BEFORE COMMISIONERS APPOINTED
BY THE OTAGO REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the Proposed Otago Regional Policy Statement 2021 (Non-freshwater parts)
AND	
IN THE MATTER	of the First Schedule to the Act
AND	
IN THE MATTER	of a submission under clause 6 of the First Schedule.
BY	**BEEF + LAMB NEW ZEALAND LIMITED** **Submitter**

BRIEF OF EVIDENCE OF JANE MARIE CHRYSTAL FOR BEEF+LAMB NEW ZEALAND LIMITED

23 November 2022

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BACKGROUND

Qualifications and Experience

1. My full name is Jane Marie Chrystal.

2. I am the Principal Science Advisor – Farm Systems & Environment for Beef + Lamb New Zealand (B+LNZ). I began this role in October 2020. Prior to this, my role with B+LNZ was Senior Environment Data Analyst. I began in that role in April 2018.

3. I have a PhD in Soil Science from Massey University (2017), a postgraduate diploma in Agricultural Science (Massey University, 2011), a Bachelor of Applied Science majoring in Agriculture (Massey University, 2000) and a certificate in Advanced Sustainable Nutrient Management (Massey University, 2007).

4. I have over 15 years' experience in agricultural science research and advisory. My particular areas of expertise are in:

   (a) NZ pastoral farm systems;

   (b) soil science;

   (c) contaminant losses to water from NZ pastoral systems;

   (d) farm GHG emissions;

   (e) wintering systems for drystock and dairy; and

   (f) modelling of the above (4. (a) to 4. (e)) using Overseer, Farmax, AgInform and APSIM.

5. I previously worked for AgResearch Ltd as a Scientist (2017/2018) and Research Associate (2006-2017) in the Farm Systems and Environment group. I was based at Invermay just out of Dunedin.

6. I am a CNMA (certified nutrient management advisor; August 2018).

7. I am a certified greenhouse gas (GHG) advisor (April 2019).

8. I have been involved in a professional capacity in the following Otago related projects:

(a) Assessing the impacts on nitrogen leaching losses by increasing the areas of irrigated farmland in the Strath Taieri (a catchment in Otago). I conducted Overseer modelling to assess the impacts of irrigation on different soil types and under different farming systems.

(b) ORC Farmer/Grower workstream.

(c) Field research on the environmental impacts of agricultural systems in the following locations and topics:

i. North Otago Rolling Downlands – impacts of irrigation v dryland, sheep v cattle, winter crop v pasture on soil structure, nitrogen and phosphorus loss.(Houlbrooke, Paton, Morton, & Littlejohn, 2009; McDowell & Houlbrooke, 2008)

ii. Telford – impacts of low rate, low depth winter applied effluent on contaminant leaching loss.(Chrystal, 2017; Cichota, Chrystal, & Laurenson, 2016)

iii. Telford – farm systems analysis of a woodchip-based wintering barn.(Chrystal, Monaghan, Hedley, & Horne, 2016b; Chrystal, Smith, Monaghan, Hedley, & Horne, 2016)

iv. Telford – phosphorus loss from paired catchments.

v. Gore – nitrogen leaching on stony soils under restricted-duration winter crop grazing(Chrystal, 2017).

vi. Wanaka – water quality on deer farms in the hill and high country.

vii. Owaka – impacts of deer farming on water quality.

viii. Taieri, Hindon – nitrous oxide emissions from soil

ix. AgResearch Invermay farm

   a. Nitrous oxide emissions from soil

   b. Critical source area management

   c. Portable pad system for dairy wintering (Chrystal, Monaghan, Hedley, & Horne, 2016a)

d. Restricted-duration winter crop grazing v conventional (Chrystal, 2017)

9. I have been lead, or co-author in eight peer-reviewed journal articles, 12 conference papers and at least 20 other forms of dissemination.

10. I have presented expert evidence in the following:

(a) Waikato Plan Change 1 Hearing Streams 1 and 2;

(b) Horizons Plan Change 2;

(c) Canterbury Plan Change 7; and

(d) Otago Plan Change 7 (Environment Court).

11. I am a member of the NZ Grassland Association and New Zealand Soil Science Society.

12. I am a member of the NZ Grassland Association Executive Committee.

13. I am a member of the Nutrient Management Advisor Certification Programme Standard Setting Group.

14. I have practical experience working on sheep, beef and deer farms (drystock farms), as well as dairy farms.

15. I facilitated the Deer Industry NZ (DINZ) Southland Environmental Advance Party for three years, during which time they won the 2019 Environment Southland community award for Environmental Action in Water and Land Management.

SCOPE OF EVIDENCE

16. I have been asked by B+LNZ to prepare evidence in relation to the proposed Otago Regional Policy Statement.

17. My evidence discusses:

(a) The complexity and diversity of sheep and beef farms in Otago;

(b) The contaminants of concern and how these relate to land type and climate;

(c) Sheep and beef farm impacts on soil health;

(d) Impacts of climate change on sheep and beef farms and what sheep and beef farmers are doing to know their emissions impact; and

(e) Key constraints of sheep and beef farms.

18. In preparing this evidence relevant to my area of expertise I have read the following:

(a) Expert evidence of Tom Orchiston

(b) Expert evidence of Andrew Burtt.

19. I have read the Code of Conduct for Expert Witnesses in the Environment Court's 2014 Practice Note and agree to comply with it. I declare I am an employee of the submitter B+LNZ. I confirm that the opinions I have expressed in this brief of evidence represent my true and complete professional opinions. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

EXECUTIVE SUMMARY

20. Sheep and beef farms are complex and diverse. They operate in harmony with the land and climate they are situated in. Nowhere in New Zealand is this more evident than in Otago where we have lowland sheep and beef farms with lush green pastures and High Country farms with native tussock, steep slopes and harsh winters.

21. A significant proportion (13 percent) of Otago sheep and beef farms also carry deer. I have experience in deer farming as well as sheep and beef (I have worked on sheep, beef and deer farms, I have been involved in deer specific research programmes, and I facilitated the deer Southland Environmental Advance Party for 3 years) and in my evidence where I speak generally about 'drystock farms', I also include deer farms under this umbrella. When I speak of 'sheep and beef farms', I am excluding deer farms from these comments.

22. Sheep and beef farms are predominantly low input and the particular farming system operated is designed to match animal feed demand with pasture and feed supply. Management practices such as winter grazing are designed to fill a feed deficit where there is insufficient pasture during the winter.

