LIKELY TRENDS FOR DRYLAND FARMING AS A PERMITTED ACTIVITY IN THE HURUNUI AND WAIAU ZONE

In the context of water quality

Abstract

This report was commissioned by Environment Canterbury to help inform the Hurunui Waiau zone committee about the likely impacts on water quality from permitting dryland farming. To do this, a survey of predominantly dryland farmers in conjunction with 10 case studies were undertaken. This report presents these results along with presenting several additional lines of evidence encountered whilst undertaking the research. In providing an answer, three key areas of evidence emerged. These were, constraints to dryland farming, plausible development options and their impact on nutrient loss, and trends. The intersecting evidence suggests that at a catchment scale there is unlikely to be significant trends that would impact nutrient loss from dryland farms for the foreseeable future due to permitting dryland farming.

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Acknowledgments

Thanks must go to all the farmers involved in the case studies and who kindly welcome us onto their properties to complete the survey; Beef + Lamb NZ, specifically Julia Beijeman and her team provided invaluable support and insight which made this report possible. Thank you also to Environment Canterbury and the Hurunui Waiau science stakeholder groups for providing feedback and a platform to bounce ideas around. Finally, a special thanks to the HDLG committee and Ben Ensor for their advice and farm systems knowledge.

Executive Summary

1. Dryland farms in the Hurunui are diverse.
2. Dryland farm systems are characterised and ultimately constrained by climatic uncertainty.
3. Plausible development on dryland farms comprises various threads of improvements woven together through farm management, culminating in an optimised system given farm constraints. Some threads are long term developments such as improved fecundity, gained through animal health and genetics (among other improvements). Others are management decisions such as a summer forage crop for strategic feed when grass doesn't grow due to the summer dry. Each dryland farm utilises a unique mix of developments and management decisions.
4. Almost 80% of surveyed farmers had a Farm Environment Plan (FEP). Good Management Practices (GMP) adopted included grazing management, erosion control planting, fencing off and retiring marginal land, and direct drilling as a preferred plant establishment technique. This suggests sediment control, erosion mitigation, and consequently phosphorus loss risk are GMP areas targeted by dryland farmers. Potential areas of improvement include using Spreadmark certified spreaders and calibrating farm owned spreading equipment to manufacturers' specifications.
5. Modelling changes in stocking rate can quantify expected nutrient loss from numerous farm developments that cannot directly be modelled.
6. OVERSEER modelling of changes in stocking rate and winter forage area showed the greatest impacts on estimated nitrogen loss (aside from irrigation effects).
7. Dryland farm stocking rates (sheep, beef and deer combined) have decreased over the past 10 years from 8.1 SU/ha in 2007 to 7.1 SU/ha in 2017. Farmers indicated their intention to increase stocking rates from current day rates to where they were ten years ago over the coming ten years.
8. 82% of surveyed farms had winter forage crop, covering an average of 2.7% of total farm area. This was more than (but comparable to) Beef + Lamb Economic Service data which showed a long-term trend of 1.9% of the farm in winter forage. Year on year this fluctuated by 30% but did not exceeded 2.5%. There was no significant trend between years. The range from the HDLG survey was 0% to 14% of total property area.
9. A 50% increase in winter forage area above the average of 1.9% is estimated to increase nitrogen root zone losses by 14%.
10. An initial assessment of the impact of increased root zone nitrogen losses on in-river nitrogen loads was made using the catchment nutrient calculator (P Brown 2017). Using this method, a 14% increase in root zone loss from dryland farms in the Hurunui and Waiau catchments could be expected to equate to a 1.3% increase in the in-river nitrogen loads of the Hurunui and Waiau.
11. Aside from irrigated blocks, nitrogen leaching losses mainly occurred from May to August. The same can be assumed for phosphorus runoff.
12. The intersecting evidence suggests that at a catchment scale there are unlikely to be significant trends that would impact nutrient loss from dryland farms for the foreseeable future due to permitting dryland farming.

Contents

Introduction

In 2013 the Hurunui Waiau sub regional plan was notified by Environment Canterbury and the now colloquially known “10% rule” became effective. This rule effectively limits the nutrient loss of any farm in the Hurunui by allowing a 10% increase on top of their nutrient loss as assessed in 2013. Intended to cap high nutrient loss emitters it had the unintentional consequence of potentially creating severe restrictions on low emitters. These low emitters have become known as “dryland farmers.” Predominantly sheep and beef farmers, they gathered at Waikari Hall in 2014 to vent their frustrations and let regulators know that they perceived this as inequitable and unfair. Since then all stakeholders including local groups, irrigators, iwi and Environment Canterbury have been in discussions to develop a rule that will allow flexibility for low emitters whilst protecting the environment. The Hurunui Waiau zone committee’s vote to put forward a targeted plan change to Environment Canterbury required further information to assess what would likely happen if dryland farming became a permitted activity.

Figure 1. Aerial photo of the Hurunui and Waiau District in North Canterbury with insert of location relative to greater New Zealand

The Hurunui District Landcare Group (HDLG), a stakeholder in the Hurunui and Waiau representing a substantial portion of dryland farmers, was asked by Environment Canterbury to provide information for the Hurunui Waiau zone committee.

The two key questions for the group:

- What is plausible dryland farm development?
- What is the likely impact of permitting dryland farming?

HDLG undertook two main lines of research - a survey of 83 predominantly dryland sheep and beef farms, and a more detailed nutrient assessment for 10 of these farms. The general survey provides insight into likely plausible development at a catchment scale. The case study assessments were used to estimate what this development would likely mean for nutrients reaching the Hurunui and Waiau River main stems.

The HDLG is an incorporated society with a committee of 15 farmers and current membership of 120 predominantly dryland farmers. Formed out of 5 catchment groups throughout the Hurunui Waiau zone, the HDLG aims to ensure dryland farmers continue to be good stewards of the land and are well represented in the development of water quality policy.

The members cover 115,000 hectares, and the full spectrum of topography and climate in the Hurunui, Waiau, Jed, Blythe, Conway and Waipara catchments.

Membership represents approximately 40% of dryland farms in the Hurunui/Waiau zone based on a total estimate of 300 commercial dryland farms.

Scope

The proposed plan change is intended to provide flexibility to "low emitters" of nutrient loss. To achieve this, Environment Canterbury's (ECan) requires a quantification of the plausible and/or possible change in nutrient loss from low emitters if they were a permitted activity. Concurrently, all other land use nutrient losses and their potential changes also need to be quantified. This led to the segmentation of the Hurunui and Waiau catchments into nutrient loss contributors based on practical groupings. The current and proposed irrigation companies (Amuri Irrigation, Hurunui Water Project and Emu Plains Irrigation) have command areas defined by their current or proposed consents. Their possible nutrient losses are also based on their consents. Independent irrigators were also grouped and their nutrient losses predicted based on an ECan GIS nitrogen loss estimate. Department of Conservation and public lands are accounted for, leaving the remaining predominantly unirrigated farms to be quantified. This report aims to provide guidance to ECan and the zone committee on possible and plausible development for the majority of these farms. However, as some of these may not necessarily be considered "low emitters", further refinement constrains this report to farming with no irrigation or a small irrigated area (<10% of farm or 50ha) and with less than 10% of the farm in winter forage crop for cattle. [1]

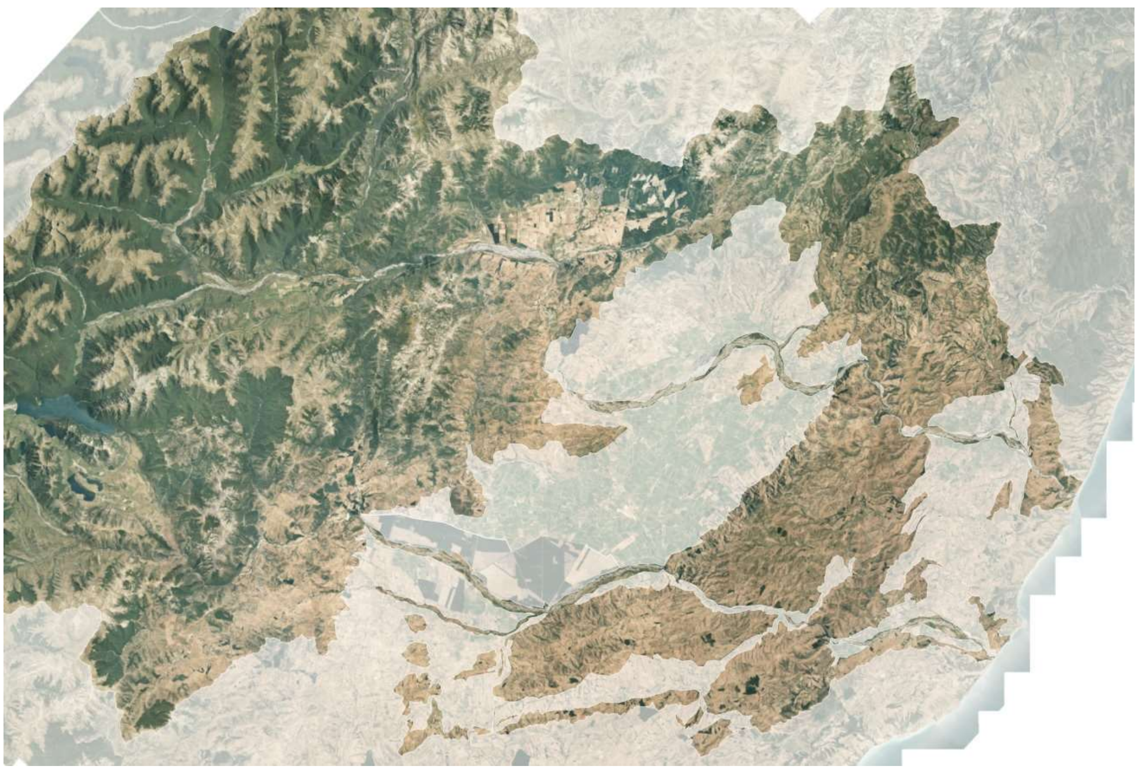

Figure 2. "Dryland" farming areas of focus

[1] This definition is not intended to advocate for a definition for creating a permitted activity rule but to provide a practical scope for this report based on planning definitions presented by ECan to the zone committee.

Dryland Farm systems in North Canterbury

Predominantly dryland farm systems in North Canterbury are "sheep and beef" farms. It is estimated that there are around 300 commercial sheep and beef farming operations in the Hurunui District.

In the Hurunui and Waiau there are approximately 600 commercial farms of various descriptions. The extent to which the climate influences and defines these farms is dictated by average climate, between year climate variation and management, and infrastructure used to maximise or mitigate the climate.

Average rainfall of most farms in the Hurunui and Waiau is 550mm to 850mm. However, the hill country runs above the Mandamus tip into significantly higher rainfall bands, triple what is seen near Masons Flat.

