MANAGING WINTER FORAGE CROPS SUSTAINABLY

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INTRODUCTION

The NZ dairy industry's goal is to increase productivity by 4% per annum. Growth at this rate is not possible with pasture production alone and increased use of supplementary feed (including winter green feed crops) is anticipated. Well grown forage crops (brassicas and cereals) provide high yielding, high quality standing green feed suitable for wintering, and as a supplement to pasture in early lactation. However, there are issues around the utilisation, environmental impact, and sustainability of growing such crops.

Whether crops are planted on the milking platform or on a support block, it is critical to grow them well. For the same level of inputs, dry matter yield can vary significantly. A well managed crop can produce double the yield of a poorly grown crop. If crops are managed effectively, the required dry matter can be grown at half the cost and on half the land area (an important consideration, particularly if they are being grown on the milking platform). Whilst the technology to produce high yielding crops is well known, less is known about utilising them efficiently and producing them sustainably.

Growing, and more particularly utilising, green feed crops in the winter creates a number of environmental risks and sustainability concerns which cannot be ignored. Intensive grazing of forage crops during wet winter conditions is conducive to poor utilisation and long-term damage to soil quality with consequent effects on the productivity of the following crops or pasture. Nutrient losses (particularly N and P) from winter crops are also are a concern and have been identified as a key priority in the recently released Dairy Industry Strategy for Sustainable Environmental Management.

This paper summarises forage crop options and potential production across different areas of the South Island. We present what is currently known about the effects of grazing on soil quality and consequent productivity, and discuss options to maximise utilisation and minimise adverse soil quality and environmental impacts. We also identify a number of knowledge gaps and make recommendations for further research.

WINTER FORAGE CROP OPTIONS

Brassicas and cereals are the main crops suitable for winter grazing, and there are several options within these groups. Other crop-based supplementary feeds for use in winter include various cut, store and carry options such as silage, hay and baleage, most of which are based on cereal crops.

Brassicas

Brassicas comprise the largest area of cultivated crops in NZ, with well over 250,000 ha grown annually to supplement NZ's pastoral systems. About 30% of the area is utilised by dairy cows, with much of this as winter crops (mainly kale and, to a lesser extent, swedes) in the South Island. Brassicas are important for their potential to produce high yields of high quality forage and for their role as break crops during pasture renewal.

Kale and swedes are usually planted in late spring and, if well managed and weather conditions are favourable, they have the potential to produce very high yields for winter grazing. For example, in the past 3 years, 20 to 25 t DM/ha of kale have been produced consistently in Canterbury trials. Growth rates averaged over 320 kg/ha/day during peak growth in mid-summer. Similarly, some of the best swede crops in Southland produce over 20 t DM/ha.

However, actual yields of winter brassicas are usually well below their potential levels. Swede yields in Southland typically range from about 5 to 20 t DM/ha, with a few good crops a little higher. Results from recent kale fertiliser response trials around NZ illustrate the variability of yields, with a range from 4.1 to 19.1 t DM/ha (Table 1). There are many causes of low brassica yields. Common ones are poor crop establishment, pest problems, water deficit, low soil quality and inadequate fertiliser applications. Fertiliser response trials show that yield often responds strongly to fertiliser application (especially N and P) (Table 1). However, they also show that nutrient availability is only part of the story, because yields with fertiliser applied are also variable. The size of the response to fertiliser depends on soil fertility as well as all the other aspects of crop management. As with all crops, good, balanced management of all aspects is needed to ensure high yields.

Table 1: Kale yields in trials at eight locations in diverse climates with different levels of soil fertility, with and without N and P fertiliser applications.

Location	**Yield (t DM/ha)**		**Soil N and P fertility**	
	Without fertiliser	**With fertiliser**	**Available N (kg/ha)**	**Olsen P (mg/l)**
Te Awamutu	10.7	14.1	168	9.6
Lochinvar	4.1	6.1	118	24.0
Lincoln	14.2	19.1	61	11.5
Te Pirita	2.8	8.1	62	10.4
Te Pirita	5.1	13.3	65	10.7
Fairlie	6.5	14.7	126	30.9
Balfour	8.2	12.6	166	9.3
Drummond	12.7	14.2	231	11.0

Winter brassicas have a high demand for nutrients. For example, typical nutrient requirements of kale crops are shown in Table 2. Fertiliser applications should be managed to ensure adequate nutrient availability, from both soil and fertiliser, to achieve the expected yield of a crop. This can mean that substantial fertiliser applications are needed for crops with high yield potential, especially if soil fertility is low.