23. Each property has unique characteristics and combinations of soil types, topographies, aspects, altitudes, rainfall patterns, and micro-climates. No two farms have the same physical characteristics, and no two farmers make the same management decisions in response to those physical characteristics.

24. The climate is important to drystock as the farming system adopted relates directly t6o the climate, soils and topography of the farms location. Farmers adopt an integrates management of the natural resources to optimize their farming business. Farmers are very aware of the need to maintain, enhance and protect their natural resources in order to maintain their viability.

25. Farmers are arguably most at risk from the impacts of climate change and thus are very aware of the need to reduce GHG emissions and mitigate the risks associated with a changing climate. The potential impact of a changing climate on farm viability is huge. Changes to the feed supply, increased risk of weed and pest incursions, new and unseen animal and plant diseases and an increased occurrence of extreme weather events, are all factors that farmers are likely to have to grapple with.

26. A successful and sustainable farming system requires sustainable management of soil, pastures, animals, and the impacts of the farming system on the receiving environment.

27. Drystock farmers are good stewards and guardians of the land. Drystock farms have significant areas of woody vegetation on their properties that provide multiple benefits in terms of native biodiversity, carbon sequestration, shade and shelter for stock, eco-corridors (areas of trees, planted areas and waterways that link significant ecological areas or habitats).

28. In the current political environment farmers are dealing with a multitude of regulatory pressures each one focusing on a single aspect of the environment that farmers are operating in. Biodiversity, greenhouse gas emissions, water quality, and farm management standards for activities such as winter grazing and fertiliser applications are all considered individually under different policy direction. However, these things do not operate or exist individually with no interaction with each other. Farmers

consider all of the above in a holistic manner and must consider the impacts of any management decision on all aspects of the farming business, farm environment and regulatory space.

29. An example of the impact of responding to one political and social pressure on other aspects of the farm and environment is responding to the pressure to reduce greenhouse gas emissions. A decision could be made to reduce stock numbers in order to reduce methane emissions and replace those stock with a cash crop (on suitable land) to ensure that income is maintained or increased. However, there may be unfavorable impacts of such a decision on soil health and nutrient losses to water due to the cultivation required for cropping and the, relatively, higher fertiliser inputs.

30. My evidence highlights the complexity of drystock farm systems and the implications of regulatory response to the complex and multifaceted aspects of the farming business and environment.

31. It is this reason that policy direction must recognise the diversity in farm systems and provide for bespoke management while enabling adoption of innovative responses that best address the impact of farming on the environment.

32. It is also important that policy recognizes the interconnectedness of farms. Farms are not operated in silos. Breeding farms in the hill and high country of Central Otago provide lambs for finishing on the flatter, easier country of the Taieri, Clutha District or North Otago. Sheep and beef farms also rear young dairy stock for the dairy sector and winter dairy animals.

33. There is an inextricable link between agricultural land uses and freshwater quality. In particular, losses of nitrogen (N), phosphorus (P), sediment and pathogens (as indicated by *E. coli*) from farming systems and practices to surface and groundwater can ultimately impact on the health of freshwater ecosystems.

34. The scale and magnitude of the impacts from agriculture on freshwater depend on a range of factors, including the type of agricultural land use, scale and intensity of land use, farming systems and practices, along with environmental conditions such as climate, and catchment and farm geology and topography.

35. Some farming activities pose a higher risk of contaminant losses to water than others. These include:

(a) Irrigation;

(b) effluent; storage, land application, management;

(c) some cropping;

(d) high stocking rates and densities; and

(e) fertiliser use, including type, timing, and load.

36. However, these risks can be managed. Mitigation approaches that are tailored to the farm including having a farm environment plan and the utilisation of farmer support tools such as soil moisture testing, irrigation scheduling, and nutrient budgeting (using tools such as Overseer) are likely to result in improved outcomes and reductions in the risk of losses of contaminants to water. Taking a tailored farm and catchment approach to the management of farming systems and practices is likely to deliver greater environmental outcomes while providing for the ongoing viability of agricultural land uses, than prescriptive one-size-fits-all standards and rules.

COMPLEXITY AND DIVERSITY OF SHEEP AND BEEF FARMS IN OTAGO

37. B+LNZ defines sheep and beef farms as one of 8 farm classes. The farm class system was devised for the purposes of the Sheep and Beef Farm Survey (Andrew Burtt explains this survey in his evidence). Of the 8 farm classes, 5 are found in Otago. These are listed below but are described fully in Andrew Burtt's evidence:

(a) Farm Class 1: South Island High Country.

(b) Farm Class 2: South Island Hill Country.

(c) Farm Class 6: South Island Breeding/Finishing

(d) Farm Class 7: South Island Finishing.

(e) Farm Class 8: mixed cropping.

38. Drystock farms predominantly farm to the grass curve. This means that the amount of pasture that they can grow, and the times of the year that it grows, dictates the livestock numbers carried and the type of system run.

39. Drystock farms are resilient and rely on harnessing the natural resources of the land and farming in harmony with regard to the ability of a parcel of land to sustainably support a particular farming enterprise.

40. It is factors such as soil type, climate, topography and geology that determine the level of production a parcel of land can sustain.

41. There is huge variation in potential pasture production in Otago. In the 1960-1980s there was a lot of published research on pasture production.

42. Radcliffe and Cossens (1974) show the differences in dryland and irrigated pasture in Central Otago and explain the importance of irrigated pasture to support livestock production. The graphs below show the seasonal distribution or pasture growth with irrigated pasture (right graph) maintaining production through January and February where it drops off considerable on dryland pasture during summer.

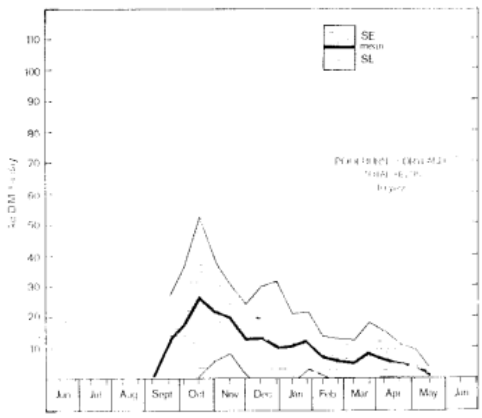


Fig. 4 — Seasonal distribution of pasture yields and standard errors for dryland pasture at Poolburn.

