BEFORE THE HEARINGS PANEL

IN THE MATTER	**of hearings on submissions concerning the Proposed One Plan notified by the Manawatu-Wanganui Regional Council**

SUPPLEMENTARY EVIDENCE OF DR ALEC DONALD MACKAY
FOR THE END OF HEARING REPORT (WATER)
ON BEHALF OF HORIZONS REGIONAL COUNCIL

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1. INTRODUCTION

1. This supplementary evidence covers some specific questions raised as part of the hearings on water concerning the Proposed One Plan notified by the Manawatu-Wanganui Regional Council. It includes discussions on the following:
   1. Dairy expansion in Southland: Predictable?
   2. Answers to questions on the Natural Capital approach using data from the LUC extended legend.
      - The natural capital based approach to the allocation of nitrogen losses limits underestimates pasture and farm productivity and associated N losses.
      - Adjustment to LUC assessment for sand country where permanent irrigation has been installed underestimates the increased capacity for long-term sustained production.
      - Anthropogenic influences on soil development.
   3. Effectiveness of N mitigation scenarios involving wintering-off dairy cows within the same catchment on the catchment outcome.

2. GROWTH OF DAIRY FARMING IN SOUTHLAND: PREDICTABLE?

2. Growth of dairying in Southland could have been predicted from an analysis of the land available for intensive pasture agriculture in the Southland Region. In Southland there has been a 2.5-fold increase in the area in dairying (from 63,000 ha in 1998-99 to 155,000 ha 2008-09) and cow numbers (from 170,000 to 418,000) in the last 10 years (Figure.1). There are still greater than 300,000 ha of land in Class 2 and 3 that could be converted in the future.

3. The growth of dairying in Southland equates to an increase of more than 9% per annum in land used for milking cows and the number of cows milked. To put that into perspective within Horizons' Region, Mr M. Newman for Fonterra provided in his evidence to the Hearing Panel some future growth scenarios based on previous growth of dairying in the Region, including the Fast Growth Scenario, which would see an annual increase in land for milking cows and number of cows milked of 1.1% and <2%, respectively.

4. Over the next 10 years the Fast Growth Scenario would see the land used for milking cows in Horizons' Region increase by 12,600 ha. That would occupy a small percentage (<5%) of the land still available for dairying. For example, in the priority catchments in the Region the potential exists for dairying on another 100,000-plus ha of land (see Figure 2b of my S42A evidence; page 21). Outside the priority catchments, a

large percentage of the Class 1-3 land (250,000 ha) located on the plains and downlands would also be suitable for more intensive uses. Scenarios of growth of the dairy sector have been presented to the Hearing Panel and it is agreed by the experts, Mr Newman, and Neild & Rhodes (2010) that growth will likely increase at a rate similar to that of the last decade. Future growth rates higher than these are possible, as shown by an analysis of the land available for intensive pastoral agriculture in the Region. Interestingly, this is located in a climate that presents a more attractive proposition than that of Southland.

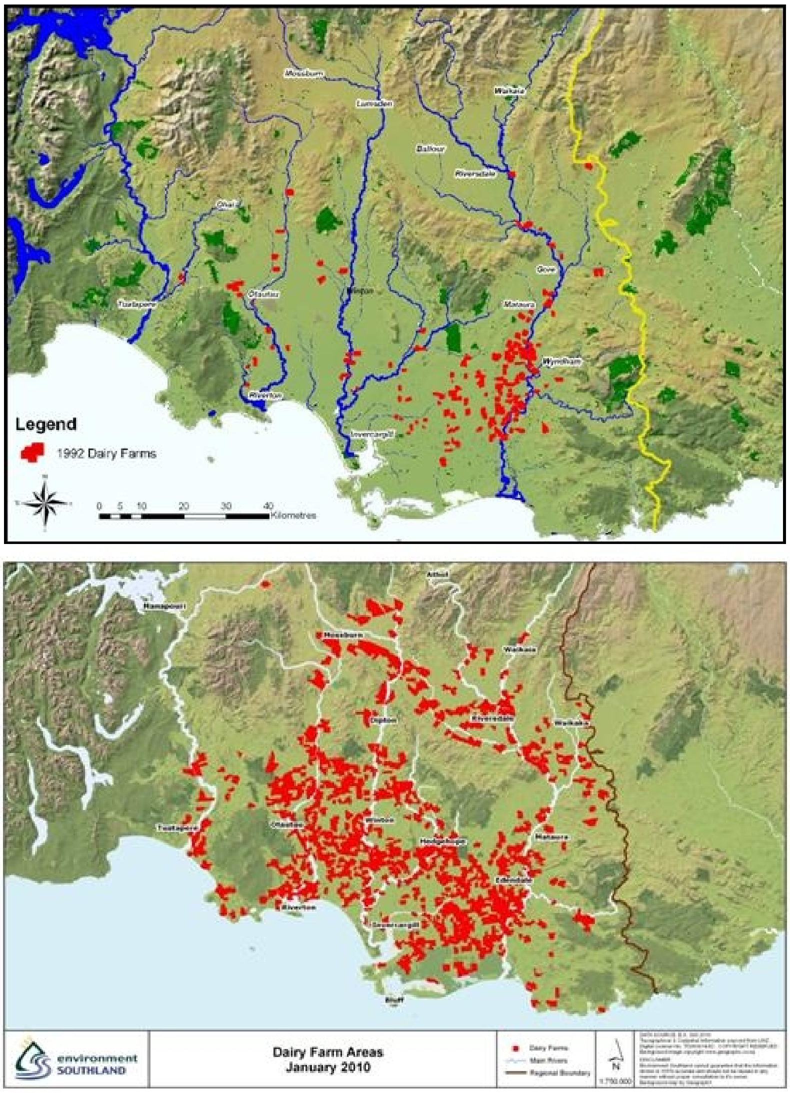

Figure 1. Dairy operations in Southland in 1992 (top) and 2010 (bottom).