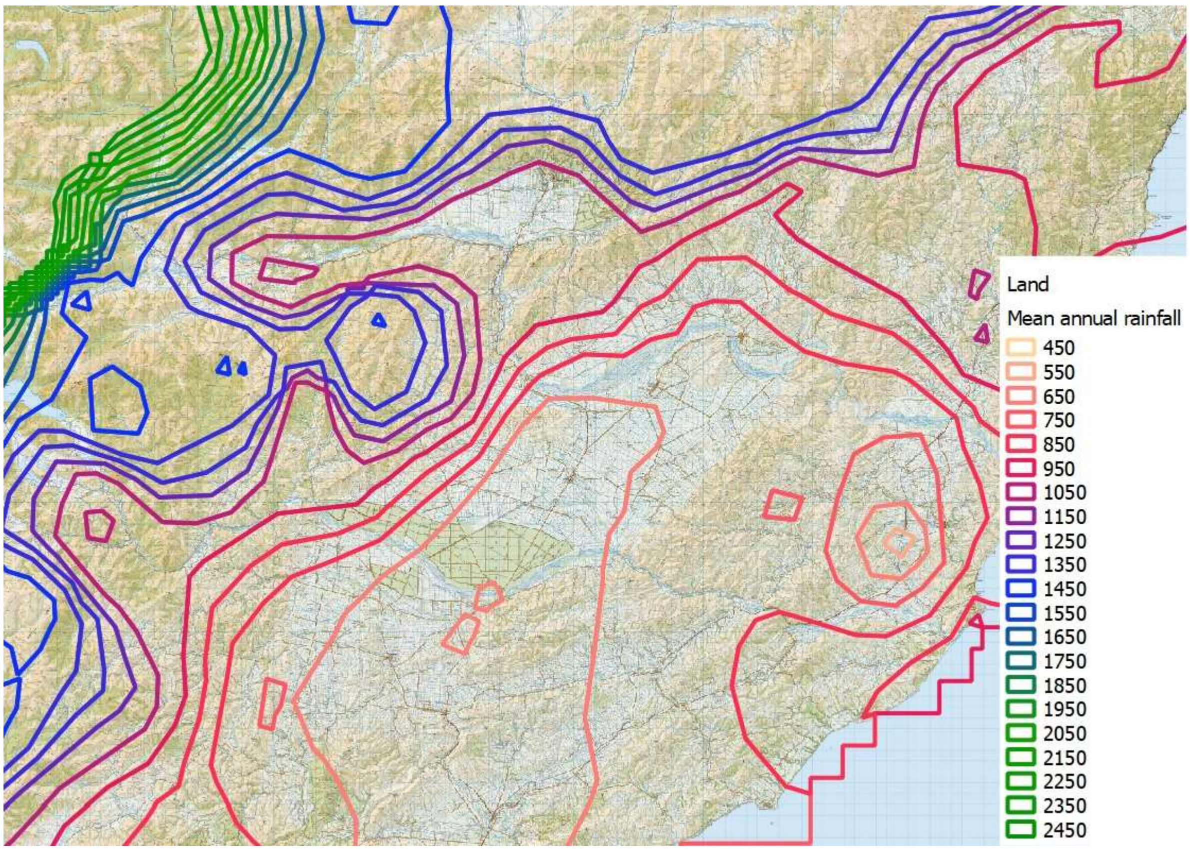

Figure 3. Long-term median rainfall bands for the Hurunui and Waiau

Commonly missed, yet integral in describing farm systems, is risk management. Farmers must grow a product whist managing risks from fluctuating markets along with physical factors such as variable weather, pests and diseases. Of these, weather variability is the most consistently influential factor, to the extent that it characterises farming even if it dictates a farm fully mitigates the risk by varying methods (Martin, 1996). On dryland farms, i.e., without irrigation, this characterisation is even more noticeable. Significant variation in year on year weather (especially rainfall) affects pasture production and subsequently productivity, finances and environmental outcomes on livestock farms (Li, Vibart, Dynes, Vogeler, & Brown, 2012). This has required farmers to develop adaptive management strategies to survive long-term. Examples include appropriate stocking rates, prioritising contingencies (such as supplementary feed stores) and allowing for failure in some components of the system whilst not compromising the entire operation. Climatic variability characterises dryland farming in the Hurunui and Waiau, and the adaptive and varying strategies used to manage the risk that define the farm systems. Each farm manages the risks in their own unique way.

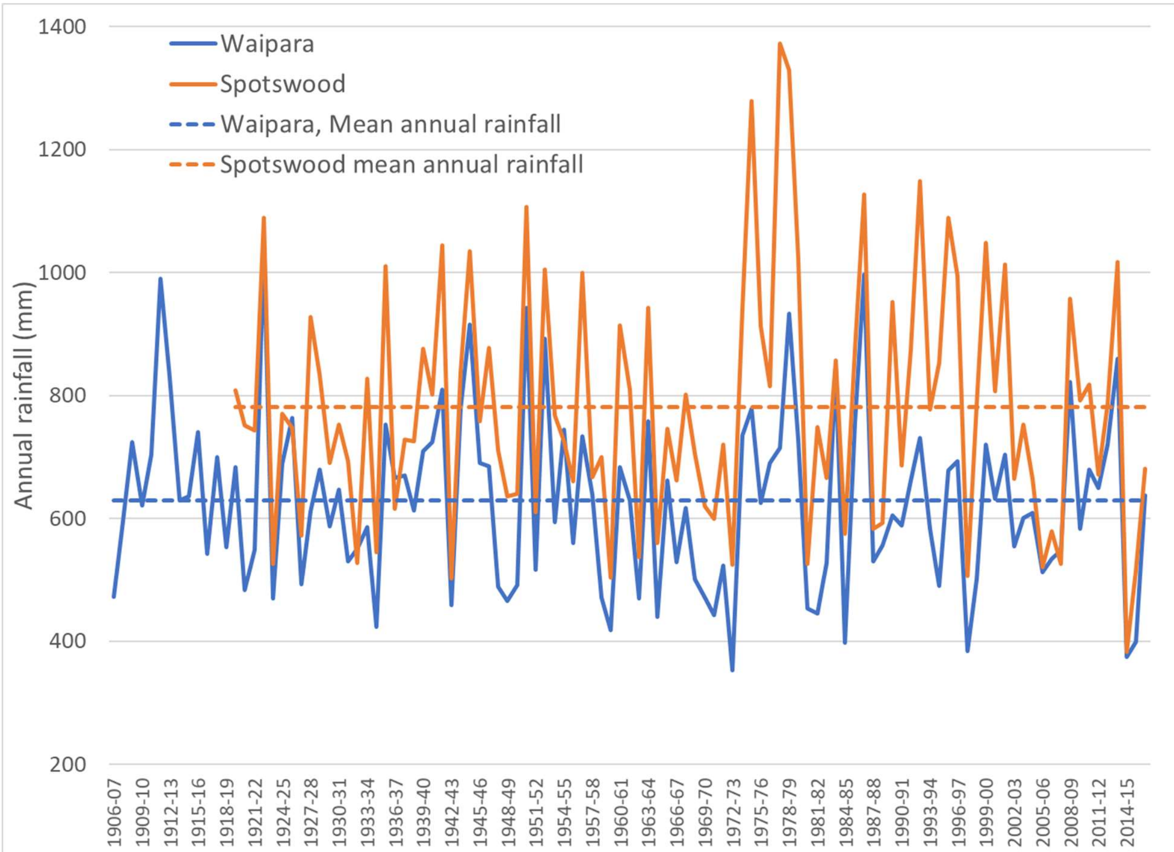

Figure 4. Rainfall variability over the last 100 years for two sites in the Hurunui and Waiau catchments.

The predicted impact of climate change adds to the challenge. All estimates suggest that the east coast of New Zealand is likely to get drier with more extreme rainfall events (Kenny, 2001). This will only compound the climatic variability risk for dryland farms and potentially further constrain dryland farm systems (Gray, Reid, & Horne, 2011).

HDLG research

Survey

Hurunui and Waiau dryland properties can be consistently characterised as constrained by variability but there is a paucity of quantitative information to allow a fuller characterisation of these farms. Furthermore, there is a lack of information on how farm management relates to 'good management practice.' A survey of HDLG members was undertaken to fill some information gaps. The sections below set out the results of this survey.

Methodology

Approach

HDLG undertook an in-person survey of 83 of its members. All except one deer farm were "sheep and beef" farmers. Deer were farmed on 12% of surveyed farms but only accounted for 1.8% of current total stock units.

Six responses were excluded from all analysis as surveys were either incomplete or contained contradictory information. For the stocking rate and winter forage analysis another 14 were excluded due to having a large (>10% of total farm & >50ha) area of irrigation. Sensitivity analysis showed these could have a significant impact on results and did not fit the scope of this report. The surveyed farms (excluding >50ha of irrigation) covered a total area of 70,000ha in the Hurunui and Waiau catchments (61,000 effective hectares). This represents 24% of the total area in the Hurunui and Waiau catchments below the Mandamus and Marble Point.

The irrigated farms were included in the GMP section as a sensitivity analysis showed no difference in responses.

Farmers were asked for wintered stock numbers 10 years ago, current day, and where they think they will be in 10 years' time. Stock numbers were converted to RSUs (explained below), summed and divided by effective farm area to express stocking rate in SU/ha.

conversion factor		
Sheep	Cattle	Deer
1.1	5	1.9

Table 1. Stock numbers to Relative Stock Unit (RSU) conversion factor[2]

A 55kg ewe with one lamb at foot, i.e., feed intake of 550kgDM/year, is one stock unit (Parker, 1998). As only total winter stock numbers for sheep, cattle and deer were gathered in the survey, assumptions were made about the mix of stock ages. These assumptions allowed for 1/3 hoggets (at 0.7 RSU) and 2/3 mixed aged ewes (at 1.3 RSU), i.e., sheep overall stock number to relative stock unit conversion ratio of 1.1. Cattle and deer numbers were less precisely converted, as 5 RSUs and 1.9 RSUs respectively. These were an estimate based on the literature (Parker, 1998), supported by conversations with HDLG farmers.

Once stock numbers were converted to RSUs, the total RSUs for each farm were summed and divided by the effective farm area[3]. This accounted for survey responses that did not have farms ten years ago, where stock numbers ten years ago were stated as zero and would have shown inappropriate jumps between historic and current stock numbers. Several farms also bought more

[2] The same stock unit definition is used by Beef + Lamb NZs economic service data

[3] In the draft interim report presented in December 2017 to the Hurunui Waiau Zone Committee, stock units by total area was used. There is no difference in trends.

farm land in the last 10 years and thus increased total stock numbers. This did not represent increased intensification as the stocking rate (RSUs/ha) did not show corresponding trends. To gauge intensification stocking rates were compared for past, current and intended. Farms without stock 10 years ago were excluded for the stocking rate trend analysis.

The remainder of the survey was either analysed linearly or, for the Good Management Practice (GMP) questions, in a matrix comparing with external literature.

Limitations

There were two main limitations to survey methodology:

- Survey respondents were restricted of HDLG members. Based on local knowledge this grouping was assumed to be reasonably representative of dryland farmers in the Hurunui and Waiau, but this assumption was not empirically tested.
- The survey was conducted as a 'kitchen table' discussion and did not include any additional checking or field validation of the information provided.

Despite these limitations the survey still provided a wealth of information.

Presentation of results

The survey results are presented in five sections.

1. Surveyed farm characteristics
2. Stocking rate
3. Winter forage crop
4. Good management practices
5. Additional comments

Surveyed farm characteristics

The survey captured farming over a wide range of climatic conditions, farm sizes, and topography. Whilst predominantly in the Hurunui and Waiau, farms were also surveyed in the Waipara, Conway, Blythe and Jed catchments, with long-term mean annual rainfall from 590mm/yr to 1017mm/yr.

Catchment	# of farms[4]	Mean rainfall for surveyed farms(mm/yr)[5]	Max (mm/yr)	Min (mm/yr)
Waiau	34	855	1017	697
Hurunui	31	725	849	590
Conway	3	857	881	833
Waipara	5	694	738	647
Jed	3	782	787	776
TOTAL	76	786	1017	590

Table 2. Surveyed farms rainfall and catchments

Of the 76 farms, 24 had some irrigation but only 14 had more than 50ha of irrigation or more than 10% of total farm area under irrigation.

Catchment	# of farms with Irrigation	# of farms with >10% of farm or 50ha of irrigation
Waiau	12	8
Hurunui	10	5
Conway	0	0
Waipara	2	1
Jed	0	0
TOTAL	24	14

Table 3. Irrigation on surveyed farms

The 76 farms covered 73,000 hectares. Over half the area was in farms greater than 1000ha but these accounted for only 29% of the number of farms surveyed.