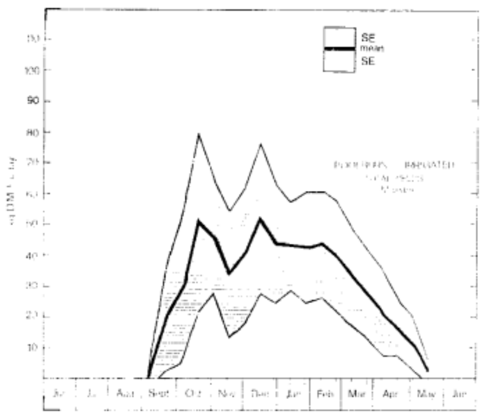


Fig. 5 — Seasonal distribution of pasture yields and standard errors for irrigated pasture at Poolburn.

Source: (Radcliffe & Cossens, 1974), Poolburn seasonal distribution of pasture yields, page 354.

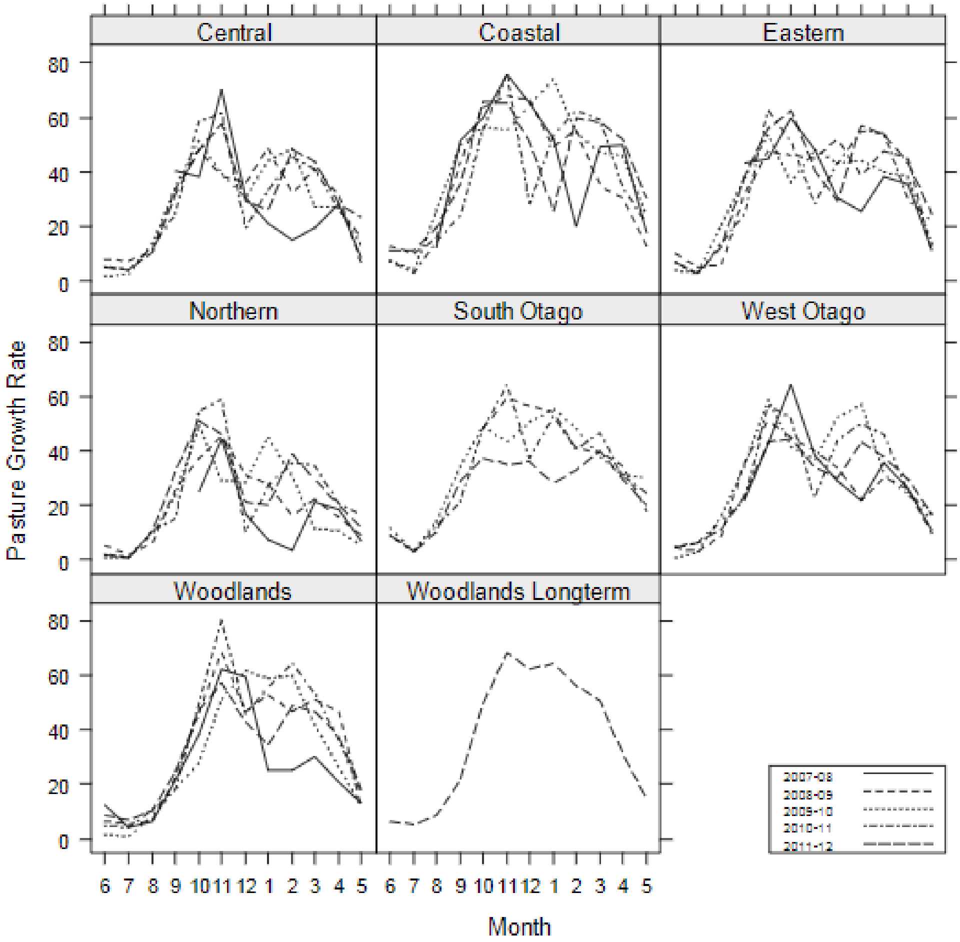
43. Radcliffe and Cossens (1974) also show the considerable increase in annual pasture production that can be achieved with irrigation (table below; 10-year mean 2,800 kg DM/ha/yr dryland compared to 8,740 kg DM/ha/yr on an irrigated sited the same year). This same table also shows the considerable between-year variation in pasture supply with dryland ranging

from 770 kg DM/ha/yr in 1967-68 to 4,570 kg DM/ha/yr in 1969-70. The irrigated range was 4,310 – 11,660 kg DM/ha/yr.

	Dryland pasture	*Irrigated pasture*
1958–59	Not measured	10 930
1959–60	Not measured	8 560
1960–61	Not measured	11 660
1961–62	4 420	9 480
1962–63	3 980	9 690
1963–64	1 890	6 350
1964–65	3 980	8 100
1965–66	2 680	5 740
1966–67	850	4 310
1967–68	770	9 220
1968–69	3 070	9 910
1969–70	4 570	10 900
1970–71	1 830	Not available
Mean	2 800	8 740

Source: (Radcliffe & Cossens, 1974), Poolburn annual yields (kg DM/ha) for 10 years (dryland pasture) and 12 years (irrigated pasture). Page 355.

44. Comparing pasture growth rates on dairy farms between different locations in Otago, Dalley and Geddes (2012) show both the between-year variation within a site and between sites, and the different pasture growth rate curves between locations.



