REDUCING OVERLAND FLOW AND SEDIMENT LOSSES FROM WINTER FORAGE CROP PADDOCKS GRAZED BY DAIRY COWS

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Abstract

The scale and extent of dairy farming in southern New Zealand has grown considerably in recent years. However, environmental concerns associated with the loss of nutrients, faecal microbes and sediment to waterways during winter grazing of dairy cows remains an issue in vulnerable landscapes. Winter forage grazing paddocks are believed to contribute a disproportionately large part of annual farm nutrient and sediment losses as a result of intensive stock grazing on soils with high moisture content. A paired catchment study was established at Telford Farm, South Otago to investigate alternative winter grazing management strategies that may reduce the volume and concentration of contaminants in overland flow. Strategies were targeted towards protecting vulnerable areas of the catchment that contribute the greatest amount of sediment and nutrient loading i.e. critical source areas (CSAs). We hypothesised that losses of sediment, phosphorous and *E. coli* could be reduced considerably through protection of the CSA, which accounted for less than 2.5% of total paddock area. In the control catchment the cows strip-grazed the crop from the bottom of the catchment and moved upslope with unrestricted access to the CSA. In the treatment catchment the cows strip-grazed from the top of the catchment and moved downslope, with restricted access to the CSA. Automated sampling and monitoring of overland and subsurface flows indicated smaller and shorter duration overland flow events in the treatment catchment compared to the control catchment, leading to a reduction in yields of sediment and nutrients lost. These findings indicate that simple and low cost techniques that take into account paddock soil type, topography, drainage and stock management can considerably reduce overland flow and contaminant losses from winter forage crop paddocks.

Introduction

Animal wintering is increasingly recognised as a critical phase of pastoral farming that has an important influence on animal performance and on contaminant losses from farms to water. Preliminary research has indicated that areas used for forage crop grazing during winter may make a disproportionately large contribution to nitrogen (N) losses from the total farm system (Shepherd et al. 2012; Smith et al. 2012). Studies in Otago have also highlighted the potential for relatively large losses of phosphorous (P) and sediment in overland flow from rolling landscapes used for winter forage crop grazing by cattle (e.g. McDowell & Houlbrooke, 2009a). Visual observation suggests that much of the overland flow is likely to originate within gullies due to natural convergence and saturation of soil, which can be exacerbated by soil disturbance. Grazing management will likely influence flow and sediment yields, particularly if animal wintering occurs on less resilient soils and landscapes.

Soil type, topography, drainage and stock management are risk factors that contribute to losses of nutrients and sediment in overland flow derived from winter forage crops. Less resilient soil types are more prone to structural damage, which can reduce water infiltration capacity resulting in proportionately greater volumes of overland flow. The topography (slope) of the paddock will also influence losses, with greater slopes having potential for greater rates of soil loss (Dymond, 2010). Soils with poor drainage will also be more prone to damage from stock through compaction and pugging, again increasing the potential for overland flow generation due to lowered soil infiltration. Stock is another risk factor, due to the effects of excretal deposition onto surfaces where overland flow may occur, and soil treading damage (Nguyen et al. 1998). Where-ever possible, limiting the extent of winter forage crop grazing in vulnerable parts of the landscape such as the CSA would help minimise soil damage and the associated risk of overland flow. This could be achieved by practising time restricted (on-off) grazing in the vulnerable areas (McDowell and Houlbrooke 2009b).

This paper presents a summary of results from years 1 and 2 of a 3-year study which intends to examine practical approaches for minimising the risk of overland flow from paddocks used for winter forage crop grazing by dairy cows. Using a paired catchment study approach, we investigated the effectiveness of optimising grazing direction, back-fencing breaks and on-off grazing of the forage crop in those areas of the catchment suspected to result in the greatest overland flow. These measures were designed to reduce overland flow volume, and as a consequence, yields of contaminant losses in this flow. A key focus of the study was the protection of Critical Source Areas (CSAs), which are parts of the landscape where the majority of overland flow and thus contaminant loss are thought to occur. These are typically located in gullies and swales where soil moisture contents can be high, leaving the soil more vulnerable to treading damage by stock. This is also an area where overland flow is most likely to occur, due to saturated soils and flow convergence. Overland flow into and through the CSA is thus a transport vector for the movement of sediments and nutrients.

Methods

The trial site at Telford Farm, Balclutha comprised two adjacent paddocks (6.3 ha and 4.3 ha) each containing a discrete drainage catchment of 2.1 ha (**Catchment A**) and 1.9 ha (**Catchment B**) respectively (Figure 1). The catchments each contained a broad basin area at the upper end that drained into a central gully. The catchments are of similar size although Catchment A has steeper topography leading into the central gully area. The paddocks were located on a Pallic soil (Te Houka silt loam) with rolling topography and were cultivated and sown with a brassica crop in both 2011 (swedes) and 2012 (kale). Average annual rainfall at Telford is approximately 700 mm. Instantaneous stocking densities of cows in the winter forage crop paddocks varied depending on the feed available and were between approximately 1000 and 1400 cows/ha.