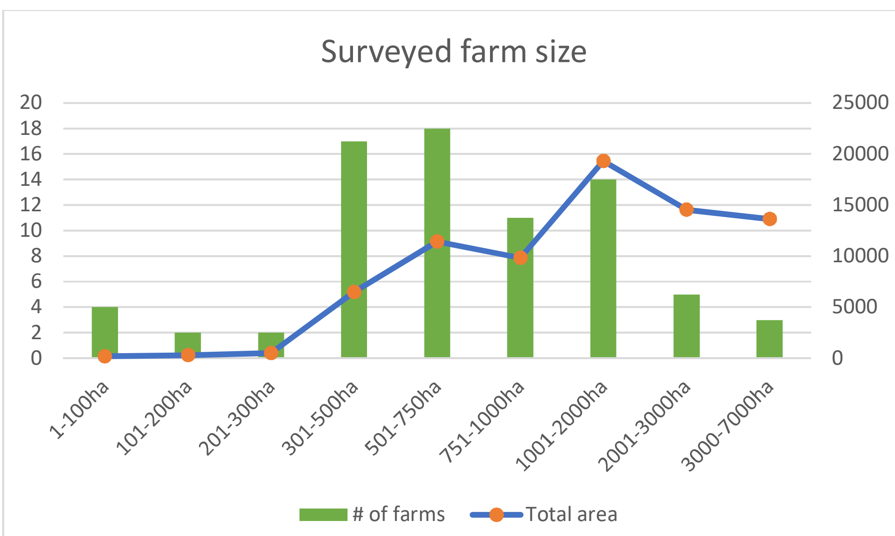

Figure 5. Surveyed farm size

[4] Some farms were in several catchments in which case they were grouped into the one they covered most.
[5] Rainfall data was gathered from OVERSEER v6.2.3 climate station tool for each farm surveyed.

Of note is the high proportion of land classed as Land Use Class (LUC) 6. LUC 6 is "Non-arable land with moderate limitation for use under perennial vegetation such as pasture or forest" (Newsome, Wilde, & Willoughby, 2008). Comparatively "high producing land" such as LUC 2 and 3 make up 23% of the surveyed farms' area.

Catchment	Area (ha) of LUC classes on surveyed farms								
	LUC 1	LUC 2	LUC 3	LUC 4	LUC 5	LUC 6	LUC 7	LUC 8	LUC 9
Waiau	0	2600	4242	5668	71	26603	2477	63	0
Hurunui	0	3100	4379	3458	0	9548	934	672	0
Waipara	0	246	1138	683	0	1886	0	63	0
Jed	0	0	167	2	0	1364	12	0	0
Conway	0	0	381	24	0	1360	0	0	0
Total	0	5946	10306	9836	71	40761	3423	798	0

Table 4. LUC classes covered by surveyed farms

The survey also signalled the difference in characteristics between irrigated and non-irrigated properties. Surveyed farms with irrigation had a significantly (60%) greater proportion of cattle compared to farms without irrigation.

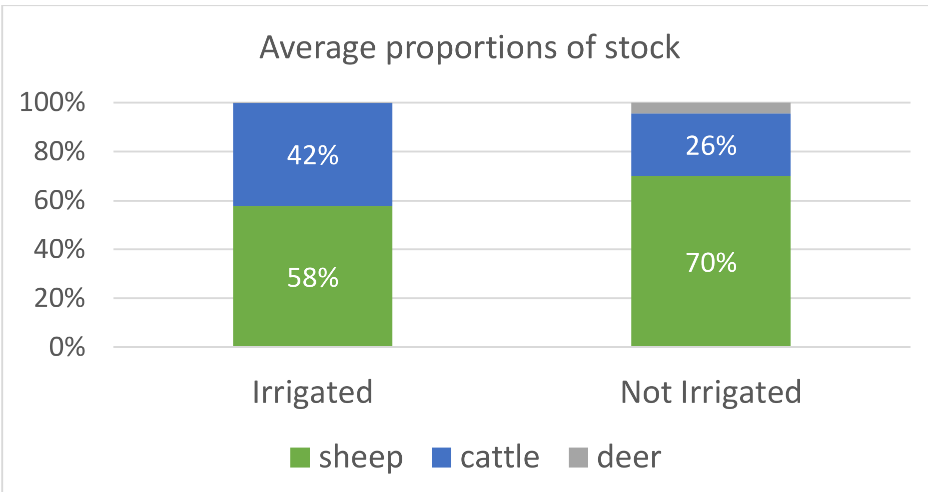

Figure 6. Proportion of stock types on irrigated verses un-irrigated farms

Irrigated properties were also comparatively more intensively stocked and had more winter forage for cattle area[6]. However, further examination showed no significant difference in stocking rate, winter forage area or proportion between unirrigated farms and those with irrigation less than 50 hectares or 10% of total farm area.

[6] This is detailed further in the sections "stocking rate" and "winter forage crop."

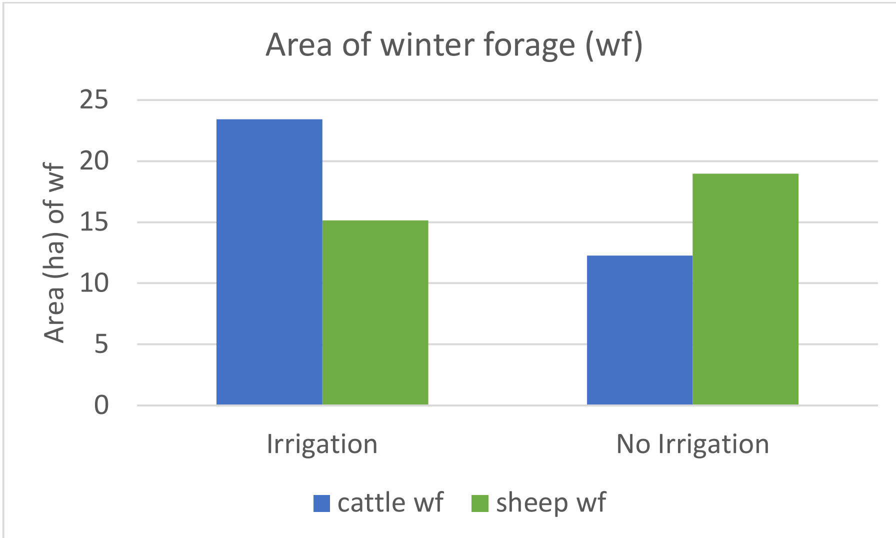

Figure 7. Area of winter forage

Stocking rate

Stocking rate change was used as an indicator of development for the surveyed farms. This data showed that farms without irrigation had dropped stocking rate by more than 10% over the last ten years. Over the next ten years their intention is to increase stocking rate from current day, but settle at less than the stocking rates of ten years ago.

A small area of irrigation (<10% or 50ha) showed comparable results to unirrigated farms. However, once farms with a larger area of irrigation were included, the trend and stocking rates changed significantly.

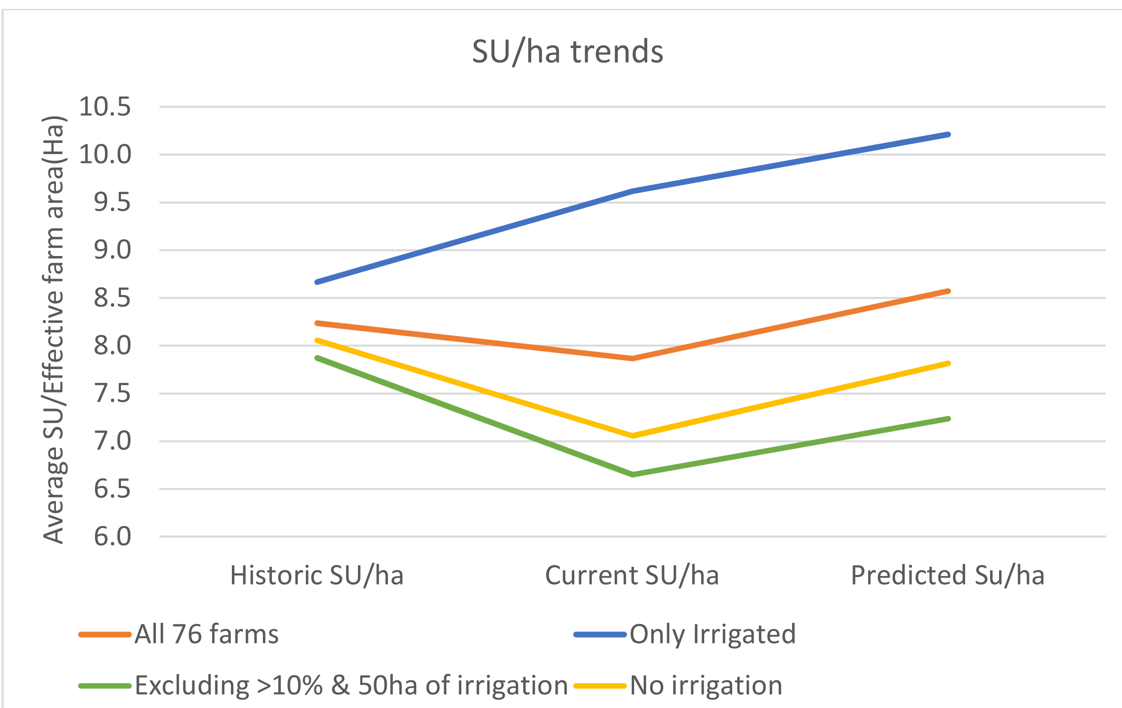

Figure 8. Stocking rate trends from surveyed farms.

Whilst it is thought that the recent drought influenced the declining stocking rate trend on unirrigated farms, the trend is consistent with national and local Beef + Lamb NZ Economic Service (B+LNZES) data. Hurunui data from B+LNZES shows a significant decline and is consistent with national trends. Beef numbers have fluctuated but show no trend over this same period. This suggests a shift in cattle to sheep ratios.

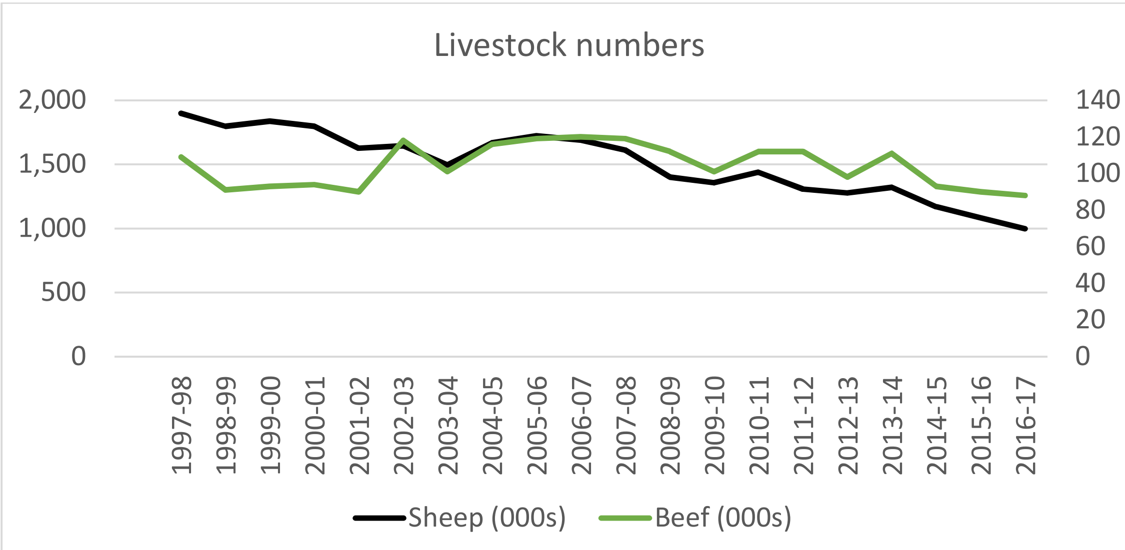

Figure 9. Hurunui stock number data (Beef + Lamb NZ, 2017)

This was also seen from the HDLG survey. On unirrigated farms there was a 3% shift from sheep to beef over the previous ten years. On irrigated properties there was a 4% shift from sheep to beef over the previous ten years.