Table 2: Nutrient uptake by kale crops with yields ranging from 6 to 18 t DM/ha.

Yield (t DM/ha)	**Nutrient uptake (kg/ha)**			
	N	**P**	**K**	**S**
6	125	17	148	34
9	190	25	222	50
12	250	33	296	68
15	315	42	370	85
18	380	50	445	102

It is important to recognise that lifting the performance of brassicas has associated animal nutrition, crop utilisation, and environmental risks that need to be managed. The nutritional requirements and animal health issues associated with wintering cows on forage brassicas have been discussed by Nichol et al. (2003).

Achieving an optimum combination of high yield and nutritional value requires an appropriate balance between N and S. An imbalance, which sometimes occurs with N fertiliser application, can lead to high concentrations of undesirable N and S compounds (SMCOs [S-methyl cysteine sulphoxide] and glucosinolates) in brassica crops. These compounds can cause poor performance or harm animals. Accumulation of nitrates, which can be toxic to grazing animals at high levels, can also occur. Research is in progress to minimise the risk of adverse effects caused by fertiliser management. The other solution is to avoid grazing or to control grazing to restrict the amount of intake at times of higher risk.

The risk of losses by wastage during grazing is high in high-yielding brassica crops. Good grazing management, especially in the way the crop is allocated, is important to ensure efficient utilisation. However, this need can be at odds with the aim of minimising the risk of adverse environmental effects on soil quality and N losses during grazing. These risks are greater for brassicas than other crops, especially in wet climates, because of the combined effects of high yield, high N content, and the intensive grazing management needed for efficient utilisation.

Cereals

Autumn-sown forage cereals provide palatable green feed suitable for non-lactating cows in winter or cows in early lactation (Clark et al, 2000). Forage cereals are usually categorised as 'single-grazers' or 'multi-grazers'. Single-grazers, usually oats, are sown in early autumn and provide a single grazing of up to 6 t DM/ha in the June-July period. Multi-grazers (primarily triticale and ryecorn) can be grazed twice or more during the winter with careful management and then, in some cases, shut up for harvesting as green-chop silage in spring or whole-crop silage in December/January. Typically the multi-grazer crops are sown in March, then grazed in May and July/August to provide a cumulative yield of up to 5 t DM/ha during the winter. If managed well, a further 12 to 18 t DM/ha can be produced if the crops are taken to a whole-crop silage harvest.

In the South Island, cereal forages are grown mainly in the drier east coast regions. Their primary advantage over brassicas is that they are sown later so their growth period is shorter. While cereal crops produce substantially less winter forage than brassicas (Table 3), they are only in the ground for 5-6 months, including the less productive winter months, compared with up to 9 months for brassicas. Forage cereals are seldom used for winter grazing in Southland and the West Coast due to the difficulties of getting them established in good time, their lack of cold tolerance, and poor utilisation in very wet conditions. They do provide a useful option if spring-sown brassica crops fail to establish, and are commonly sown in Southland later in the autumn and harvested as green chop silage in spring. Figure 1 shows typical dry matter accumulation and quality changes for a single graze oat and the multi-graze triticale 'Doubletake'. Feed quality of cereal forages is similar to pasture until ear emergence in mid spring.

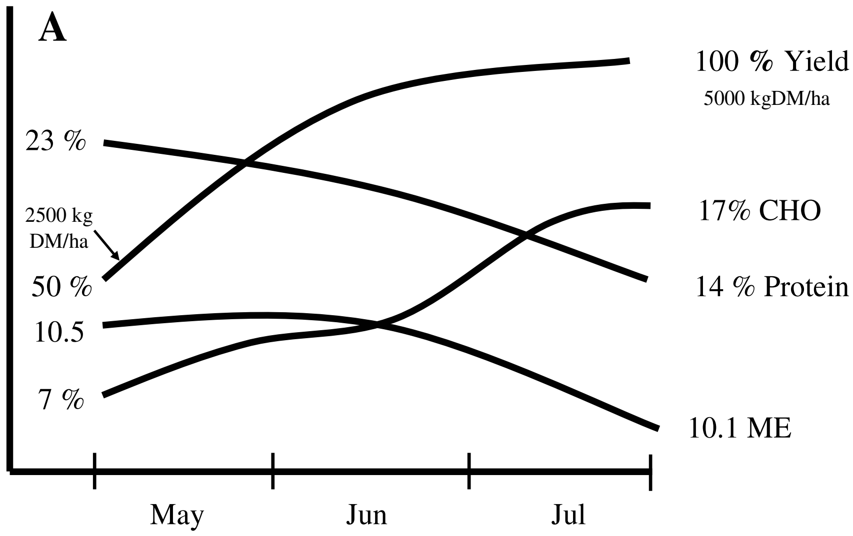
Table 3: Summary of forage cereal crop yields by crop type and location.