It was hypothesised that strategic grazing of cows in a winter forage crop paddock could reduce overland flow and thus sediment and nutrient losses. To test this hypothesis, two treatments were used:

Control Cows entering at the lower end of the paddock
Strip grazed moving in an uphill direction
No protection of the CSA
No backfencing

Treatment Cows entering at top end of the paddock
Strip grazed moving in a downhill direction
Protection of the CSA
Backfencing every 4-5 days
Final time-restricted grazing of CSA if conditions suitable

In 2011, both paddocks were managed according to the control grazing strategy, and acted as a baseline calibration in order to characterise the hydrology of each catchment. The cows entered both paddocks from the lower end and strip grazed upwards with no back fencing and with free access to the CSA. In 2012, the paddocks were treated differently, whereby Catchment A was managed under a strategic grazing treatment and Catchment B as a control treatment i.e. the same management as in 2011 (Table 1, Figure 1). The research project continues in 2013, where the two catchment treatments will be switched with Catchment A being the control and Catchment B having strategic grazing applied (Table 1).

Table 1. Experimental design of the two trial catchments 2011-2013.

Year	Catchment A	Catchment B
2011	Baseline (Control)	Baseline (Control)
2012	Strategic Grazing Treatment	Control
2013 (Proposed)	Control	Strategic Grazing Treatment

Our research identified the CSA as the bottom of the gully in each catchment (Figure 1). This is the area where saturated soil conditions due to ephemeral overland flow were expected during the rainfall events that occurred throughout winter and spring (May-October). In 2012, the CSA in Catchment A was fenced off to exclude stock (100 metres long and 15 metres wide at the lower end of the gully, tapering to 5 metres wide at the upper end). This area accounted for less than 2.5% of the total paddock area in each of the two paddocks.

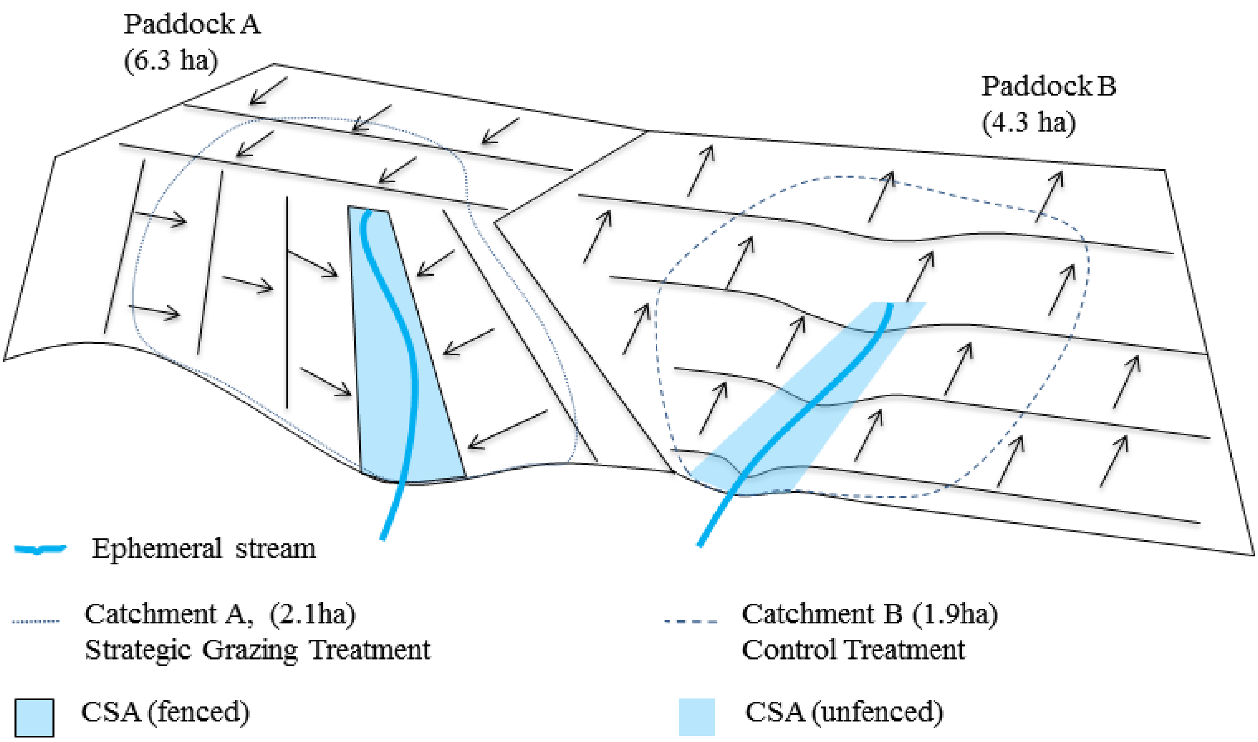

Figure 1. Paddock layout and treatments imposed in the 2012 winter season at Telford Farm. Arrows indicate the different grazing patterns and directions followed for each catchment.