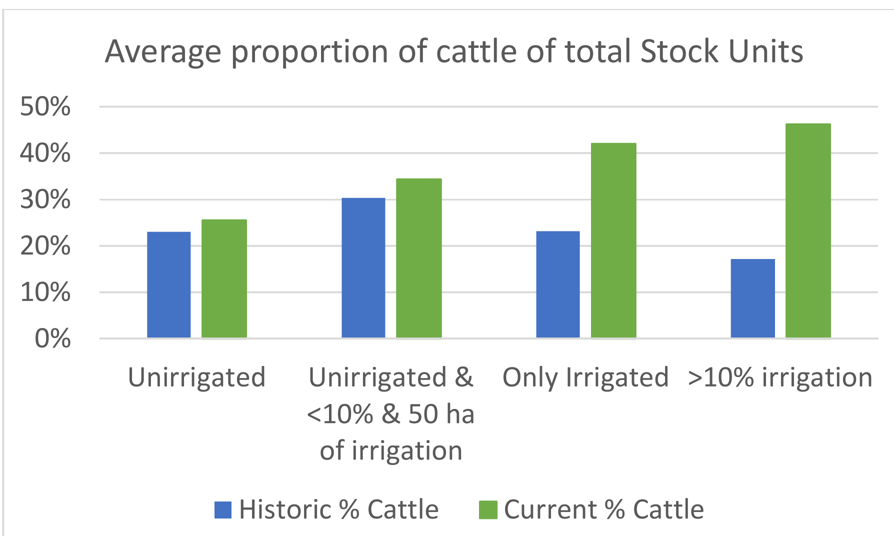

Figure 10. Average proportion of cattle of total stock units

The survey information suggests a small area (<10% of 50ha) of irrigation is unlikely to have an impact on overall stocking rates but the proportion of cattle carried is likely to be higher than on dryland. The bigger the proportion and area of irrigation, the greater the stocking rate and cattle proportion of total stock units.

Unirrigated properties had a significantly lesser proportion of cattle and made much slower shifts in sheep to cattle ratios.

An OVERSEER® modelling exercise was used to gauge the impact of a shift in sheep to beef ratios. 100% sheep was modelled at a stocking rate of 8 SU/ha on Lismore soils, and then a series of shifts towards beef were undertaken until the farms were 100% cattle (beef). The modelling assumed no other changes in farm management and stocking rate. This exercise showed a 17% increase in nitrogen loss from 6kgN/ha/yr to 7kgN/ha/yr[7]. This suggests that the small shift in sheep to beef ratios in the survey, by itself, is unlikely to have a significant impact on nitrogen losses.

While OVERSEER® estimated no increase in phosphorus loss, in practice there is greater potential for sediment and phosphorus losses. This is due to heavier stock (cattle) having a greater impact on soil physical properties promoting surface runoff (Cournane, Mcdowell, Littlejohn, & Condron, 2011). The potential impact is directly linked to management, specifically whether good management practice is undertaken and critical source areas are appropriately managed (Mcdowell & Wilcock, 2009).

Winter forage crop

83% of unirrigated farms had winter forage crop with the average winter forage area being 2.7% of the total farm area (range 0% to 15%). Farms with irrigation over more than 10% of their farm or 50ha had on average 6.1% in winter forage crop.

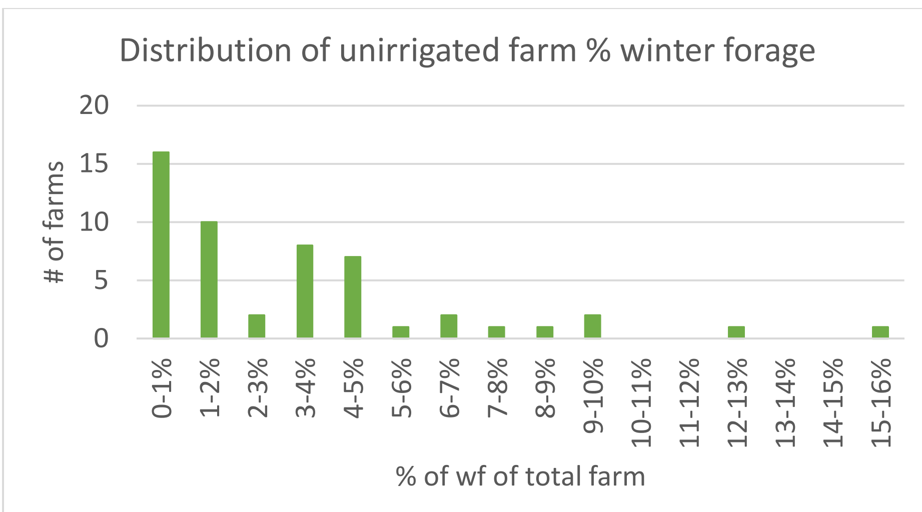

Figure 11. Distribution of unirrigated farm % winter forage of total farm area from survey.

[7] Appendix 3

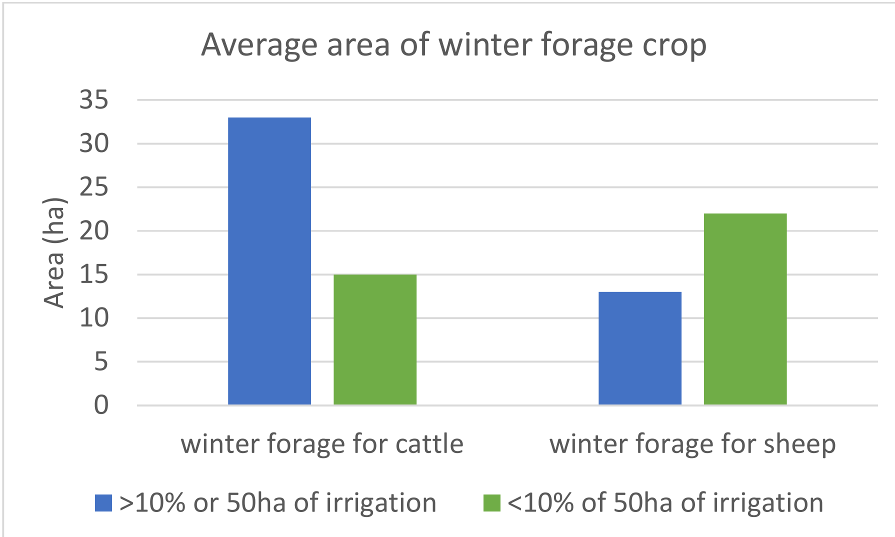

Figure 12. Average area of winter forage crop on surveyed farms

As the HDLG survey only asked for winter forage area for one year, B+LNZES data was used for trend analysis. This showed that over the last 10 years, average winter forage area on sheep and beef farms in the Hurunui fluctuated by 30% year on year but had not exceeded 2.5% of effective farm area. There is no significant trend.

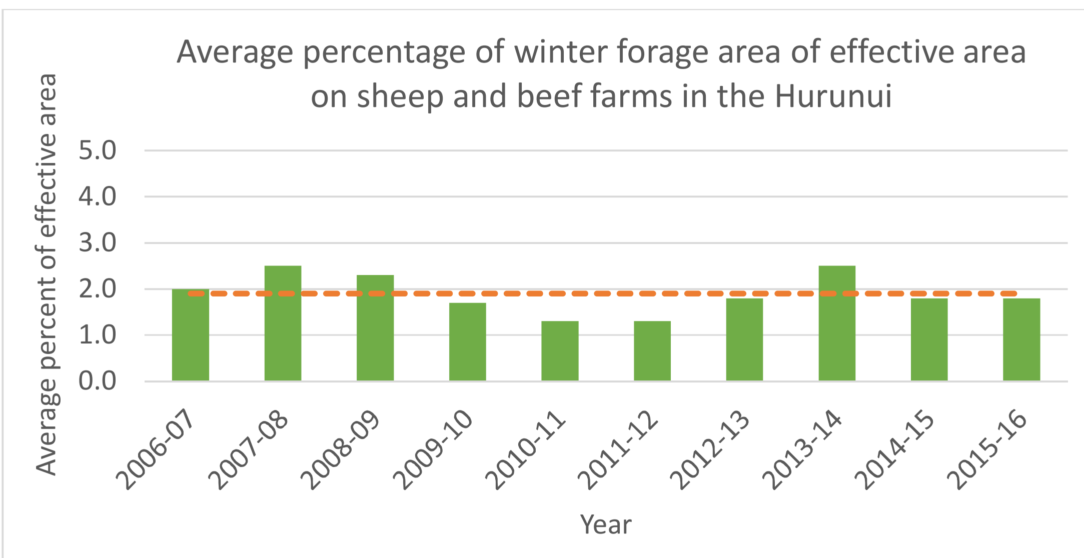

Figure 13. Average percentage of winter forage area of effective area on sheep and beef farms in the Hurunui (Beef + Lamb NZ, 2017)

From this data, the average winter forage area was 1.9% of effective area on sheep and beef farms in the Hurunui.

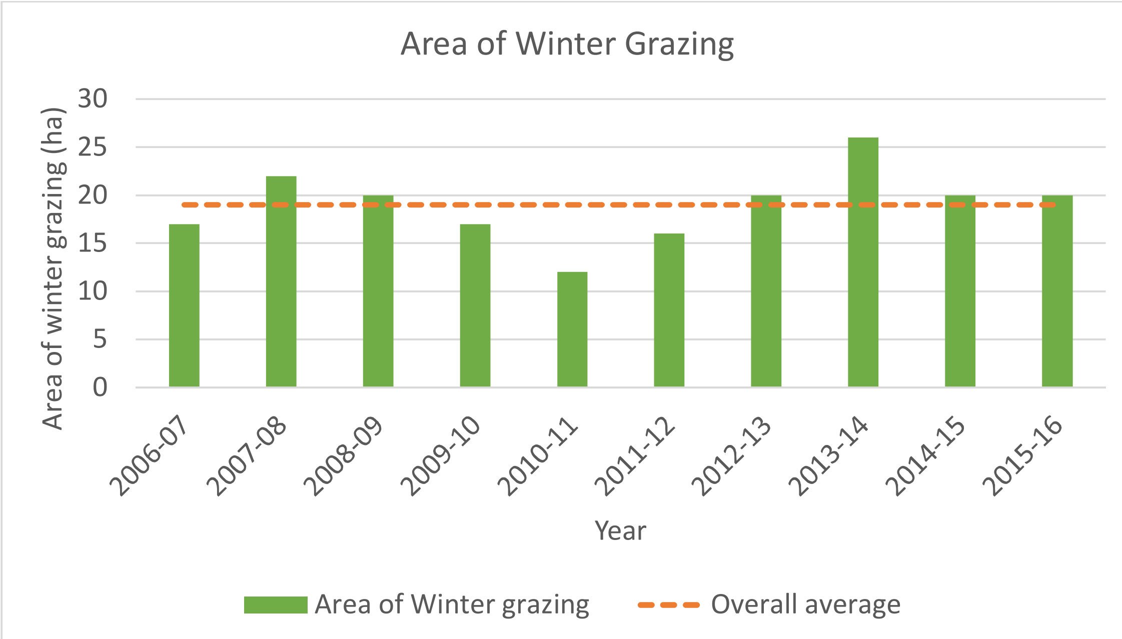

Figure 14. Average area of winter forage crop for the Hurunui (Beef + Lamb NZ, 2017).

Change in winter forage area calculator

A rudimentary calculation was used to estimate the impact of increasing winter forage crop area on changes in nitrogen loss. This calculation is as follows:

((Projected wf area * wf kgN/ha/yr) + (Projected remainder area * remainder kgN/ha/yr)) - ((Base wf area * wf kgN/ha/yr) + (Base remainder area * remainder kgN/ha/yr)) / ((Base wf area * wf kgN/ha/yr) + (Base remainder area * remainder kgN/ha/yr)) = % change in overall root zone kgN loss

Where:

- wf = Winter forage crop
- wf kgN/ha/yr = **150**
- remainder kgN/ha/yr = **7**
- remainder area = (total area (1000) – (base or projected wf area respectively)

The 'wf kgN/ha/yr' was derived from the OVERSEER v6.2.3 dryland winter forage crop block losses (grazed by cattle) on the case study farms.

The 'remainder kgN/ha/yr' was derived from the OVERSEER v6.2.3 pasture block losses on the case study farms.

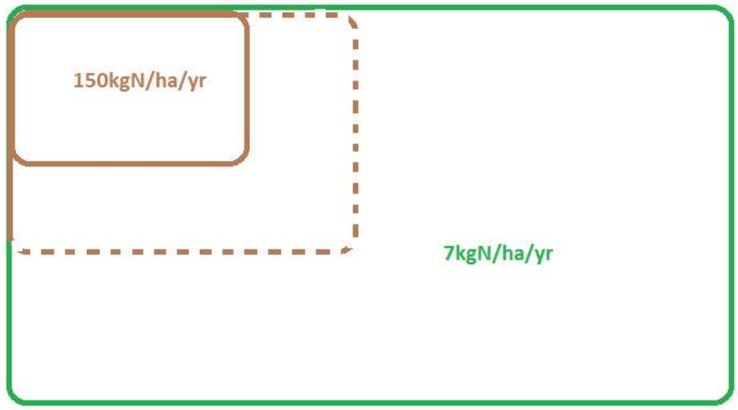

Figure 15. Example of changes in winter forage area where the dotted brown line is the projected winter forage area.