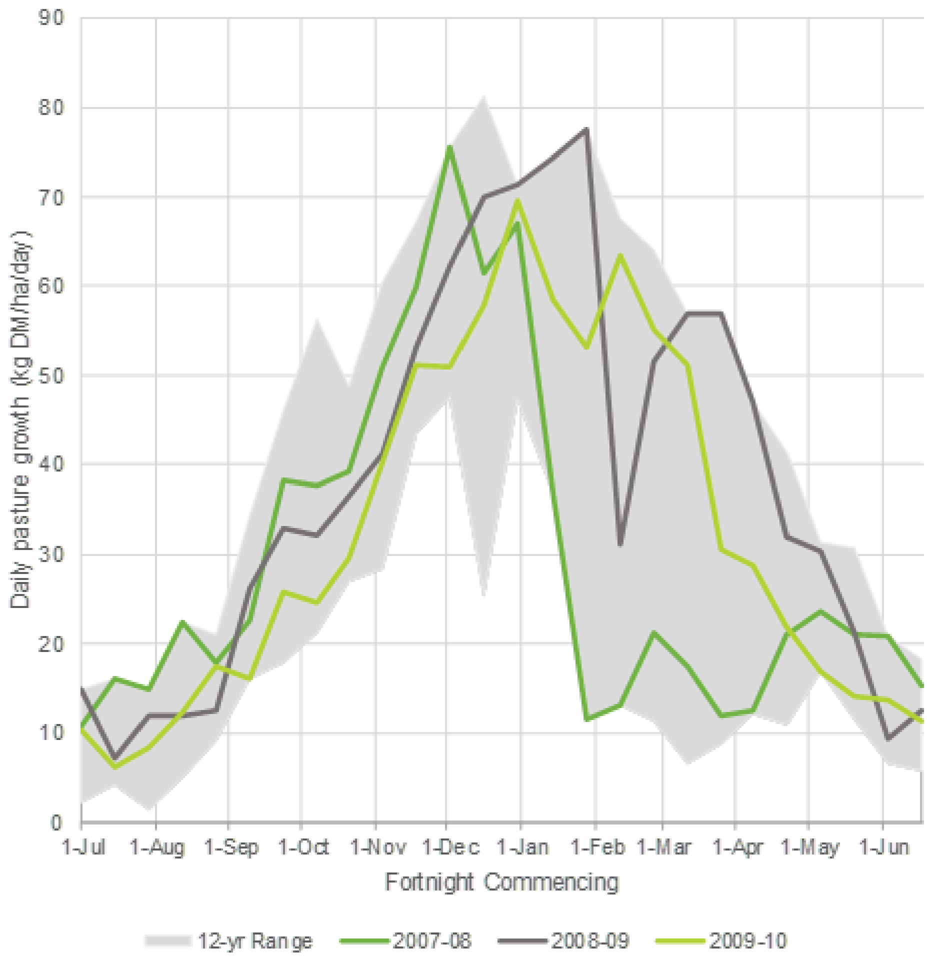
Source: (Dalley & Geddes, 2012), Figure 1, Average monthly pasture growth rate (kg/ha/day) for seven dairy sites across Southland and south and west Otago from August 2007 to May 2012 and Woodlands long-term average growth rates under sheep grazing from 1978 to 2007.

45. In addition to the variation between farms of total annual potential pasture production and the growth rate curve, there is also considerable between year variation for a single location. Due to climate conditions the amount of feed grown and when that feed in grown can change year-on-year. Drystock farms remain flexible enough to adapt their stock numbers to match feed demand to feed supply.

46. This variation between years is highlighted by some pasture growth rate modelling I did for a Waikato situation using the modelling tool APSIM (Holzworth et al., 2014). It highlights:

(a) The wide range in pasture growth rates that occur in response to annual climate patterns; and

(b) The variation in daily pasture growth rates between seasons, which (in the Waikato case) is greatest during summer/autumn.



47. There are a number of key factors that influence the pasture growth rate potential. These are:

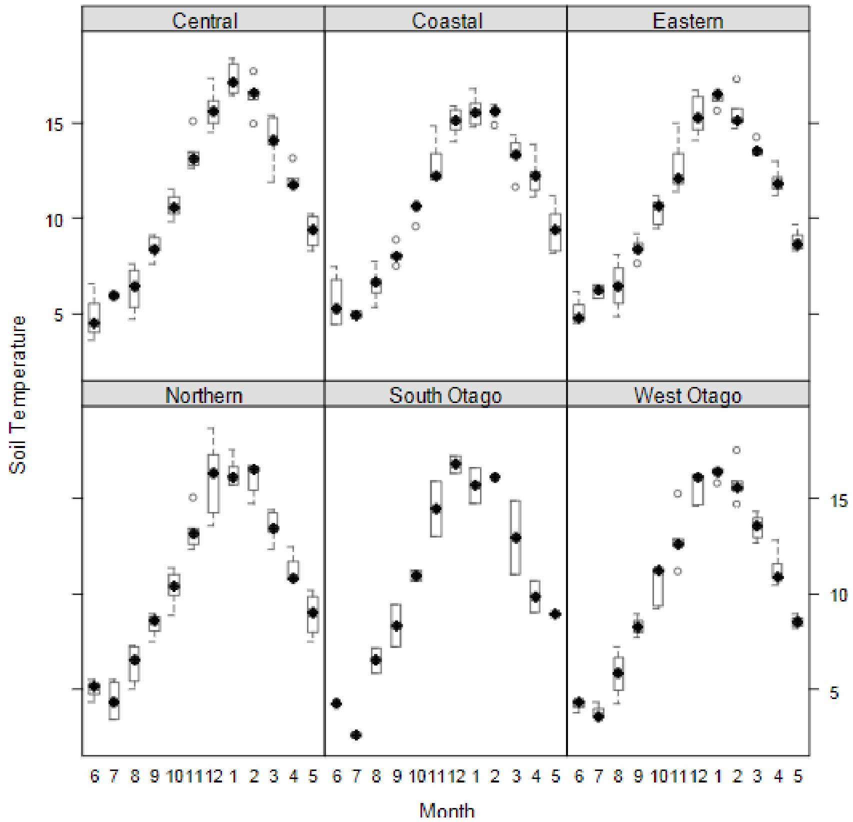
(a) Soil temperature;

(b) Water availability;

(c) Soil fertility; and

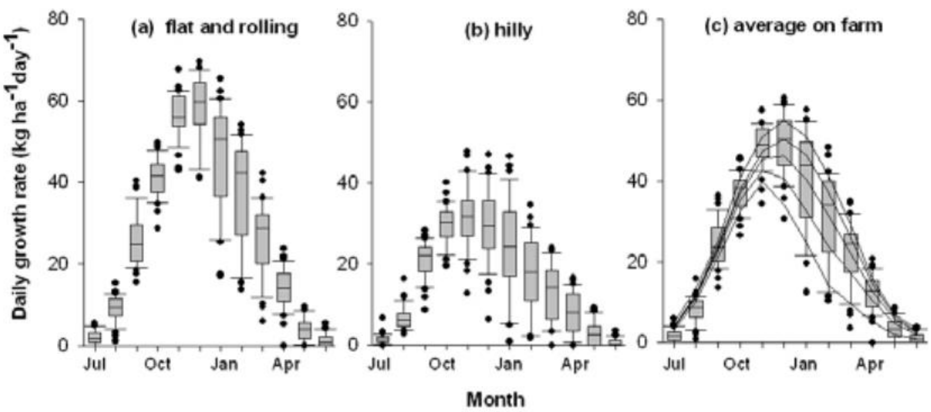
(d) Topography.

48. Dalley and Geddes (2012) show the average monthly soil temperatures for the different sites (below) and there is a clear comparison with the pasture growth rate curves seen in the figure above.