Grazing of the CSA was time-restricted in the treatment paddock (Catchment A). No grazing occurred in the CSA until the rest of the paddock had been grazed. A decision was made to graze the CSA only when soil moisture conditions allowed for minimal disturbance and damage to the soil within the CSA. This final grazing of the crop in the CSA was limited to a 4 hour period, to reduce damage to the soil, yet remove the bulk of the standing crop.

Rainfall was measured with a 0.2 mm electronic tipping bucket. Overland flow was measured as stage height across an H-flume and weir, installed at the overland flow exit point from each catchment. Attached to each flume was a stilling well with a water level sensor (NIWA Hydrologger) and a Manning 4901 vacuum autosampler. The system was set up to automatically begin measuring and sampling any overland flow that occurred. The Manning sampler was programmed to take a sample every hour when stage height was above 10 mm. An automated alert message was generated and sent to a mobile phone so that samples could be retrieved within 24 hours.

Tile drains located at the bottom of each catchment collected subsurface flow. During the winter season, samples of subsurface flow were taken at weekly intervals over the two year trial period. During the second year of the trial, subsurface flow rates were also measured. The results from the subsurface flow are not presented in this paper.

Water samples were returned to the lab and analysed for a range of nutrients and physical measurements. Results for suspended sediment, total phosphorous and ammonium-nitrogen are presented in this paper.

Results and Discussion

Rainfall from June until the end of September in 2011 was 198 mm, and 262 mm in 2012 (Figure 2). In 2011, the occurrence of overland flow during high rainfall events was similar between Catchment A and B suggesting that the catchments were comparable. However, they did yield different volumes of total overland flow, probably due to a number of factors including the slightly larger size and steeper topography of Catchment A. There were 6 overland flow events in 2011 and 10 events in 2012. The biggest events occurred during July and August in both years. There were more events in 2012 that occurred in late winter and spring. During 2011 total overland flow derived from Catchment A was 41 mm, and 27 mm for Catchment B (Figure 2). The annual total overland flow following the implementation of the strategic grazing treatment in 2012 was 10 mm. This was lower than the 56 mm of overland flow measured in Catchment B during 2012, and during 2011 in Catchment A. This marked decline in overland flow occurred despite winter rainfall being higher in 2012, suggesting that the strategic grazing was highly effective in reducing overland flow.

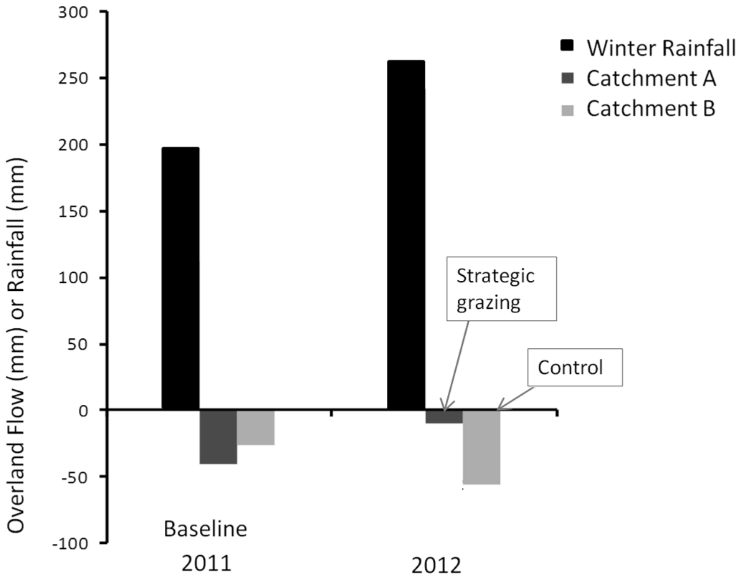

Figure 2. Winter rainfall (1 June to 30 September) and annual overland flow for 2011 and 2012. Rainfall and overland flow are shown as bars above and below the x-axis, respectively.