In figure 14 the solid brown line is the base winter forage area and the green line is the total farm. As the proportion of the winter forage area increases, the impact on overall nutrient loss increases.

The assumptions included in the calculator:

- There are no changes in per/ha nitrogen losses from winter forage crop or pasture with a change in winter forage area.
- There is no change in factors that might influence a change in estimated kgN/ha/yr losses, i.e., grazing by sheep verses cattle, forage crop species, stocking rates both on crop and whole farm.
- Large ineffective areas (hill country runs) are excluded from the estimation of remainder kgN/ha/yr. If included, these would decrease the estimation.

A 50% increase in winter forage area is estimated to be a "worst-case" scenario of unlikely intensification from dryland farmers in the Hurunui and Waiau. This is based on the 30% year on year fluctuation from the long term average (1.9%) and then allowing a further 20%.

From this calculation, with these scenarios and assumptions, a 14% increase in nitrogen root zone loss from dryland farms was expected.

Base % WF	Projected % WF	Average WF kgN/ha/yr	Average Pasture kgN/ha/yr	% Change in overall N loss	% change in WF
1.9%	2.9%	150	7	**14%**	**50%**

Table 5. Change in winter forage area impact calculator

No attempt was made to quantify increases in phosphorus losses from increases in winter forage grazing. The potential for increased phosphorus loss is largely governed by the location of the forage crop in the landscape and grazing management practices.

This result in nitrogen root zone increase was entered into the catchment nutrient calculators (Brown, 2017), which estimated that a 14% increase in root zone nitrogen loss from these dryland farms would equate to a 1.3% increase in the in-river nitrogen loads of the Hurunui and Waiau.

Row	Zone	2013-15 baseline		With consented increase		Scenario exploring		
		SH1	Mouth	SH1	Mouth	% change	SH1	Mouth
1	Upstream Mandamus	51	51	51	51	**0%**	51	51
2	AIC	448	448	448	448	**0%**	448	448
3	HWP & NTP (excl. AIC overlap)	169	169	362	362	**0%**	362	362
4	Lower Hurunui irrigators (below SH1)	0	34	0	34	**0%**	0	34
5	Other irrigation	11	17	11	17	**0%**	11	17
6	Dryland	91	106	91	106	**14%**	113	132
7	**Total**	**770**	**825**	**963**	**1018**		**985**	**1044**
8	**Change from HWRRP Schedule 1 limit**						**13**	
9	**% change (from consented baseline)**						**101.3%**	**102.5 %**

Table 6. Hurunui River in-river load (t-N/yr) (Brown, 2017)

Notes (Brown, 2017)**:**

1. Per hectare losses by land use class are the average of the upper and lower bounds presented in Brown (2015) "Hurunui River nutrient modelling: impact of dryland intensification." Memorandum dated 10 March 2015 from Peter Brown to the Hurunui Waiau and Jed Nutrient Working Group.
2. Baseline values scaled by 0.95 to match 770 t-N/yr HWRRP baseline load.
3. Assumes HWP's & NTP's command area in-river load is the 2013 baseline plus 193 t-N/yr (193 t-N/yr is a 25% increase on 770 t-N/yr).
4. About 20% of existing irrigation [above SH1] is outside of AIC's command area. Their baseline load is included in line 3, since they lie within HWP's command area. This irrigation accounts for about 93t-N/yr in-river, or 26% of the 362 t-N/yr in-river load.
5. "Other irrigation" (line 5) is irrigation that falls outside AIC, HWP & 'Lower Hurunui Irrigators' zones. It is primarily from irrigated land along the Hurunui and Waitohi main stems.
6. 'Lower Hurunui Irrigators' zone covers most of the irrigable land below SH1.

Row	Zone	2013-15 baseline		With consented increase		Scenario exploring		
		SH1	Mouth	SH1	Mouth	% change	SH1	Mouth
1	Upstream Marble Point	215	215	221	221	9%	241	241
2	Emu Plains	214	214	214	214	22%	261	261
3	AIC	499	499	518	518	0%	518	518
4	Lower Waiau irrigators	66	169	66	169	0%	66	169
5	Other irrigation	2	11	12	19	0%	12	19
6	Other dryland	104	138	104	138	14%	130	171
7	Total	1100	1247	1136	1280		1228	1381
7	Change from consented increase						83	101
8	% change (from consented increase)						107.2%	107.9%

Table 7. Waiau River in-river load (t-N/yr) - DRAFT (Brown, 2017)

Notes (Brown, 2017)**:**

1. Per hectare losses by land use class are the average of the upper and lower bounds presented in Brown (2015) "Hurunui River nutrient modelling: impact of dryland intensification.
2. Baseline values scaled by 1.45 to match a preliminary estimate of in-river load at SH1 of about 1100 t-N/yr (range 1,000 - 1,400).
3. Emu Plains % increase is from B Ellwood memorandum dated 24 October 2017.
4. % increase for consents in process above Marble Point from Ellwood memorandum dated 24 October 2017. Assumes an attenuation factor of 1247 / 2,201 = in-river estimate / ECan root zone estimate = 0.57.
5. "Other irrigation" (line 5) is irrigation below Marble Point that falls outside AIC's (consented), Emu Plains (proposed) and Lower Waiau Irrigators (assumed) command areas.
6. Without “other dryland” % change the in-river load at SH1 is calculated to be 105.9%.

Good management practices

Good management practices (GMPs) are industry agreed practices that can be used on farm to improve water quality (Environment Canterbury, 2018). Because no two farms are the same, there is no 'one size fits all' approach to GMPs. Some are considered common sense for most farms, while others might only be practical at certain times of year on a small number of farms (Hoban, 2015).

This section compares the survey answers from the 'GMP' questions to the "Industry-agreed Good Management Practices relating to water quality" (2015)[8] and draws in comments made by the farmers to support or highlight anything they felt they did to improve or maintain the environment.

Seven themes emerged. These were: grazing management pest and weed control, tree planting/erosion control, appropriate cultivation, biodiversity enhancement, stock water supply, shelter, and riparian management.

These comments were impromptu, suggesting they were back of mind issues for the farmers. No attempt was made to encourage more out of the farmers than was volunteered. The analysis was not meant as a quantitative exercise but as supporting material for the picture painted by all the lines of evidence combined.

It became clear that the ambiguity of some GMPs and the lack of prescription made it impossible to quantitatively rank farmers adoption of GMPs. Therefore, this report reviews the results, including comments, to subjectively estimate GMP areas of strength and weakness for dryland farmers.

The responses suggest that areas of strength include soil conservation and erosion control. This was seen in responses and comments about grazing management, erosion control, tree planting, riparian management and cultivation techniques. This may be linked to the history of Catchment Boards working with hill country farmers to control sediment losses and better utilise their farms through land use capability assessments.

In addition, but outside of GMPs, many farmers talked about their work to maintain and improve biodiversity. Numerous comments mentioned flourishing vegetative biodiversity.

A potential area that dryland farmers could improve is the use of Spreadmark certified spreaders, and/or calibrating their own spreaders according to manufacturers' specifications. Note that further use of Spreadmark certified spreaders may be hampered by the lack of local certified spreaders.

Exclusion of intensively grazed cattle from waterways could benefit from further investigation. The results from this survey were inconclusive and show the need for more detailed studies, especially in drought-prone dryland areas where waterways may dry up for large parts of the year.

[8] Note sections 13-14 and 16-19 of the GMPs have not been reviewed as they relate to irrigation and effluent respectively and are outside the scope of this report

A comparison of industry agreed GMPs and survey results

GMP MANAGEMENT AREA	GMP	GMP PRACTICE	Survey results and commentary
WHOLE FARM			
FARM PLANNING AND RECORDING	GMP1	Identify the physical and biophysical characteristics of the farm system, assess the risk factors to water quality associated with the farm system, and manage appropriately.	The HDLG strongly encourage members to prepare and implement a farm environment plan (FEP) for their properties. Of the 77 members surveyed, 60 (78% of respondents) had a FEP. While not a specific survey question, most of these plans are likely to be Beef + Lamb NZ FEPs. These plans generally cover nutrient, soil and waterway management, and irrigation if it is an irrigated property. An FEP encourages farmers to document management practices that make their farm a sustainable business. The FEP is specific to the property recognising its physical and biophysical characteristics, and the risks that various farming activities pose to the environment. Farmers were asked 'how often they referred to their plan.' While the responses to this question were inconclusive, individual comments provided some insight. *" …environmental plan, actively used in decision of paddocks used for cropping … Animal class selection around soil type..."*
	GMP2	Maintain accurate and auditable records of annual farm inputs, outputs and management practices.	The extent to which farmers in general maintain accurate and auditable records is known to vary widely. HDLG members are no exception. While gauging record quality was not a specific survey objective, it was clear that some of the respondents had detailed records while others tended more to the 'back of the cigarette packet' approach. All had some records for stock numbers, soil tests and fertiliser use. Areas of winter feed crops were taken from the paddock areas.

LAND			
CULTIVATION AND SOIL STRUCTURE	GMP3	Manage farming operations to minimise direct and indirect losses of sediment and nutrients to water, and maintain or enhance soil structure, where agronomically appropriate.	Respondents were asked their preferred method of cultivation. The results were: • Direct drilling – 77% • Conventional – 2.6% • Minimum tillage – 2.6% • No responses – 18% Direct drilling is known to better maintain soil moisture, improve soil structure, and reduce soil loss from wind and surface erosion (Caruiso, 2000). Direct drilling is common practice amongst dryland farmers. From associated comments the links between the use of direct drilling and protection of the soil were evident. *"(We use) direct drilling, (helping) reducing loss of soils."* *"Direct drilling – we are huge on it. Less disturbing of the soil, the better. (we are big on) soil conservation."* Other cultivation techniques, such as conventional cultivation or minimum tillage, were used for various reasons including personal preference and sometimes because the paddock is "just too rough" to direct drill.
GROUND COVER	GMP4	Manage periods of exposed soil between crops/pasture to reduce risk of erosion, overland flow and leaching.	The survey did not gather direct information on farmers' uptake of this GMP. Indirectly, the significant use of direct drilling and emphasis on soil conservation of many farmers suggests a strong understanding of erosion and run-off risks. This is also support by the number (21) of individual comments from farmers who talked about grazing management. Effective grazing management will reduce over-grazing and help protect covers, thereby meeting a component of this GMP. *"…Grazing longer rotation, longer grass across the whole farm."*
	GMP5	Retire all land use capability (LUC) class 8	Erosion control is an important part of dryland farms, which are predominantly hill country, protecting waterways (Cameron, 2016). Class 8e land only made up 1% of land covered by

		and either retire, or actively manage, all class 7e to ensure intensive soil conservation measures and practices are in place.	surveyed farms. LUC 7 was 5% of land covered. Given that 9,000ha was rated ineffective (of 70,000 ha surveyed), it can be assumed that land classes 7 and 8 made up a majority of this land. In addition, 19 comments from those surveyed highlighting the importance of soil conservation suggested that this topic was regularly considered by dryland farmers. Comments received included: *"…(We undertake) plantings for soil erosion/under runners, etc."* *"… Any work fences/tracks put in or plantings are well thought out where to put, so sheep create pathways to help with erosion."* *"Plantings of trees on steep terrain. …try to protect bushes, the gullies and let regenerate."* *" … we have 41.6 ha of trees in 11 tree blocks. Pro-active on erosion control work. In ETS with significant planned planting as part of the ETS. Goal to get 100ha within the next 3 years."*
SEDIMENT, PHOSPHORUS AND FAECAL BACTERIA	GMP6	Identify risk of overland flow of sediment and faecal bacteria on the property and implement measures to minimise transport of these to water bodies.	No specific question related to this however a FEP should cover this (77% of respondents had an FEP). Farmer progress on this can be supported by other GMPs relating to soil conservation. Farmers were also asked how many sediment traps/dams they had, one method for minimising the transport of sediment through water bodies. While it is difficult to quantify whether having more was better than less, 87% of farmers had either a sediment trap or dam.