Source: (Beukes, Gregorini, Romera, & Dalley, 2010), Figure 2, Average monthly soil temperature (10 cam at 10 am) for six sites across Southland and south and west Otago from August 2007 to May 2012.

49. Vibart, Dynes, Vogeler, and Brown (2012) show well the different pasture growth rates and seasonal patterns within a farm on the flat to rolling country compared to the hilly country which produces less pasture. These data were simulated using a pasture growth model.



Source: (Vibart et al., 2012). Figure 1, Page 79. Variation of monthly pasture growth rates over the simulated period 1971-2010 on two land classes (a) flat to rolling land (Waikoikoi soil) and (b) hills (Wendon soil), and their weighted average at farm scale. The five lines on (c) represent pasture growth rates in a year of bottom 8% (=mean of three bottom years), lower quarter (Q1 = mean of the bottom half), base (overall mean), upper quarter (Q3 = mean of the upper half), and top 8% (=mean of three top years) of annual pasture production.

50. To stretch production beyond the natural production capacity of land requires addressing the limiting factors of water and nutrient status with such things as irrigation, fertiliser, drainage, or by importing additional feed for livestock.

51. These things are not always practical nor financially sound and are thus most often seen on higher producing classes of land (flatter dairy or finishing country).

52. One common method of increasing the feed production on drystock farm is to grow an area of fodder crop, particularly to be fed in winter when pasture growth rates are low. Other alternative corps such as lucerne or plantain may also be grown. It is important that policy allows for such innovative solutions to addressing deficits in feed supply particularly as we do not know what innovative plant species may be available in the future that could help with feed production as well as such things as reduced nitrogen leaching and reduced GHG emissions.

53. Sheep and beef farms in farm classes 1, 2 and 6 are characterized by minimal nitrogen fertiliser inputs, little or no imported supplementary feed, little or no grazing-off of stock, and little or no irrigation. Thus, they are predominantly extensive, low input systems with relatively low stocking rates. The evidence of Andrew Burt discusses this in more detail.

54. While irrigation is not used extensively it is an important component of some farm systems as it provides a buffer against Otago's climate variability.

55. These more extensive, low-input farms have significant areas of indigenous biodiversity in both flora and fauna.

56. Policy needs to be broad enough so that farmers have the flexibility in their farming systems to ensure that their farming systems are resilient, and that biodiversity and the health of the environment is maintained and/or enhanced. For example, farms may intensify certain areas of their property

and farming system to allow them to retire other areas (e.g. to regenerating native) while still remaining profitable and resilient.

57. As mentioned, sheep and beef farms systems are designed around the natural characteristics of the land. Andrew Burtt's evidence shows that these different and diverse farm systems are all able to be profitable.

58. It is important to understand the interconnectedness of drystock farms. A high or hill country farm may produce lambs, calves and fawns to be finished on a lowland farm. Finishing farms may rear and finish dairy origin cattle, drystock farms may graze dairy replacement animals year-round or over winter.

59. It is also important to understand the different land classes that these farming activities occur on. Tom Orchiston describes Land Use Capability classes (LUC). Breeding farms may be situated on LUC classes 4-7 which may not be deemed "*highly productive land for land-based primary production"* as stated in the LF-FS-O11A "*highly productive land for land-based primary production is maintained now and for future generations"* of which LUC classes 1-3 are deemed "highly productive". However, sheep and beef farmers consider their land to be highly productive and sue to the interconnectedness of the drystock sector these farms are extremely important in their ability to produce food. Most notably in their ability to produce youngstock that are able to be finished on the LUC classes 1-3. This is a much more efficient use of these farms on LUC 1-3 classes than grazing them with breeding stock. These are integrated management systems that together make the best use of the soils, climates, topographies and natural resources within, and outside of, Otago.

60. Drystock farmers are adept at tailoring their farming system to the capability and capacity of the land by incorporating flexibility in their systems they can respond to changes in feed supply, adverse weather events and market demands. They are able to generate a profitable, sustainable business in some of the more extreme locations that would be unsuitable for other enterprises such as cropping, horticulture, dairy, even forestry.

61. There is a risk that policy can result in unintended consequences. Policy that supports blanket planting of exotic forestry on what some, inaccurately, deem to be 'marginal land' could result in a loss of drystock land that was

used for breeding animals to be finished on other farms. This has implications for supply of store animals for finishing. The other implication is on biodiversity where existing drystock farms have a mosaic of land use including areas of native forest, bush and scrub. Compared to the blanket planting of a monoculture of pine trees.

62. Farmers are continuously seeking to improve their farming systems, reduce their environmental impact, meet and exceed relevant regulations, and maintain or improve their profitability. Change to new farming practices or the incorporation of new mitigations can take time. Policy makers need to understand this in the development of regulation.

63. The reason for the length of time it may take to change an aspect of the farming system is multifaceted and includes:

(a) seasonal and farm system constraints. Due to the seasonal nature of farming implementing changes may require time. For example, changing livestock breed or species requires time to breed and incorporate genetics through the herd or flock. Eliminating or reducing the use of winter fodder crops requires altering the farm system to either carry fewer stock through the winter or finding another source of feed for the existing stock. Policy makers must understand that a farming system works holistically and when one component is altered or removed it impacts the entire farming system. The loss of breeding country to blanket forestry impacts the young stock available to be finishes on the highly productive land.

(b) Financial constraints. Some changes require considerable financial investment. An example of this would be changing from border dyke irrigation to a spray irrigation. In addition to having to source finances, there is also the sourcing of the equipment, and hiring or earthworks contractors which can all hold up and delay such a project.

(c) Priority considerations. Farmers have many areas in which they are wanting to make improvements, and many different policies they are responding to. Part of the Farm Planning process is to identify actions and then to prioritise those with the time and finds available.

(d) Availability of materials. The ability of farmers to source materials for different mitigations and activities varies, particularly if there is a new policy or mitigation that a large number of farmers adopt. An example of this is the lack of native seedlings in Southland when the 1 Billion Trees plan came out. All of a sudden there was a dramatic increase in the demand for native seedlings and some farmers were unable to source native seedlings, that were suited to their region, for a number of years while supply caught up with demand.

CONTAMINANTS OF CONCERN FOR SHEEP AND BEEF FARMS

64. Nutrient and contaminant management on farms is important because it can affect the quality of water in rivers, lakes, and streams, as well as groundwater reservoirs in relation to nitrogen. Farming practices can lead to an impact on the aquatic environment via nutrient and contaminant losses to water.