Estimated sediment yields derived from the catchments are shown in Table 2. Sediment yields appear to be strongly driven by the flow volumes. In the 2011 baseline year, the sediment yields were higher for Catchment A than Catchment B. This was mostly due to the higher flows. Concentration data shows a similar pattern, with slightly higher sediment concentrations in Catchment A, attributable in part to its steeper topography, that makes it more prone to sediment loss.

Table 2. Total sediment load and concentrations in overland flow derived from the catchments.

	Catchment A		**Catchment B**	
	Yield kg ha^{-1}	**Concentration g m^{-3}**	**Yield kg ha^{-1}**	**Concentration g m^{-3}**
2011	720	1780	280	1060
2012	130	1280	1140	2050

In 2012, when the strategic grazing management was implemented in Catchment A, there was a marked decline in sediment yields compared to both the baseline data and also the control Catchment B. This was largely driven by the reduction in flow in Catchment A as a result of the strategic grazing. The sediment concentrations were also reduced in Catchment A, suggesting that the strategic grazing management was reducing the amount of sediment available for loss or entrainment in overland flow. Larger amounts of sediment were expected in Catchment A due to its steeper topography making it more susceptible to sediment loss. However, strategic grazing in Catchment A reduced the sediment load, even with the steeper topography.

The annual yield of total P measured in 2011 (baseline) in Catchment A (2.1 kg/ha) was higher compared to Catchment B (0.7 kg/ha). This follows the pattern of greater overland flow and sediment losses in Catchment A which had steeper topography. During 2012 there was a considerable reduction in the yield of total P lost under the strategic grazing treatment. This is clearly highlighted in Figure 3, where the yield of total P in the strategic grazing treatment was approximately 20% of the control.

Ammonium-N yields (Figure 3) responded in a similar way to total P whereby losses were reduced in the strategically grazed catchment (Catchment A).

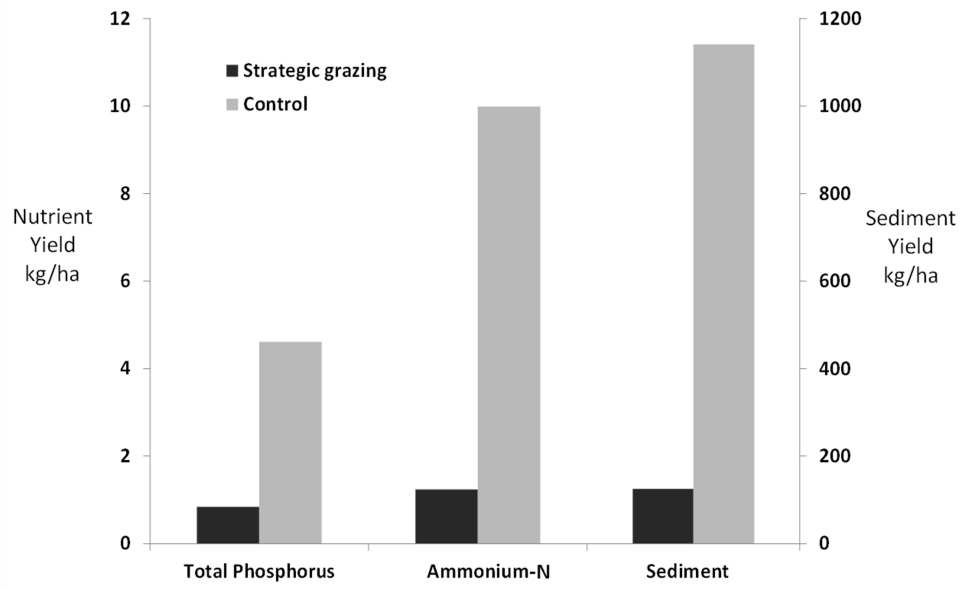

Figure 3. Yields (kg/ha) of total P, ammonium-N and sediment in overland flow during winter 2012.

There is a strong link between the yield of sediment and nutrients lost and the volume of overland flow from each of the catchments. Any decrease in the size or frequency in overland flow events will assist in reducing the overall yield of sediment and nutrients entering waterways and may improve water quality.

Summary

This trial has shown that strategic grazing of dairy winter forage paddocks can considerably reduce volumes of overland flow. By reducing overland flow, the yields of sediment and nutrients carried in the flow were also reduced considerably. The strategic grazing method was a combination of protecting the CSA from stock by fencing, and grazing the least risky areas first and grazing towards the higher risk areas. This effectively left the most vulnerable areas (e.g. the CSA) with minimal soil damage for as long as possible throughout the winter season. Protection of the CSA, gullies and areas prone to soil saturation is a key part to reducing overland flow and sediment loss. Grazing the CSA can still occur, but only when soil conditions allow. These grazing managements are relatively simple to implement and low cost.

Acknowledgments

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