	GMP7	Locate and manage farm tracks, gateways, water troughs, self-feeding areas, stock camps, wallows and other sources of runoff to minimise risks to water quality.	No question in the survey specifically answers this. Several (6) comments made mention of stock water use to discourage stock from seeking waterways. *"Put in stock water system, detracting stock from waterways."* *"Put in 19 water troughs & active plans to complete the water supply.*
	GMP8	To the extent that is compatible with land form, stock class and intensity, exclude stock from waterways.	Looking after waterways is a challenge on many farms and solutions which match the property are important. The biggest risks to waterways on most farms include stock damage to stream banks and beds, stream bank erosion, weed and pest management, and flooding. Generally, stock should be excluded from streams where they have an impact and where this is practical (The Fourth report of the Land and Water Forum, 2015). "To the extent that is compatible…" makes this GMP very farm specific. Therefore, to identify whether a farm has attained GMP or not would require more in-depth analysis than the survey. The survey did ask whether "cattle and deer are excluded from waterways on paddocks with average slope less than 15 degrees" – 32% responded yes. It is unknown whether the rest of the farms did let stock into waterways on slope less than 15 degrees or whether they had waterways that fit this description at all. 32% of respondents had a fully reticulated water system, which reduces stock impact on waterways as they are not required for drinking. A number of comments talked about riparian planting: *"Active plans to plant and fence wetlands."* *"riparian plantings and fenced off waterways, …weed control."*
	GMP9	Monitor soil phosphorus levels and maintain them at or below the agronomic	No soil test information was gathered. However, the average phosphorus applications from the survey suggest that farmers are applying at or below maintenance levels given the stocking rates (Ballance Agri-Nutrients, 2014). The Average application rates are below in GMP10.

		optimum for the farm system.	
		PLANTS	
NUTRIENT MANAGEMENT	GMP10	Manage the amount and timing of fertiliser inputs, taking account of all sources of nutrients, to match plant requirements and minimise risk of losses.	Injudicious use of fertiliser may result in adverse environmental effects so management of fertiliser applications is key to minimising or mitigating risk. The risk associated with fertiliser on sheep and beef farms must be put into context regarding the quantity used. The survey results showed: • Use of nitrogen fertiliser on dryland farms is common (74% of farms) but targeted (i.e., 35kgN/ha/yr over 20% of the farm). Use of nitrogen fertiliser on extensive/hill country is uncommon (8%) and at low annual rates (13.7kgN/ha/yr). • Use of conventional phosphorus fertiliser is common (87% of farms) on intensive land[9] (average 30% farm) at rates averaging 18.6kgP/ha/yr. Use on extensive country is less common (44% of farms) at rates averaging 13.7kgP/ha/yr.[10] These rates would be considered maintenance rates given the average stocking rates (Fertiliser Association, 2016). These application rates are relatively conservative relative to other pastoral farming enterprises, lessening (but not completely mitigating) the risk to the environment. Management and systems used in fertiliser application remain important. Farmers were asked: • Do you have a nutrient budget? – 65% said yes. A nutrient budget with an FEP would help identify areas of risk for fertiliser use. • Are you aware of the Spreadmark certification program for fertiliser spreader operators? - 79% said yes. • Are Spreadmark certified spreaders available in your area? - 61% said yes.

[9] Intensive was described as flatter land, or land that was more intensively farmed. Extensive land was the remainder of the farm

[10] The average application rates must be used with caution. The results probably over estimate P rates as many farmers did not know the exact phosphorus product they used, there by the default was superphosphate.

			• Contractors used for fertiliser spreading are Spreadmark certified - 49% said yes. • Do you spread your own fertiliser? - 40% said yes. • Is your own fertiliser spreading equipment calibrated according to manufacturer's recommendations? - 27% said yes. • Fertiliser is not applied when the soil temperate is less than 10 degrees – 79% said yes they do not apply fertiliser when the soil temperate is less than 10 degrees.[11] This has greatest significance for nitrogen fertiliser application. The strong response here combined with the relatively low application rates of nitrogen fertiliser suggests dryland farmers have a minimal risk of nitrogen loss associated with fertiliser use. • GPS technology is used for precise application of all fertiliser spread (e.g., proof of placement) – 79% said yes. Generally, fertiliser application on dryland farms seems to be of minimal risk and mitigation strategies (GMPs) are being utilised by most farmers. There is room for improvement surrounding the calibration of fertiliser spreading equipment and/or the use of Spreadmark certified spreaders. Access to certified spreaders is potentially a limitation.
	GMP11	Store and load fertiliser to minimise risk of spillage, leaching and loss into water bodies.	No information.
	GMP12	Ensure equipment for spreading fertilisers is well maintained and calibrated.	Refer to GMP10 above.
ANIMALS			

[11] A double negative could be read into the answers, however it has been assumed that respondents were answering; "yes I do not apply fertiliser when the soil temperate is less than 10 degrees."

FEED	GMP15	Store, transport and distribute feed to minimise wastage, leachate and soil damage.	No information
INTENSIVE GRAZING	GMP20	Select appropriate paddocks for intensive grazing, recognising and mitigating possible nutrient and sediment loss from critical source areas (CSA).	Buffer strips of a sufficient width can mitigate a considerable proportion of overland flows, e.g., associated with intensively grazed areas (McDowell, et al., 2008) In the survey, farmers were asked: Do you use uncultivated buffer strips of at least 2m on flat land and wider on sloping land to filter runoff? – 68% said yes. The survey also asked: Do you leave gullies and swales uncultivated on rolling down country (refer photo)? – 69% responded yes.
	GMP21	Manage grazing to minimise losses from critical source areas.	Good grazing management was the most prevalent theme in the additional comments. Comments varied but there seemed to be an understanding of links between nutrient loss risk and grazing management. Two facets were seen: 1. Less intensive grazing rotations allow for better pasture covers, thereby aiding in the filtering of runoff, especially on steeper terrain (Lambert, Devantier, Nes, & Penny, 1985). This was exemplified by the comments: *"… less (grazing) pressure on steeper country, good stock management grazing…"* *"…Grazing longer rotation, longer grass across the whole farm."* *"…(We use) rotational grazing, (and) don't over graze."* 2. The impact of stock on critical source areas: *"…fencing of gullies and graze very lightly in winter (with) sheep only…"* *"…Careful where graze cattle and monitor weather (to reduce) pugging…"* *"…Managing grass next to rivers, strip graze stock"*
POINT SOURCE DISCHARGES			

POINT SOURCE DISCHARGES	GMP22	Manage point sources such as offal pits, rubbish holes, silage pits to avoid contamination.	No Information

Case Studies

10 HDLG farms had historical changes modelled in OVERSEER to quantify the impact of "plausible" dryland farm development on nitrogen loss. Development was defined as "plausible" to contrast it from previous predictive development scenarios for dryland farms. Plausible in this case is to infer common and/or undertaken development that might be seen in the future given historic trends.

Each farm had a nutrient budget generated for a time in the past and the current day. Historical nutrient budgets represented 6 to 45 years ago, with the average period being 24 years ago. The case study farms are considered to provide a fair representation of "plausible" dryland development but no link is made to catchment level development trends due to the size of the sample. A comparison of the 10 case study farms trend to the survey results showed differing trends in stocking rate. Given the size of the sample for the case study, no statistically significant trend has been drawn from the results. There is a further brief discussion in the results.

Phosphorus loss is highly impacted by critical source area management (Mcdowell & Wilcock, 2009). As OVERSEER is not the most effective method of modelling or predicting critical source areas, phosphorus loss was not a focus of the analysis. Further exploration of the impact of phosphorus losses is included in the general discussion.

The results from this section have been broken into:

- Overall OVERSEER results
- 'Developments' undertaken by the case study farms and a commentary[12]
- A summary
- GIS comparisons
-

[12] Irrigation development has been excluded from the discussion as any further irrigation would put it through a consenting process with ECan, thereby requiring the farm to quantify the impact.

Case study OVERSEER results

	Mean annual Rainfall	Farm description[13,14]	Historic N Loss (kgN/ha/yr)	Current N loss (kgN/ha/yr)	Historic stocking rate (SU/ha)	Current Stocking rate (SU/ha)	Historic % total area in wf	Current % total farm area in wf	Historic % total farm irrigated	Current % total farm irrigated
Farm 1	769	~300ha Flat	20	18	10.8	11.4	0.0%	0.0%	14%	0%
Farm 2	716	~600ha flat	17	17	13.1	11.9	7.7%	3.6%	0%	7%
Farm 3	993	~800ha easy hill	16	15	10.4	9.7	0.0%	0.0%	0%	0%
Farm 4	801	~400ha easy hill	21	22	8.3	9.2	0.0%	0.0%	0%	0%
Farm 5	628	~2500ha easy hill	9	14	3.0	4.4	0.0%[15]	2.4%	0%	0%
Farm 6	597	~500ha rolling	14	15	7.6	10.6	10.6%	10.8%	0%	0%
Farm 7	815	~600ha rolling	10	12	8.4	9.6	1.8%	2.2%	0%	0%
Farm 8	1328	~7000ha steep hill	10	8	1.0	0.7	0.0%[15]	0.0%[15]	0%	0%
Farm 9	954	~1000ha easy hill	21	26	9.3	8.9	5.1%	13.2%	0%	0%
Farm 10	765	~800ha easy hill	10	12	3.4	5.0	0.0%	0.0%	0%	0%

Table 8. Case study OVERSEER results

[13] Farm areas have been rounded to the nearest 100ha to protect anonymity of the farms.

[14]Described topography is the predominant slope class on farm as defined by OVERSEER®:

Slope Class	Access description	Slope	LRI 1 class *
Flat		0° to 7°	A-B
Rolling	Area mostly navigable by tractor	8° to 15°	C
Easy	>50% area navigable by tractor	16° to 25°	D-E
Steep	<50% area navigable by tractor	26° or more	F-G

(OVERSEER®,2018)

[15] There was an area of winter forage crop but it fell below 0.0% of the total farm area

Developments undertaken on case study farms

Change	OVERSEER estimated influence on N loss	Literature and case study result commentary
Stock genetics	None	Improvements in animal genetics tend to improve efficiency of animal production and resilience to health issues. Changes in whole mob/herd genetics occur over many years and do not directly affect nutrient loss. Efficiency effects (e.g., more wool and/or lambs per sheep) could have an indirect impact on nutrient loss. The association is most closely linked to a change in stocking rate that may occur due to increased efficiencies.
Stock breed	Low	Subject to the weight of the animal being similar then there would be no impact on the environment. However, many stock breed changes will result in a net change in average animal weights, affecting nutrient loss through several mechanisms. Animal live weight is known to affect both the amount and concentration of nitrogen in excreta (Smitha & Frostb, 2000). This relationship is not linear, as improvements in live weight can also have a marked impact on fecundity and potentially improve eco-efficiency (MacKay, Rhodes, Powers, & Wedderburn, 2011). Therefore, stocking rate, in combination with animal live weight, dictates the impact on the environment. A change in animal live weight without changing overall animal numbers will also change the stocking rate.
Stocking rate	High	The OVERSEER® case study results suggested an increase in stocking rate could be a surrogate for many changes that increase nitrogen loss. In the case studies where the overall nitrogen leaching did not increase, and stocking rate did, other factors influenced the overall nitrogen loss, e.g., decreased winter forage area or removed irrigation. However, on the pasture blocks where the influence of stocking rate could best be identified, nitrogen loss had still increased. The offset of lower winter forage area nitrogen losses impacted the overall nitrogen loss. The case studies suggested that while many farm management decisions and improvements had minimal impact on nitrogen loss, subsequent influences on stocking rate were of more consequence for OVERSEER estimates of nitrogen loss.
Pasture species/sward mixes	Low	There few pasture species options in the OVERSEER® model so it was not possible to estimate the impact of pasture species changes on nitrogen loss from the case study farms. In literature, pasture species can influence nitrogen loss through three pathways. These are the nitrogen concentration of the plant influencing animal excreta nitrogen concentrations, the influence