Crop type	Location	Yield range (mtDM/ha)	Comment
Oats	Culverden [1]	2.8 – 4.0	Dryland, sown March, harvest August [5]
	Lincoln [2]	8.0	Irrigated, sown March, harvest July [6]
	Methven [3]	3.8 – 4.4	Dryland, sown March, harvest July [7]
	Riverton [4]	1.5 – 2.9	Dryland, Sown April, harvest August [8]
Triticale	Culverden	2.8 – 5.0	Dryland sown March harvest August [5]
	Lincoln	4.2 - 4.9	Irrigated sown March, harvest May & July [7]
	Methven	3.4 – 4.7	Dryland sown March harvest July [7]
	Riverton	2.0 – 2.2	Sown April, harvest August [8]
Ryecorn	Lincoln	4.8	Irrigated sown March harvest May & July [7]
	Methven	4.0	Dryland sown March harvest July [7]
Italian ryegrass	Culverden	2.1 – 4.3	Dryland sown March harvest August [5]
	Lincoln	2.8	Irrigated sown March harvest June [7]
	Riverton	1.2	Sown April, harvest August [8]

[1] North Canterbury, [2] Central Canterbury, [3] Mid Canterbury, [4] Southland
[5] Hanson et al 2006, [6] de Ruiter et al 2002, [7] Unpublished 2005, [8] Unpublished 2001

Cut and carry crops

Cut and carry crops may provide a more sustainable option for the production of supplementary feed crops on poorly drained soil in winter wet climates such as Southland and the West Coast. Cut and carry crops are those that are harvested and fed out as silage, hay or baleage to livestock on a feed pad, in a "Herd Home" or in a sacrifice paddock. Effective systems for cut and carry feeding of brassica crops have not been developed in NZ, but it might be possible to adapt kaleage technology used in the UK and Ireland. Ultimately this might be the best solution if grazing brassicas during winter in wet conditions proves to be unsustainable. A discussion of the issues surrounding production and utilisation of high quality silage, hay and baleage feed is beyond the scope of this workshop.



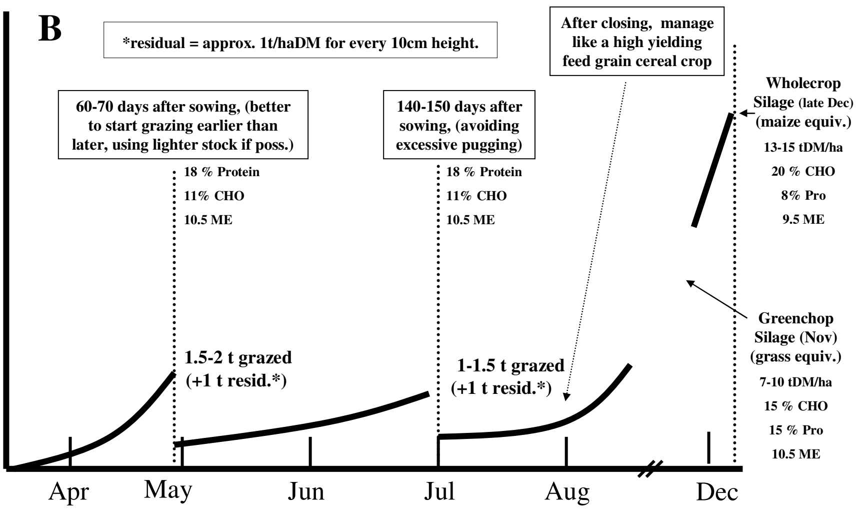


Figure 1: Typical yield and quality changes in (A) single-grazed forage oats and (B) a multi-graze and cereal silage triticale (cv Doubletake) crop (R Hanson, unpublished). Values not to scale.