65. The main contaminants of concern on sheep and beef farms are nitrogen, phosphorus, sediment and faecal microbes. The level of risk for contaminant loss varies between farms and also varies depending on the receiving waterbodies.

66. Most elevated losses of N and P to water begins with an enriched source area being mobilized. This can result from nutrient input (e.g. fertiliser) or mobilization of nutrients already in the system. The enriched sources of N and P and loss pathways are depicted in Figure 1. These include:

(a) Cultivation;

(b) Fertiliser spreading;

(c) Effluent spreading; and

(d) Dung and urine deposition.

67. Losses to water are in surface runoff and drainage.

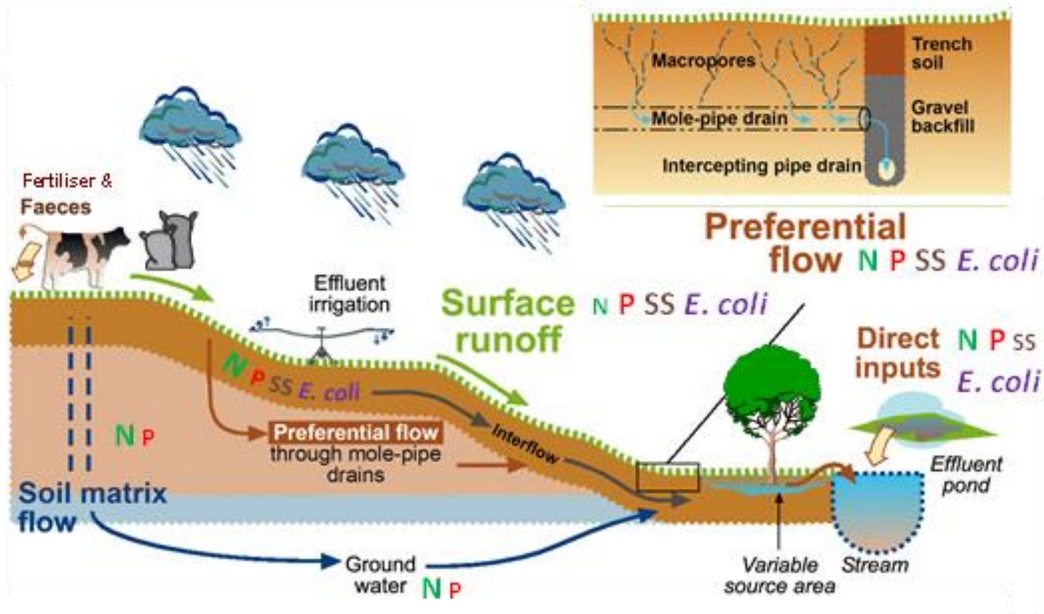


Figure 1:Conceptual diagram of the transport pathways involved in the transfer of contaminants (N, P, SS, and E. coli) from land to water. The presence and relative size of each of the contaminants indicates the importance of the pathway to contaminant-specific loss (McDowell, Monaghan, Close, & Tanner, 2016))

68. The predominant pathway for loss of phosphorous, sediment and faecal microbes (*E. coli*) is via surface runoff. For nitrogen the predominant pathway for loss is leaching through the soil profile.

Nitrogen loss to receiving waters

69. The predominant pathway of N loss is via leaching rather than surface runoff (Figure 1). This is because:

(a) nitrate (NO_3^-) is generated in soil (Figure 2), and

(b) is not adsorbed by positively charged soil surfaces.

70. Leaching of nitrate occurs when there is nitrate present in the soil in excess of plants requirements at a time when there is drainage occurring.

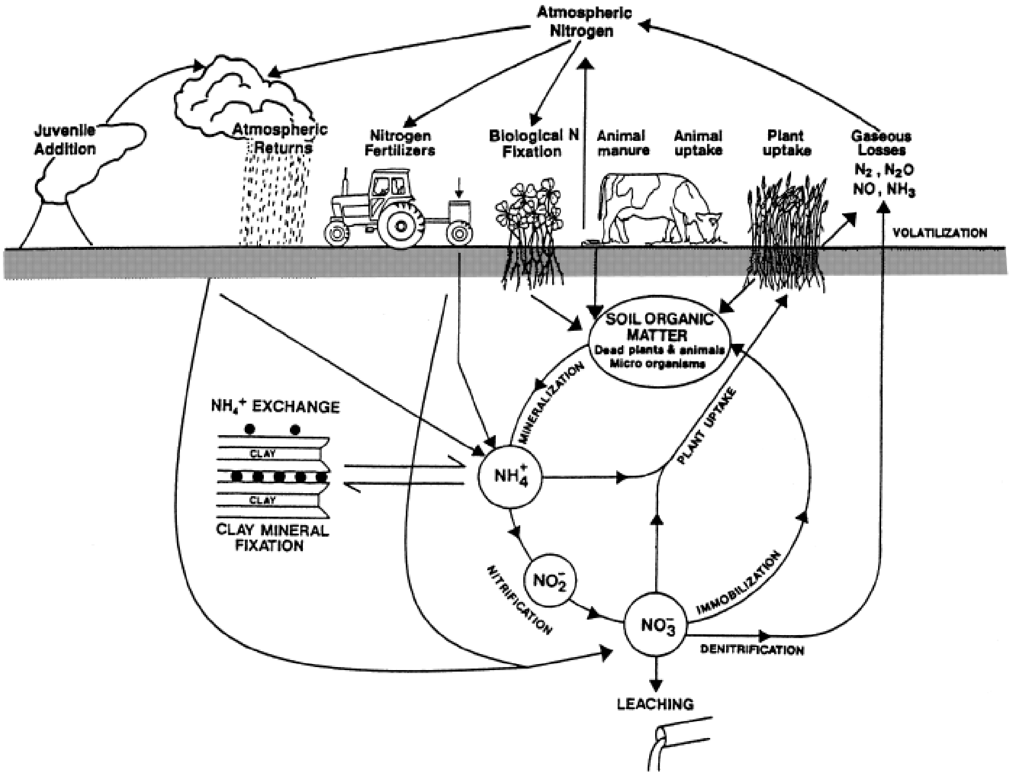


Figure 2: The Nitrogen Cycle in agricultural systems ((Di & Cameron, 2002), Figure 1)

71. The main drivers of N leaching are:

(a) Urine patches. Effected by the: stocking density (higher = greater losses), stock class (mature cattle > young cattle > deer/sheep > lambs), concentration of N in urine (high protein feed increases urinary N).