		on volume and frequency of urine deposits, and the ability of the pasture to soak up nitrogen from the soil (Hoogendoorn, Betteridge, Costall, & Ledgard, 2010).
Lucerne/clover	Medium	OVERSEER® modelling of lucerne from the case study farms consistently showed the estimated nitrogen losses to be approximately triple the grazed grass nitrogen losses (e.g., 25kgN/ha/yr compared to 8kgN/ha/yr). The influence of lucerne on overall leaching losses was mitigated by the relatively minor uptake of lucerne as a pasture option relative to the size of the farms. The exception was Farm 1 which went from no lucerne to over half the farm in lucerne.
Fencing	-	The impact of fencing on nutrient loss is directly related to critical source management. This could not be quantified in OVERSEER® but the actual fencing off of CSAs by case study farmers is likely to significantly reduce both nitrogen and phosphorus losses (Low, McNab, & Brennan, 2017).
Tracks/yards	Low	Tracks and yards can be CSAs for nutrient and sediment loss (Low, McNab, & Brennan, 2017). Given OVERSEER® assumes good management practice, any changes in placement and thoughtful planning would not be reflected in nutrient loss estimates.
Retiring marginal land	Low	OVERSEER® modelling of estimated impacts of retiring marginal land is limited to selecting productive land verses ineffective or bush. Nitrogen losses are estimated to reduce when modelled in OVERSEER® but caution should be given to their actual impact. Anecdotal evidence suggests even when marginal land is grazed it is grazed at a very low stocking rate for a short amount of time. A brief comparative OVERSEER® block analysis suggests OVERSEER® overestimates nutrient loss at very low stocking rates. Further work is needed to investigate this.
Clearing land	Medium	The modelling of clearing land, e.g., of matagouri, is limited in OVERSEER® to reflecting the relative block productivity compared to a cleared block. The modelled impact on nutrient loss is captured as a change (likely an increase) in stocking rate as there is an increase in available feed.
Winter forage crop	Medium to high	Winter forage crop is considered a critical source area for nutrient loss (McDowell, 2006). Nitrogen loss from winter forage crop comes from two key areas: 1. Cultivation to plant the crop creates mineralisation of organic nitrogen locked up in the soil, making it susceptible to leaching. 2. The high stocking rate on winter forage crop has a direct effect. These factors coupled with winter rainfall create high risk areas for nutrient loss.

		OVERSEER® estimated winter forage crop nitrogen losses on case study farms at 6kgN/ha/yr to 220kgN/ha/yr. Average nitrogen loss from dryland winter forage block was estimated at 86kgN/ha/yr (ignoring influencing factors). Average winter forage block grazed by sheep nitrogen loss was estimated at 63kgN/ha/yr. Average winter forage block grazed by cattle nitrogen loss was estimated at 108kgN/ha/yr. The blocks covered a range of rainfall, soil type, stock type grazing, fertiliser applied, crop type and rotations. Cattle grazed crops consistently had higher leaching losses than sheep grazed crops.
Summer forage crop	Medium	Summer forage crops are similar to winter forage crops but have one key mitigating factor in the significantly lower rainfall on summer forage crops on average. This is especially true in North Canterbury where summers are predominantly hot and dry.
Sheep to beef ratios	Low – medium	A slight shift from sheep to beef was seen on several case study farms. While it is unknown whether this was a long term shift or temporary, it is reflective industry trends (Beef + Lamb NZ, 2017). The impact on nitrogen loss was difficult to gauge in OVERSEER® due to myriad other changes occurring at the same time. An OVERSEER® sensitivity exercise showed that if all other factors are kept the same a 100% shift from sheep to beef increased nitrogen loss by 23% from 13kgN/ha/yr to 16kgN/ha/yr. The shifts seen in the case studies and the industry trends suggest the actual change is far slighter, around 5% shift towards beef over 10 years.
Reticulated water	None – low	Troughs placed away from water ways draw stock away from waterways. The impact on nutrient loss depends on the risk associated with stock in the waterway. OVERSEER® has limited ability to model this effect and therefore no information was gathered on improved reticulated water systems. Other benefits of reticulated water systems such as improved animal health and the ability to increase stocking rates (Journeaux & van Reenen, 2016) are likely captured in the OVERSEER® modelling through the stocking rate impact on nutrient loss.

Case study summary

The case study results showed:

1. Changes in stocking rate can be used as a proxy for quantifying the impact of nutrient loss from numerous farm developments that cannot directly be modelled in OVERSEER®. Examples of these 'developments' include improved genetics, changes in pasture species, fencing and land clearance (e.g., of matagouri).
2. Aside from irrigation, changes in stocking rate and winter forage area had the greatest impacts on estimated nitrogen loss.

3. On unirrigated blocks nitrogen leaching losses predominantly occurred from May to August. The same can be assumed for phosphorus runoff.

4. Numerous improvements and management decisions occur simultaneously on dryland farm, clouding what is driving the change in nutrient loss. However, in the case studies an increase in stocking rate and an increase in winter forage area always increased the estimated root zone nitrogen loss.

5. Current day nitrogen losses ranged from 8kgN/ha/yr to 26kgN/ha/yr. The mean was 16kgN/ha/yr. The weighted average (by farm size) of nitrogen loss was 12kgN/ha/yr.

6. To describe all the farms as sheep and beef potentially takes a narrow view of farm diversity. Sheep and beef are only two of the potentially numerous income streams commonly found on these farms. Other income sources include deer, dairy grazing, feed exporting, arable crops, tourism, and honey. Each farm’s revenue stream comes from a unique mix of activities. This diversity is closely linked to rainfall variability as the key constraint.

Additionally; in discussions of the case study results it was proposed that percentage change in nutrient losses from the case study farms could be matched to survey results and used to estimate a percentage increase in nutrient loss at a catchment scale. Statistical analysis showed that this could not be robustly achieved given the small number of case study farms relative to the number and diversity of dryland farms. However, as crude indicators, two methods of applying the case study change in nutrient losses to the catchment level were used:

1. Weighing nitrogen loss changes by farm size and sum indicated an increase of 4.1% in nitrogen losses from the plausible development on the case study farms.
2. Applying the case study results to the surveyed farms indicated a 4.9% increase nitrogen loss.[16]

[16] For this, the case study farms were segmented into those that increased, remained neutral or decreased nitrogen losses. The surveyed farms were then segmented based on historic stocking rate change (as an indicator of "development") into those that increased by greater than 10%, 10% to -10% change, and greater than -10% decrease. The segmented case study results were then weighted to the proportion of survey farms in each segment.
This method relies on matching survey farms change in stocking rate to a change in nutrient loss. The case study farms showed that this was not always the case due to other simultaneous changes. It also requires trends in nutrient loss from 3 – 4 of the case study farms. This is an extremely small sample from which to develop a trend.

	>10%	+10% to -10%	<-10%
Average N Change	+33%	+3%	-9%
Survey farms proportion	23%	35%	42%
Weighted change	+7%	+1%	-4%
Overall weighted change in N loss			+4.9%

Conclusion

"For a range of reasons, it is realistic to assume agriculture is moving into a phase where productivity growth will be driven by greater efficiency of use of fixed and variable inputs rather than an increase in input levels. This will occur against a background of climate change, which will place particular stress on industries limited by water supply (Robertson, 2010)*."*

This statement summarises the trends and limitations dryland farms in the Hurunui and Waiau can expect during the foreseeable future. The indicators of intensification, i.e., an increase in stocking rate or winter forage area, are declining or static at a catchment level. Add to this, whilst numerous development options and farm management decisions are possible on any given farm, the overall nutrient loss impacts of these changes are limited at a catchment scale given the variability in climate constraining any given farm.

The responses to the good management practice questions, including comments, suggest a 75% uptake amongst dryland farmers. Key risk areas, including erosion and soil conservation, were issues of focus and their management a strength among those surveyed.

Environment Canterbury and the Hurunui Waiau zone committee have a focus on winter forage grazing by cattle. The research suggests that its impact on nitrogen loss is minimal and the emphasis should be on critical source area management. Done well, this is likely to mitigate a substantial portion of risk of nutrient loss associated with winter forage grazing.

Overall the intersecting evidence suggests that at a catchment scale there are unlikely to be significant trends that would impact nutrient loss from dryland farms for the foreseeable future due to permitting dryland farming.

Recommendations

While there is a solid base of research into phosphorus and sediment losses on sheep and beef farms, there is limited New Zealand scientific research into nitrogen losses from the same systems (especially unirrigated farms in drought prone areas). Further research into nitrogen loss and attenuation in hill country catchments, especially drought prone areas, would have considerable benefit in understanding the risks and opportunities available to dryland farmers whilst protecting the environment.

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Appendix 1: Comparisons

(NOTE) This section was presented in an earlier draft to Environment Canterbury who took the results into consideration and have since made changes. The results presented here on the comparison between ECan's nitrogen loss layer and the case study OVERSEER® losses have not been updated to reflect the changes.

Ground truthing & comparisons

In the Hurunui and Waiau two other methods, other than OVERSEER®, have been used to estimate nutrient losses from dryland farming. These methods are outlined below and compared with the OVERSEER® estimates from the 10 case study farms.

Ground truthing ECan nitrogen loss layer for dryland farms

Environment Canterbury presented a draft GIS nitrogen loss 'lookup table" in 2017. This method spatially represented previous modelling done through the Matrix of Good Management(MGM) MGM project.

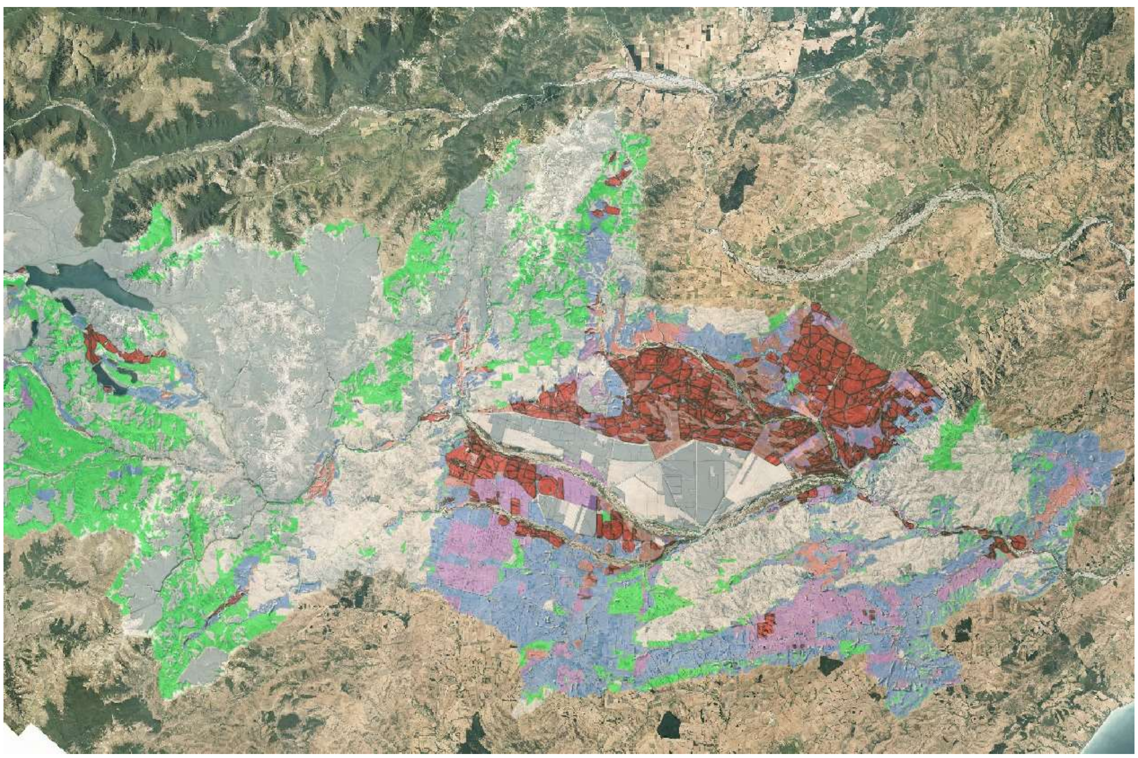

Figure 16. ECan Draft GIS nitrogen loss estimate layer for the Hurunui

It relies on publicly available information such as satellite imagery, Land Cover Database and AgriBase survey data. The HDLG was asked to ground truth the dryland component of land-use layer and associated nitrogen loss layer, while AIC would provide verification for the irrigated areas.