One area of concern with whole crop removal is the replacement of nutrients exported from the production platform. At present there is little information on the amount of nutrients removed in different whole crops in Southland. However, trial results from Canterbury (de Ruiter 2002) showed that up to 200 kg N/ha and 170 kg K/ha can be removed in forage crop harvests (Table 4), whereas much lower amounts of P, Ca and S are removed. In this study, most of the differences in nutrient removal were due to differences in total dry matter production rather than differences in nutrient concentrations in the tissue. The cost of replacing the nutrients removed in whole crops for silage can be much greater than for grain (Table 5). As with brassica crops, fertiliser applications should be managed to ensure the availability of nutrients (from soil and fertiliser) needed to achieve the expected whole crop yield while avoiding excess nutrient losses.

Table 4: Total dry matter (DM) and nutrients removed in different whole crop cereals for silage. Data from Highbank, Canterbury (de Ruiter 2002).

Crop (cultivar)	**Yield**	**N**	**P**	**K**	**Ca**	**S**
	(t DM/ha)	**(kg/ha)**				
Wheat (Sapphire)	11.3	170	15	113	27	13
Triticale (Rocket)	13.6	170	16	119	36	14
Barley (Omaka)	13.4	189	16	142	40	17
Oat (Hokonui)	14.4	208	22	176	46	22

Table 5: Replacement costs ($/ha, fertiliser equivalents) for nutrients removed in silage and grain crops from Highbank (de Ruiter and Hanson 2004).

Crop (cultivar)	**Silage**	**Grain**	**Grain + baled straw**
Wheat (Sapphire)	$348	$217	$270
Triticale (Rocket)	$355	$244	$330
Barley (Omaka)	$270	$208	$253
Oat (Hokonui)	$398	$264	$382

SOIL MANAGEMENT ISSUES

The treading of dairy cows on wet soil has important effects on soil quality that can affect future dry matter production and increase the risk of nutrient losses. The nature and extent of treading damage (pugging) depends on factors such as soil moisture, soil physical properties (e.g. soil strength) and grazing intensity. Soil strength describes the ability of soil to withstand the force of compression under cow hooves without compacting or deforming. It is greatly affected by soil moisture and soil aggregate stability. Two different forms of treading damage are recognised. Where soils are very wet (at or near saturation) they become fluid. In this state they are less prone to compaction but are very susceptible to remoulding (deforming) of the soil surface during stock treading. This often results in the loss of larger soil pores (important for drainage) and the tearing and burial of plants. Compaction usually results when soils are trodden at lower soil moisture levels around field capacity (i.e. soil saturated and drained for 24-48 hours). Whilst compaction damage is not always visible at the surface it can occur to depths of greater than 15 cm.

Damage from treading tends to be a “self perpetuating” phenomenon (Haynes 1994). Tread damaged soils often have less plant cover and remain wetter owing to reduced drainage and lower water use by the plants. These conditions leave the soils susceptible to further treading damage.

The effects of treading on soil quality and the productivity of perennial pastures are relatively well known. Where pugging is severe, annual dry matter production can be reduced by up to 40% and this is usually associated with an increase in top soil bulk density and a reduction in macroporosity over a period of weeks to months after the pugging event (Menneer et al. 2005).

Cultivated soils are much more prone to compaction from stock treading than grass pastures because they have a lower density (which contributes to reduced soil strength) and, therefore, are more likely to deform or compact under the weight of cows. Cultivated soils also often require deeper and more intensive cultivation to break up compacted layers and produce a tilth suitable for sowing subsequent crops. However, regular use of intensive cultivation contributes to a decline in soil organic matter and aggregate stability (Fig. 2 A). Soils with unstable aggregates are prone to collapsing (“slumping”) when soils become wet after cultivation, leading to an increase in soil density. Hard-setting occurs when the slumped soil dries out, forming large dense clods that lack larger pores and cracks. This condition can restrict root growth and development and, thereby, reduce water availability, nutrient usage and consequently crop performance (Fig 2 B).

