only. All other bulk density measurements were made on 15 cm cores.

Soil leachate nitrate concentration (collected in ceramic cups 60 cm and 30 cm) was measured in all three winters using the method of Francis *et al.* (1998). Samples were collected when a rainfall event exceeded 10 mm. At the end of the third winter, five soil cores were collected and bulked $plot^{-1}$ at four depths (0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm) and tested for mineral N (nitrate and ammonium).

Plant measurements

At the end of each winter, grass biomass (kg DM ha^{-1}) was assessed from five 1 m^2 ground-cut quadrats $plot^{-1}$. Grass samples were bulked $plot^{-1}$, washed and submitted to a commercial laboratory for plant tissue analysis and dry matter content determination.

Crop yield of the subsequent summer crop was assessed just prior to commercial harvest. The method of yield assessment depended on the crop, but involved at least three hand-harvested yield assessments $plot^{-1}$. The crop sequence for the paddock over the duration of the trial is shown in Table 1.

Table 1. Crop sequence for trial paddock.

Year	Autumn sown winter crop	Spring sown summer crop
Winter 2000 and Summer 2000-01	Annual ryegrass	Sweet corn
Winter 2001 and Summer 2001-02	Annual ryegrass	Sweet corn
Winter 2002 and Summer 2002-03	Annual ryegrass	Process tomatoes

Statistical methods

Statistical interpretation was by Analysis of variance (ANOVA), using Genstat version 8.2 (Lawes Agricultural Trust, 2005).

Results

As many of the variables measured change slowly in response to the treatments imposed, only the results from year three are reported. Data from other years will be reported only where relevant.

Winter grass biomass yield and dry matter content

Due to time constraints in year 3 (Winter 2002), pasture measurements were only conducted in the ungrazed plots. Cuts were made to the same level as the grazed plots, so the figure for year three represent the differences between treatments, rather than total biomass yield for that treatment.

The difference between grazed and ungrazed treatments differed among years (Table 2). In year 2 ungrazed pasture had a higher proportion of leafy green pasture in the sward compared with the grazed pasture (shorter and stalkier), hence the lower dry matter percentage. There were no consistent effects of grazing on pasture nutrient content (data not shown).

Table 2. Pasture biomass at the end of each winter.

	2000		2001		2002	
	Kg DM ha^{-1}	DM %	Kg DM ha^{-1}	DM %	Kg DM ha^{-1}	DM %
Grazed	2,462	17.7	1,829	23.5	-	-
Ungrazed	5,077	18.5	4,028	12.4	6,455	18.7
Significance	< 0.01	NS	< 0.01	< 0.001		
$LSD_{0.05}$	1,070		809	3.2		

As our trial paddock was set-stocked, pasture growth rates could not be measured. These are often reduced with increased grazing intensity due to direct burial, plant losses and root damage. Indirect effects of soil physical degradation on pasture production have been noted by Drewry and Paton (2000).

Summer crop yields

There was no significant difference in sweet corn (*Zea mays* L.) crop yield in the first two years of the study (average yield 27 t ha^{-1}). Process tomato (*Lycopersicon esculentum* Mill.) yields were not measured in year 3 (2002-03).

Incorporation of high levels of biomass, prior to sowing spring crops, can immobilise N and reduce crop yield (Francis *et al.*, 1998). Low fertiliser N rates can overcome short-term N deficiencies caused by decomposition of winter pasture. The sweet corn crops received adequate N fertiliser (150 kg N/ha).

Soil chemical and biological indicators

There was no treatment effect on any of the soil chemical indicators measured. At the end of the final winter (2002), soil nutrient tests (0-15 cm) gave the following results; pH 7.7, Olsen phosphorus 26 µg/ml, calcium 17.8 me/100g, potassium of 0.62 me 100 g^{-1} and cation exchange capacity of 21 me 100 g^{-1}.

After three years, soil organic carbon (0-15 cm, 2.01 % C) and total N (0.22 %N) were unaffected by winter grazing management. The additional pasture incorporated into the soil over the three winters was therefore not enough to significantly affect soil organic matter. Microbial biomass carbon (0-15 cm) was also unaffected (460 ppm) although increases, observed in stock camps, have been attributed to increased soil enzyme activity (Haynes and Williams 1999).

Soil physical indicators

Withholding grazing over the winter improved soil aggregate stability (0-15 cm) in two of the three years of the study (data not shown). Aggregate stability at this site is very low (MWD = 0.4mm), probably due to the saline nature of this soil.

In all three years grazing stock increased soil bulk density (Table 3). However, subsequent cultivation for the summer crop eliminated any treatment effect (data not shown). The impact of stock grazing on soil bulk density was clearer in the top 5 cm of the soil than below this depth (data not shown).

Table 3. Effect of winter grazing on soil bulk density (g cm^{-3}, 0-15 cm) measured at the end of winter

	Winter 2000	Winter 2001	Winter 2002
Grazed	1.27	1.34	1.32
Ungrazed	1.23	1.27	1.25
Significance	< 0.05	< 0.1	< 0.05
$LSD_{0.05}$	0.03	0.09	0.05

An effect of stock treading on soil bulk density has been observed by a number of researchers although most conclude that soil macroporosity is a more sensitive indicator of treading damage than bulk density (Climo and Richardson, 1984; Drewry and Paton, 2000).

Nitrate leaching and soil nitrate concentration

In all three winters the nitrate concentration in drainage water (leachate) was highly variable. There was no effect of grazing on nitrate concentration in leachate collected at either 30 or 60 cm depth (data not shown).

Grazing significantly increased the amount of soil nitrate at the end of winter 2002 (Table 4). The greatest difference between treatments ($p < 0.1$) was observed in the topsoil (0-15 cm). There were no differences below this depth. In all treatments soil nitrate decreased with depth (Table 4). It is notable that these levels of soil nitrate are low.

Excluding stock generally decreases soil mineral N levels, which reduces the risk of N leaching (Francis *et al.*, 1998), although pasture production can be affected when soil mineral N is reduced (de Klein and Ledgard, 2001).

Conclusions

Incorporation of greater amounts of pasture into the soil at the end of winter did not, in this three-year study, affect soil nutrient status, organic matter or subsequent crop yields. Cultivation negated the beneficial effects of excluding stock on soil physical properties. The most immediate impact of grazing cropping paddocks over winter is an increase in soil mineral N and nitrate leaching risk.

Table 4. Soil nitrate concentration (ppm) at the end of winter 2002.

Soil depth	Grazed	Ungrazed	Depth average
0-15	4.5	3.3	3.9
15-30	3.3	3.0	3.2
30-45	2.6	2.2	2.4
45-60	2.3	2.1	2.2
Treatment average	3.2	2.6	2.9
Treatment	$p < 0.05$, LSD = 0.5		
Depth	$p < 0.001$, LSD = 0.6		
Treatment x depth	NS, LSD = 0.9		

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