While difficult to check at individual farm scale, the land-use layer at catchment scale seems relatively consistent with farm land use. Detailed comparison of case study farms found these roughly similar to actual land use. More work is to be done to compare this layer at a finer scale.

HDLG was also able to compare the OVERSEER® budgets with ECan's nitrogen loss layer. The summary is provided in tables 7 and 8.

	In-river (kgN/ha	ECan N loss layer	OVERSEER® kgN/ha/yr	ECan vs OVERSEER® difference
Farm1	Flat	18.5	18	-2.6%
Farm2	Flat	18.3	17	-7.6%
Farm3	Easy hill	10.2	15	31.7%
Farm4	Easy hill	10.5	22	52.3%
Farm5	Easy hill	2.7	14	80.7%
Farm6	Rolling	10.8	15	28.2%
Farm7	Rolling	16.0	12	-33.1%
Farm8	Steep hill	3.2	8	59.7%
Farm9	Easy hill	16.8	26	35.4%
Farm10	Easy hill	7.1	12	40.8%
Average		6.6	12.0	-45%

Table 9. ECan nitrogen loss layer compared to OVERSEER® on dryland farms

The key conclusions are:

- On flatter topography there is a correlation between ECan N loss layer nitrogen root zone loss estimates and OVERSEER® nitrogen root zone loss estimates.
- On extensive hill country there was a significant difference between ECan N loss layer root zone losses and OVERSEER® root zone losses.
- Further work is needed to fully explore this difference in root zone loss estimates on extensive hill country.

Extensive hill country component N loss	ECan N loss layer (kgN/ha/yr)	OVERSEER® (kgN/ha/yr)	Factor difference
Farm3	0.5	10	20.0
Farm4	6.5	23	3.5
Farm5	2	10	5.0
Farm7	1	12	12.0
Farm8	0.5	11	22.0
Farm9	0.5	7	14.0

Table 10. Comparison of extensive hill country areas on the case study farms showing the difference between the ECan nitrogen loss layer estimates for that area and OVERSEER® estimates

In-river nitrogen load layer

The case study OVERSEER® results were compared with the in-river nitrogen load calculators (Brown, 2017). Peter Brown used water quality samples from numerous sites in the Hurunui and Waiau to estimate contributions of nitrogen from differing land classes. These land classes were then spatially mapped. This method was presented several times to the Hurunui/Waiau science stakeholders' group and nutrient working group.

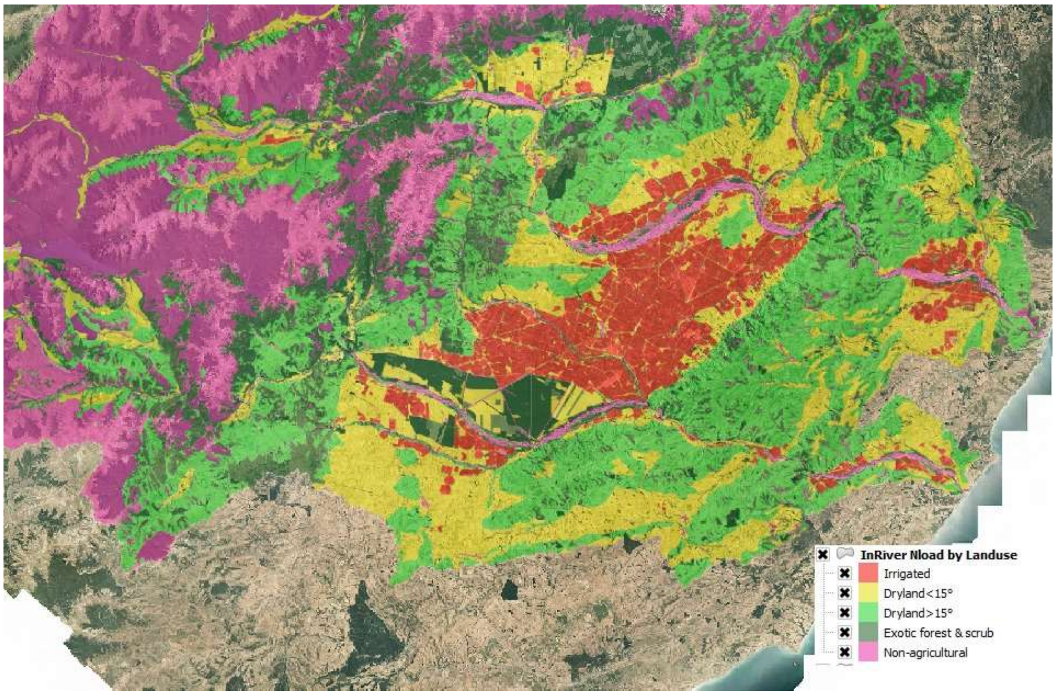

Figure 17. (Brown, 2017) In-river load layer for the Hurunui and Waiau catchments

To compare the OVERSEER® results, the in-river load layer was clipped to the spatially mapped case study farms. Using the nitrogen loss table below (Brown, 2017) the in-river attributed load was summed.

Class	Load (kgN/ha/yr)	Description
1	29.0	Irrigation
2	3.5	Dryland<15° (tractor country)
3	1.4	Dryland>15° (high country)
4	0.3	Exotic forest & scrub
5	0.3	Non-agricultural (e.g. Native forest, alpine)

Table 11. (Brown, 2017) In-river nitrogen load attribution to land-use

To allow for the variation in total area (due to farm boundary differences) both results were converted to kgN/ha for direct comparison.

The results from this comparison are displayed below:

	In-river	ECan N loss layer	OVERSEER®
Area (ha)	13,020	13,076	13,570
Total kgN	18,525	85,562	162,634
kgN/ha	1.4	6.5	12.0
Comparison factor	1.0	4.6	8.4
Estimated % of below root zone N loss likely to reach main stem of river from this method		22%	12%

Table 12. Comparison of aggregated OVERSEER® estimated below root zone nitrogen loss from case study farms and in-river nitrogen attribution from P Brown's in-river load layer.

Notes:

- For this process, case study Farm 10 was excluded as the in-river load layer did not cover its area.
- The small variation in in-river area verses ECan N loss area is due to 56ha on one case study farm lying outside the catchment, thus not covered by the in-river layer. The OVERSEER® area difference is due to farm ownership boundaries varying from actual farmed area. These variations make negligible difference to the overall comparison.

As discussed earlier, Farm 8 was a large portion of total case study area. The comparison below excludes both Farms 8 and 10.

	In-river	ECan N loss layer	OVERSEER®
Area (ha)	6,163	6,219	6,622
Total kgN	15,806	63,437	110,057
kgN/ha	2.6	10.2	16.6
Comparison factor	1.0	4.0	6.5
Estimated % of below root zone N loss likely to reach main stem of river from this method		25%	15.4%

Table 13. Comparison calculation excluding Farms 8 and 10

Appendix 2. Copy of survey form

Question	Answer	Rating	Comments
HDLG Number			
Farm Name			
Farmer			
Contact Number			
Email			
Farm Block Address 1			
Farm Block Address 2			
Farm Block Address 3			
Farm Block Address 4			
Total Farm Area			
Effective Farm Area			
Irrigated Area			
Winter Crop for Cattle Area			
Winter Crop for Sheep Area			
Winter Crop for Deer Area			
Summer Crop Area			
Farm Environment Plan completed for the Farm. (How often do you look at it)			
Nutrient Budget completed for the farm			
Effective land area 10 years ago			
Current wintered sheep numbers			
Wintered sheep numbers 10 years ago			
10 year prediction of sheep numbers			
Current wintered Cattle numbers			
Wintered Cattle numbers 10 years ago			
10 year prediction of Cattle numbers			
Current wintered Deer Numbers			
Wintered Deer numbers 10 years ago			
10 year prediction of wintering Deer			
Do you have soil moisture measuring tools (ie soil moisture tapes, probes) that you use to decide when to turn on the irrigators			
Rainfall records are kept and rainfall forecasts monitored and used in decision making			
Full pre-season maintenance checks undertaken on irrigators			

Bucket test done on all irrigators within the last 3 years			
Bucket tests showed adjustments needed to be made			
Adjustments were made to fix the issue found in bucket tests			
Staff have been trained in irrigation procedures			
Do you use conventional fertiliser			
Are you aware of the spreadmark certification program for fertiliser spreader operaters			
Are spreadmark certified spreaders available in your area			
Contractors used for fertiliser spreading are spreadmark certified			
Do you spread your own fertiliser			
Is your own fertiliser spreading equipment calibrated according to manufacturers recommendations			
Intensive land area that receives nitrogen fertiliser annually			
Average annual application rate of nitrogen on intensive land			
Extensive/hill area that receives nitrogen fertiliser annually			
Average annual application rate of nitrogen on extensive/hill country			
Intensive land area that receives Phosphorus fertiliser annually			
Average annual application rate of phosphorus on intensive land			
Extensive/hill country area that receives phosphorus fertiliser annually			
Average annual application rate of phosphorus on extensive/hill country			

Fertiliser is not applied when the soil temperate is less than 10 degrees			
GPS technology is used for precise application of all fertiliser spread (e.g. Proof of placement)			
Stock are excluded from permanently flowing waterways in intensively grazed areas			
Cattle and deer are excluded from waterways on paddocks with average slope less than 15 degrees			
Over what proportion of your extensive/hill country do you rely on surface water for stock drinking			
What is your preferred method of cultivation (direct drilled, minimum tilled, conventional tilage)			
Do you leave gullies and swales uncultivated on rolling down country (refer photo)			
Uncultivated buffer strips of at least 2m on flat land and wider on sloping land are left to filter any runoff			
Deer are provided with out of creek wallows			
Effective measures are taken to prevent fence line pacing (very little fence line pacing)			
How many sediment traps/dams do you have? (Mark on map)			
Riparian plantings are established in gullies			
Riparian planting programme prepared			
Do you actively protect vegetation biodiversity and wetlands			
how many km of fencing for above			
Area of Pest Trapping for above			

Area of weed control for above			
How many km of permanently flowing waterways do you have			
Do you actively protect permanently flowing waterways			
How many km of fencing for above			
Can you describe the change in biodiversity on your property over the last generation (area and predator control)			
Additonal Comments (Anything that you do that you believe protects or enhances the environment)			

Appendix 3. Change in Sheep to Beef ratio modelling

100% Sheep – 8 SU/ha

Farm name: stock ratio 100 sheep

Farm Nutrient Budget - Whole farm

	N	P	K	S	Ca	Mg	Na
				(kg/ha/yr)			
Nutrients added							
Fertiliser, lime & other	32	18	0	21	44	0	0
Rain/clover N fixation	31	0	3	5	2	5	29
Irrigation	0	0	0	0	0	0	0
Supplements imported	0	0	0	0	0	0	0
Nutrients removed							
As products	13	2	1	2	3	0	0
Exported effluent	0	0	0	0	0	0	0
As supplements	0	0	0	0	0	0	0
To atmospheric	13	0	0	0	0	0	0
To water	6	0	5	33	12	1	1
Change in internal pools							
Plant material	0	0	0	0	0	0	0
Organic pool	32	7	0	-8	0	0	0
Inorganic mineral	0	2	-21	0	-1	-1	-1
Inorganic soil pool	0	7	19	0	32	5	29

100% Cattle – 8 SU/ha

Farm name: stock ratio 100 beef

Farm Nutrient Budget - Whole farm

	N	P	K	S	Ca	Mg	Na
				(kg/ha/yr)			
Nutrients added							
Fertiliser, lime & other	32	18	0	21	44	0	0
Rain/clover N fixation	36	0	3	5	2	5	29
Irrigation	0	0	0	0	0	0	0
Supplements imported	0	0	0	0	0	0	0
Nutrients removed							
As products	7	2	0	1	4	0	0
Exported effluent	0	0	0	0	0	0	0
As supplements	0	0	0	0	0	0	0
To atmospheric	17	0	0	0	0	0	0
To water	7	0	5	34	13	1	1
Change in internal pools							
Plant material	0	0	0	0	0	0	0
Organic pool	37	7	0	-8	0	0	0
Inorganic mineral	0	2	-21	0	-1	-1	-1
Inorganic soil pool	0	7	19	0	30	5	29