Very little information is available on the effects of continuous cropping and winter grazing on soil quality and the sustained productivity of dedicated dairy support units. However recent research (Beare and Tregurtha 2004) on arable cropping farms in Southland has shown that winter grazing with cows can markedly reduce soil quality and subsequent crop performance. In this study of paired paddocks on three different farms, paddocks winter grazed with cows had much lower soil structural condition scores, higher profile density scores (indicating greater compaction) and lower earthworm populations than paddocks not winter grazed on the same farms (Table 6). Earthworms can be important for rebuilding soil structure so, where their populations are reduced, the restoration of soil structure may be somewhat slower. The yields of subsequent crops grown on paddocks previously winter grazed were 28-36 % lower than those on paddocks not winter grazed (Table 7). The results of this study (Beare and Tregurtha 2004) also showed that crop yields were reduced for 2-3 years after a single pugging event.

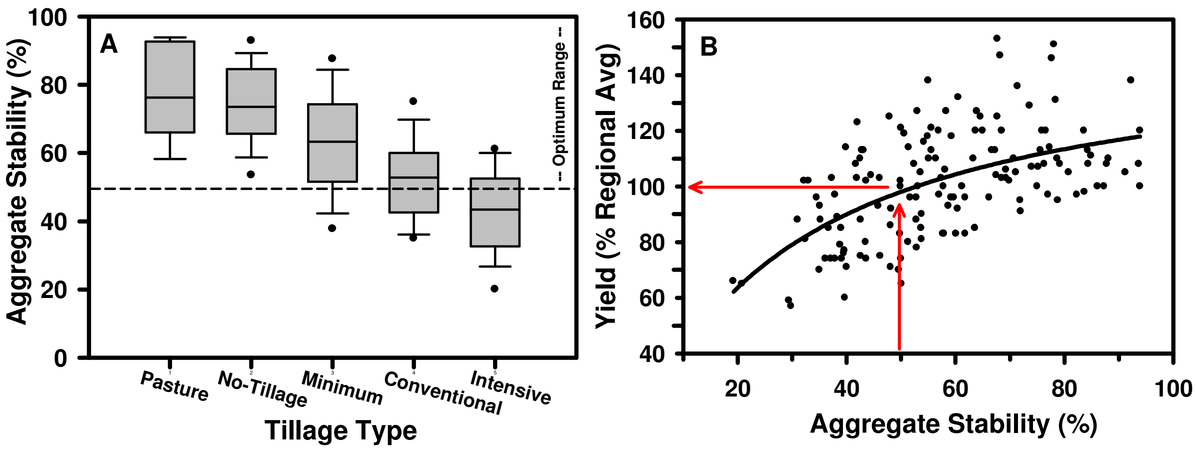


Figure 2: A) The range of aggregate stability values measured under different tillage practices [the shaded box contains the median value [line] +/- 25 % of the values, the dots are outliers] and B) the relationship between aggregate stability and relative crop yields on Canterbury cropping farms (Beare and Tregurtha 2004).

Table 6: Differences in soil quality indicators measured on cropping paddocks with and without winter grazing with dairy cows compared with continuous sheep pastures. Values are means of three sites (Beare and Tregurtha 2004).

Soil Quality Indicators	**Pasture**	**Long-term cropping**		**Optimum range**
		Not winter grazed	**Winter grazed**	
Structural condition score	4.2	2.5	1.7	2.5 – 5.0
Profile density score	10.7	12.4	14.0	8 – 12.5
Earthworms (No. / m^2)	879	280	88	> 200

Table 7: Crop yields (t/ha) in the following season on winter grazed paddocks [dairy cows] and paddocks not winter grazed but with similar soil types and crop histories.

Crop type	Winter grazed	Not winter grazed
Wheat (grain)	7.0	11.0
Barley (grain)	4.5	6.5
Barley (silage)	5.7	7.9

SUSTAINABLE MANAGEMENT OF WINTER FORAGE CROPS

Considerable research has been directed at developing economically and environmentally sustainable management practices for arable crop production on the South Island. While some of this research will be applicable to winter forage crop systems, new research is needed to minimise the adverse effects of winter grazing and to sustain the production of high quality forage crops. Current research at Lincoln is focused on developing crop establishment and winter grazing practices that achieve these goals. For example, a recent study by Crop & Food Research (Thomas et al. 2004) has shown that establishment of winter forage crops with no-tillage (Direct drill) practices (ex pasture) can reduce soil compaction during grazing and markedly improved the regrowth of cereal silage crops. In that trial, a multi-graze triticale (cv Doubletake) crop was sown on treatments established with three different tillage practices (i.e. conventional tillage, minimum tillage and no-tillage) following continuous pasture. The triticale was grazed in mid-winter and allowed to regrow before a green-chop silage harvest in October. Simulated grazing (cow treading) was done at three different soil moisture levels, < field capacity (moist conditions), field capacity (soil saturated and allowed to drain for 24-48 hours) and > field capacity (soil saturated, water ponding).