(b) N fertiliser. Via: applying excessive fertiliser that exceeds plant requirements, applications during high-risk months of the year (around winter), applications directly followed by a heavy rainfall event. Direct inputs of N fertiliser to water is a cause of increased N in waterways but not via leaching.

(c) Effluent. Losses via: preferential flow pathways, high application depths (>20 mm), ineffective effluent systems, application at high risk times of the year. Direct discharges to waterways is a cause of increased N in waterways but not via leaching.

Phosphorus loss to receiving waters

72. The predominant loss pathway for P to waterway is via surface runoff (also known as overland flow or surface flow). This is because P is attached to soil particles and is lost during erosion events.

(a) Examples of this are stream bank erosion caused by stock accessing streams; fence pacing; wallowing by deer; bare soil; heavy animals on steep slopes.

(b) In addition, the soil Olsen P level is an important consideration. When Olsen P exceeds optimum soil test levels there is an increased risk of P loss during surface runoff events.

73. Losses of P are very site specific and occur from a small percentage of the landscape from areas commonly referred to as critical source areas (CSA).

74. As P loss is strongly related to losses from CSAs then identifying these areas and applying good management and mitigation practices to manage CSAs can result in considerable reductions in the losses of P, sediment and faecal microbes (represented as losses of *E. coli)*.

75. In summary the main drivers of P loss are:

(a) Losses of sediment and soil. This occurs in CSA's and a small area of the farm can be contributing the majority of the P loss.

(b) Olsen P levels. Levels above the optimum for pasture or crop result in increased P losses.

(c) Fertiliser form, timing of applications and loading. Applications of fertiliser and/or effluent and rainfall events causing overland flow can result in losses of P. Readily available forms of P fertiliser have a high risk of losses than slower release forms such as reactive phosphate rock (RPR). Levels exceeding plant requirements increase the risk of losses.

(d) Effluent applications causing ponding (when the soil infiltration rate is slower than the effluent application rate) increases the risk of effluent P losses.

76. As mentioned above there are other important contaminants that are lost from agricultural landscapes. These are sediment and *E. coli.* The main

loss pathways for these are in surface runoff. Therefore, management practices addressing CSAs and the avoidance, or interception of, surface runoff result in the reduction of multiple contaminants (P, sediment and *E. coli*).

77. Management practices that involve the interception of nutrients and contaminants lost in overland flow include:

   (a) Buffer strips. A strip of grass left to decrease P sediment and *E. coli* in runoff by a combination of filtration and improved infiltration.

   (b) Sediment traps are used for the retention of course sized sediment. The water flows into the 'trap', which should be longer, wider and deeper than the existing channel bed, the sediment drops to the bottom of the 'trap' and the filtered water flows out. These need to be emptied of sediment on a regular basis.

   (c) Natural and constructed wetlands

      i. Natural wetlands can be a sink or source of P. Particularly if the input is sediment-rich (e.g from cropland or largely from surface runoff). As a wetland becomes choked with sediment its ability to retain P decreases. The form of P retained by wetlands is particulate P rather than dissolved P.

      ii. Constructed wetlands can be designed to remove P from waterways by decreasing flow rates and increasing contact with vegetation thus encouraging sedimentation.

High risk farm management practices that increase nutrient and contaminant losses to water

78. Higher risk farm management practices that have the potential to result in increased losses of nutrients and contaminants are:

   (a) Some cropping. This is a high-risk farm management practice as it has the potential to incorporate some or all of points b to e below. To reduce the impact of grazing any or all of the points b to e can be addressed to minimise risk.

(b) Cultivation. This can leave soil exposed and vulnerable to erosion. Erosion results in losses of, primarily, P and sediment. Cultivation also results in mineralisation of the N in the soil which is then available for either plant uptake – or in some cases leaching to groundwater.

(c) Intensive grazing on wet soils. The impact of intensive grazing can occur in two ways. Firstly, having a large number of animals per area results in soil damage which can increase the risk of overland flow and thus losses of P, sediment and *E. coli.* It also can reduce subsequent pasture growth. Secondly, it results in an area where there has been a condensed area of urination events. Animal urine is high in N and large concentrations of N deposited on wet soils (where the soils are at or nearing field capacity) results in increased N leaching losses. Stocking density for dairy cows during the milking season can be around 70-90 cows/ha for a 24-hour period. Based on a dairy cow being 7.5 stock units this equates to a stocking density of 525-675 su/ha. During winter grazing this figure can be a stocking density of 300-600 cows/ha (2,250-4,500 su/ha) in the north of New Zealand (Drewry, Cameron, & Buchan, 2008). The impacts on both soil structure and N leaching are increased when the area is grazed by larger animals. This is due to the size of the animal and also the volume and concentration of urinary N. For example the figures most often quoted for urinary N load are 500 kg N/ha for a ewe and 1000 kg N/ha for a dairy cow (Haynes & Williams, 1993).

(d) Intensive grazing on soils with a low soil water holding capacity (e/g stony soils and excessively free-draining soils). In these situations, the main risk is N leaching loss. This comes from large numbers of animals per area held for periods of time resulting in large numbers of urination events per hectare. As these stony and excessively free-draining soils have a low capacity to hold water the N in the urine patches is more prone to leaching during rainfall events. The higher the stocking density the higher the risk and also the larger the size and higher the N concentration in the urine patches the higher the risk of N leaching. Thus mature female cattle have a higher risk than sheep/deer or younger cattle.

(e) Fertiliser applications. Fertiliser applications need to be calculated using current soil test results to ensure that nutrient applications do not exceed soil and plant requirements for optimal soil nutrient pools and for plant growth. The two pathways of nutrient loss from fertiliser applications are:

i. Direct applications into waterways, and

ii. When nutrients exceed requirements and are available in the soil to be lost via leaching when drainage events occur.

79. Despite saying that different farm practices have different nutrient outputs. There are other factors that impact on the degree of nutrient loss. These include soil type, climate and topography. So identical farming systems and practices could occur on different soil types and under different climates and result in different nutrient loss values.

80. The impact of this on pORPS is that it is extremely important to realise that there is no 'one-size-fits-all' approach to farm mitigation strategies. It is important that the policy direction recognises the diversity in farm systems and provides for adaptive management. It is also important that policy enables the adoption of innovative responses that best address the impact of a particular farm on the environment. This is addressed in the evidence of Tom Orchiston.

81. The sections above outline the main contaminant loss pathways and risk factors that should be considered when developing policy frameworks to support sustainable and resilient farming systems and land use practices. For nitrogen the main levers are in relation to stock type and stocking rate relative to the farms soil, geology and climate, feed types, grazing management, fertiliser application, effluent management, irrigation, and crop grazing management including stocking density. For phosphorus, sediment and *E.coli* the main levers are in relation to mitigating overland flow so intercepting or preventing overland flow pathways from connecting to waterways, reducing P in the system (optimum Olsen P levels rather than high levels), excluding cattle and deer from waterways (where practicable).

SHEEP AND BEEF FARM IMPACTS ON SOIL HEALTH

82. There are a number of land use management practices and systems that impact soil health indicators such as compaction, water infiltration rate, and organic matter.

83. Stocking density (the number of animals on an area of soil at one time) impacts soil compaction, especially when grazing by heavy animals and high stocking densities occur at times when the soil is saturated.

84. Sheep and beef farms, especially those that are more extensive and have lower stocking rates, generally have less of a negative impact on soils as the weight of animals, on the soil during high-risk periods, is lower than other systems with higher stocking rates. Sheep also have less of an impact on soil compaction than heavier cattle.

85. Soil erosion from sheep and beef farms often occurs on steep slopes and on certain soil types. Farmers employ a number of mitigation measures to reduce the risk of erosion, including:

    (a) retiring high-risk areas of the farm;

    (b) not grazing higher-risk areas with heavy animals or at high-risk times of the year (e.g. winter);

    (c) protecting critical source areas;

    (d) large riparian buffers; and

    (e) sediment traps.

86. New Zealand soils have relatively high carbon contents compared to other soils internationally. This is due to their comparatively young age. Grazed pasture systems increase or maintain the carbon content of the soil, particularly compared to a pine forest. It has been found that afforestation of grassland soils can reduce the carbon levels in the top 10 cm layer of soil by 4.5 t/ha in the short-term, however after 20 years or longer the soil Carbon difference between the two systems disappears (Davis & Condron, 2002).

87. A study looking at pine compared to pasture sites found that the pine sites had, on average, 17.4 t C/ha less than pasture sites (Hewitt et al., 2012)

88. Conversions of pine plantation to pasture have recorded an average soil carbon accumulation rate of 1.67 t C/ha/yr in the first 10 years and then 0.27 t C/ha/yr from years 10-50 (Schipper et al., 2017).

89. The table below shows the modelled soil carbon change (a negative denotes a loss of soil carbon) attributed to changing from a low-producing grassland to a different land use. Those land uses with significant losses of soil carbon compared to the low-producing grassland are; forests and cropland. Conversion to vegetated wetland significantly increases soil C

Table 1. Soil C change attributable to land-use change: LUE relative to low-producing grassland (t C ha^{-1}), the model intercept, based on McNeill and Barringer (2014), updated from McNeill et al. (2014).

Soil CMS model intercept	SOC (t C ha^{-1})	Standard error
Low-producing grassland	106.0	3.9
Land-use category	**LUE (t C ha^{-1})**	**Standard error**
Pre-1990 natural forests	−13.7	3.7
Pre-1990 planted forests	−13.5	5.8
Post-1989 planted forests	−14.1	4.9
Grassland with woody biomass	−7.8	3.7
High-producing grassland	−0.6	3.1
Perennial cropland	−17.5	6.4
Annual cropland	−16.2	4.5
Vegetated wetland	30.1	8.5

Source: (Schipper et al., 2017), Table 1.

CLIMATE IMPACT MITIGATIONS

90. Farmers are arguably most at risk of a changing climate. The impacts of drought, floods, extreme heat or cold and changes to the annual climate impact pasture and crop production. Increased temperatures mean that different plant, and animal pests and diseases are seen in regions where they were not previously found. For example, facial eczema is increasingly being seen further south in the country than previous decades.

91. In response to the Government stating that agriculture will be charged for their greenhouse gas emissions, a Primary Sector Climate Action Partnership called He Waka Eke Noa, was established (www.hewakaekenoa.nz).

92. While there has been much angst, farmers have embraced the He Waka Eke Noa milestone targets of all farmers knowing their GHG emissions number by the end of 2022 and having an action plan to reduce those

emissions. The target is to have 100% of farms with a written plan in place to measure and manage their emissions by 2025.

93. Over 8400 sheep and beef farmers know their number, over 3000 have attended more than 250 B+LNZ GHG workshops which lead farmers through the B+LNZ GHG calculator which calculates their GHG emissions. At these workshops farmers also learn about the mitigation options available to sheep and beef farms, and can incorporate into their GHG action plan, those that are relevant to their farming system.

94. Sheep and beef farms have significant areas of woody vegetation on their properties that provide multiple benefits in terms of native biodiversity, carbon sequestration, shade and shelter for stock, eco-corridors (areas of trees, planted areas and waterways that link significant ecological areas or habitats).

95. At a sector level GHG emissions from sheep and beef farming has reduced by 30% since 1990. At a farm level there has not been a significant increase in GHG emissions per hectare despite a significant increase in agricultural production from sheep and beef farms.

KEY CONSTRAINTS OF SHEEP AND BEEF FARMS

96. "SRMR – I2 – *Climate change* is likely to impact our economy and *environment"* (p 67 pORPS June 2021). The implications of climate change are also important for sheep and beef farmers in Otago. Climate change has the potential to alter the pasture production in the region. Implications could be:

(a) a decrease or increase in the total annual pasture production,

(b) a change to the shape of the pasture curve potentially resulting in:

i. a change in the times of the year for feed constraints

ii. a change to the annual pattern of feed supply

(c) a change in the pasture weeds and pests in the region,

(d) a change in the pasture species suitable for the new climate.

97. Climate change also has the potential to impact the animal pests (SRMR – I3, p69 pORPS) and diseases experienced in the region or the suitability of different livestock species to the changed climatic conditions (maximum and minimum temperatures, snow falls, etc).

98. These potential changes to the climate will impact the sheep and beef farming systems. Due to the nature of drystock farming systems being based around the pasture supply, as this changes, so too could the farming systems. In the future sheep and beef systems may see changes to:

(a) Wintering systems;

(b) Peak animal numbers and the timing of this peak;

(c) Livestock trading policies; and

(d) Sheep to cattle ratios.

99. It is important that regional policy allows flexibility into the future for farms to continue to innovate and adapt to a changing climate as well as a change in consumer demands while maintaining the health and wellbeing of all aspects of the physical environment.

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