Where the triticale crop was established with intensive tillage, the bulk density of the top soil (as a measure of compaction) was much higher after treading at field capacity or higher soil moisture than under moist conditions (Table 8). However, there was little or no increase in bulk density with increasing soil moisture at grazing for the triticale crops established with minimum and no-tillage practices.

Table 8: The effects of soil moisture content at the time of grazing on soil bulk density (top 7.5 cm) under the three different tillage practices.

Tillage practice	**Moist (< field capacity)**	**Saturated & drained (field capacity)**	**Saturated & ponding (> field capacity)**
		(g/cm^3)	
Intensive Tillage [1]	1.14	1.32	1.31
Minimum Tillage [2]	1.03	1.09	1.12
No-Tillage [3]	1.15	1.15	1.15

[1] Intensive Tillage: Plough (20 cm) plus maxi-till/grub (10 cm), harrow and roll.
[2] Minimum Tillage: Disc (10 cm) plus maxi-till/grub (10 cm), harrow and roll.
[3] No-Tillage: Direct drilled into sprayed out grass pasture.

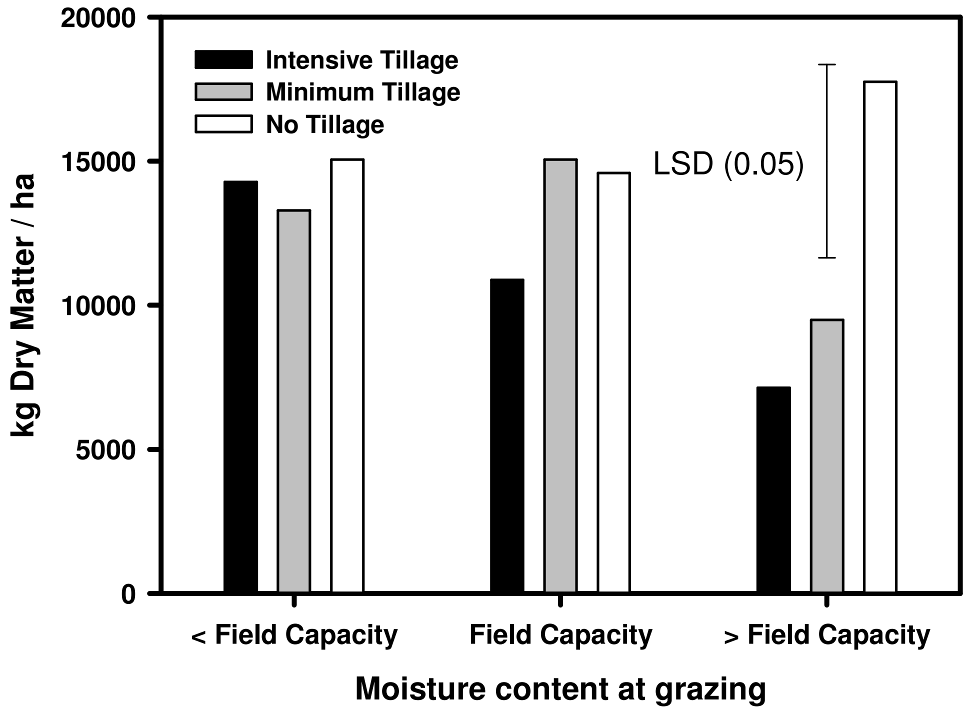


Figure 3: Dry matter production during the regrowth of triticale crops established with different tillage practices and grazed at three different soil moistures (Thomas et al. 2004).

Regrowth of the triticale was similar for crops established with all three tillage practices when grazed under moist conditions (< field capacity) (Fig. 3). However, where the crop was established with minimum or intensive tillage practices and grazed under fully saturated conditions (> field capacity), regrowth was much less than the crop established with no-tillage. The more stable soil surface (i.e. higher soil strength) created by direct drilling forage crops into long-term pasture appears to reduce the risk of surface compaction from heavy stock treading, even under very wet conditions.

This reduction in compaction not only improved the regrowth of the forage crops but also reduced the losses of nitrogen in the form of greenhouse gases (data not shown, see Thomas et al. 2004). Further research is needed to evaluate the effects of these different establishment systems on forage crop production in the longer-term, to assess their effects on nitrate leaching and to adapt reduced tillage practices to the production of forage crop (including brassicas) in other regions.

FUTURE RESEARCH

There is further scope to adapt knowledge and experience about sustainable crop management from arable systems to forage crop production and utilisation in dairying systems. The main unknowns are in areas beyond production of the crops, including utilisation of the various feed options (grazing, cut and carry, feed pads, etc.), how they influence animal performance, their contributions to the economic performance of a dairying business, their effects on soil quality and the environment (especially contributions to N losses), and their effects on subsequent crop and pasture production.

Much is already known about cereals, with well-established production solutions such as reduced tillage to minimise adverse effects on the environment and on subsequent production. Various forms of feed conservation are already established for cereals, but gaps remain around utilisation, effects on animal performance, and effects on subsequent production.

There is a greater need for research on winter brassicas. Reduced tillage practices may not be feasible for these crops and the risk of adverse impacts is greater than for cereals. Therefore, the focus is likely to be on judicious selection of soils for brassica production, growing the crops well to maximise their economic value, developing grazing management practices to utilise the feed sustainably, and investigating the feasibility of cut and carry options.

A start has been made on several of these topics in a new project (Sustainable productive support land for South Island dairying) which is supported by SIDE and the Sustainable Farming Fund, and operated by the South Island Dairying Development Centre (SIDDC). Current activities in the project are centred on three focus farms, one each in Canterbury, Southland and on the West Coast. The project will expand with studies of production, utilisation and impacts of cropping sequences, including cereals and brassicas, during pasture renewal. The first site was established in autumn 2006 on the Lincoln University dairy farm, and more are planned around the South Island.

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REFERENCES

Beare, M.H. and Tregurtha C.S. 2004. Soil Quality on Southland Cropping Farms: A guide to monitoring and best management practices. New Zealand Institute for Crop & Food Research, Christchurch, ISBN 0478108486, 51 p.

Clark DA, Thom ER, and Roche JR. 2000. Oats for Dairying. Proceedings of the Sixth International Oat Conference, Lincoln University.

de Ruiter JM, White S and Hanson R. 2002. Autumn cereals for grazing. *In:* Proceedings of the SIDE 2002. Published by South Island Dairy Event, Canterbury, New Zealand.

de Ruiter JM and Hanson R. 2004. Whole crop cereal silage: Production and use for Dairy, Beef, Sheep and Deer. Crop & Food Research.

de Ruiter JM 2002. Herbage quality and mineral composition of spring wheat, barley and triticale for silage at Highbank. Crop & Food Research confidential report No. 664. 45 p.

Hanson R, Armstrong K, de Ruiter J, Hay A and Milne G. 2006. Cereal forage breeding for New Zealand agriculture. In Breeding for Success - Proceedings of the 13th Australasian Plant Breeding Conference

Haynes R J. 1994. Soil structural breakdown and compaction in New Zealand soils. CropSeed Confidential Report No. 122b. Crop & Food Research.

Menneer, JC, Ledgard SF, McLay CDA, and Silvester WB. 2005. The effects of treading by dairy cows during wet soils conditions on white clover productivity, growth and morphology in a white clover-perennial ryegrass pasture. Grass and Forage Science. 60, 46-58.

Nichol W, Westwood C, Dumbleton A, and Amyes J. 2003. Brassica wintering for dairy cows: Overcoming the challenges. Pp 154-172. *In:* Proceedings of the SIDE 2003. Published by South Island Dairy Event, Canterbury, New Zealand.

Thomas SM, Francis GS, Barlow HE, Beare MH, Trimmer LA, Gillespie RN, Tabley FJ (2004). Winter grazing of forages - soil moisture and tillage effects impact nitrous oxide emissions and dry matter production. Proceedings of the New Zealand Grassland Association. 66, 135-140.