5. In summary, what is certain and agreed by all experts is that the dairy industry will continue to grow, as will the other sectors of the pastoral industry, placing additional pressure on natural resources and the environment.

3. ANSWERS TO QUESTIONS ON THE NATURAL CAPITAL APPROACH USING DATA FROM THE LUC EXTENDED LEGEND

Summary of submitters' questions

6. Submitters have raised several questions on the Natural Capital approach using data from the LUC extended legend. These are grouped into the following subheadings:
   - i. The Natural Capital based approach underestimates pasture and farm productivity and associated N losses.
   - ii. Adjustment to LUC assessment for sand country where permanent irrigation has been installed underestimates the increased capacity for long-term sustained production.
   - iii. Anthropogenic influences on soil development.

7. In addressing these three topics a number of other questions raised by submitters are also addressed.

Natural Capital based approach underestimates pasture and hence farm productivity and associated N losses

8. A number of submitters have raised concerns that the Natural Capital based approach underestimates pasture and hence farm productivity and associated N losses.

9. According to the evidence in chief of Dr Roberts for Ravensdown Fertiliser Co-operative Ltd: *"N loss from grazed pasture systems is directly linked to biological productivity which is least often linked to LUC* ***where productive constraints are overcome by introducing technological advances****" (paragraph 8); "Approach* ***does not accurately reflect current agricultural practice and as such will inequitably limit or reduce future agricultural production****" (paragraph 9); "Stock carrying capacity is itself a moving target* ***as technologies, knowledge and experience allows land managers to improve pasture productivity*** *and hence carrying capacity (paragraph 19); and "It unfairly penalises farm businesses who have* ***introduced technologies and developed skills and abilities to farm productively****, despite the limitations imposed by the physical resources of the land involved" (paragraph 51).*

10. This concern was also raised by S. Newland for Fonterra: "*N loss limit for LUC Class 2-6 are to low" No recognition of existing land use decisions;* D. Smeaton for Fonterra: *"N loss in Table 13.2 for LUC Classes 3-7 should be increased to better reflect the NC approach"*; N. Sadlier for Ballance Agri-nutrients: *"Over the long-term values must be*

adapted to land use and technology changes" and C. Hansen for Ravensdown Fertiliser Co-operative Ltd: *"Subdivisions and changes in land use and value over recent years means the LUC data may not be accurate", and "Current land use are unlikely to reflect the old LUC data" (Paragraph 18).*

11. In summary, the submitters are concerned that the Natural Capital based approach, based on the potential production of a legume based pasture listed in the extended legend of the LUC worksheets, **does not recognise the technological advances that have improved pasture production and farm productivity and hence, associated N losses are underestimated.**

12. This concern is addressed in the following section by briefly recapping on the Natural Capital based approach, examining the impact technological advances have had on the production levels of a legume based pasture in the last 50 years, and exploring the contribution technological advances other than the legume based pasture make to farm productivity.

Recap on the proxy for Natural Capital

13. The Natural Capital approach is based on the ability of the soil to sustain a legume-based pasture fixing N biologically under optimum management (ie. new plant germplasm, use of P, S, K fertilisers, lime, trace elements and technologies to control pests and weeds), before the introduction of additional technologies (eg. N fertiliser, supplements). A legume-based pasture is a self-regulating biological system with an upper limit on the amount of N that can be fixed, retained, cycled, made available for plant growth and lost by leaching. It reflects the underlying capacity of soil to retain and supply nutrients and water, and the capacity of the soil to provide an environment to sustain legume and grass growth under the pressure of grazing animals.

14. Dr Roberts in his supplementary evidence (paragraph 7; which was not available for discussion at the time of caucusing) introduces data from a DSIR trial on the Judgeford subsoil (B Horizon) to suggest good legume growth can be obtained in soils of poor natural capital, because the N status of the soil is low. The definition he uses of natural capital is incomplete. The definition of natural capital is not limited to the underlying capacity of soil to retain and supply nutrients and water, but also includes the capacity of the soil to provide an environment to sustain both legume and grass growth under the pressure of grazing animals. The Judgeford subsoil (B Horizon) has little physical structure (low natural capital) and would collapse under the pressure of grazing. Inclusion of the physical integrity of the Judgeford subsoil (B Horizon) in the calculation

of natural capital identifies the Judgeford subsoil as a soil of low natural capital. The Judgeford subsoil provides a very good example of the importance of considering all of the soil's attributes in assessing the natural capital

Legume based pasture production

15. Submitters suggest that use of the estimates of the potential productive capacity of a legume-based pasture, fixing N biologically under a "typical sheep and beef farming system", for each Land Use Capability (LUC) unit in New Zealand listed under "attainable potential carrying capacity" in the extended legend of the Land Use Capability worksheets produced in the late 1970s are no longer applicable. They argue that this is because technological advances have resulted in marked increases in pasture production from our legume based pastures. This suggestion is not supported by the scientific literature.

16. There is substantial evidence to show there has been no measurable increase in the level of pasture production from our legume based pastures over the last 50 years. Hodgson (1989) found that ceiling pasture yields have not changed in 50 years. Hodgson's data were updated by Deane (1999) from research stations in Taranaki and Waikato, and from top farms in the main North Island dairying areas (Figure 2). Deane (1999) concluded that little had changed.

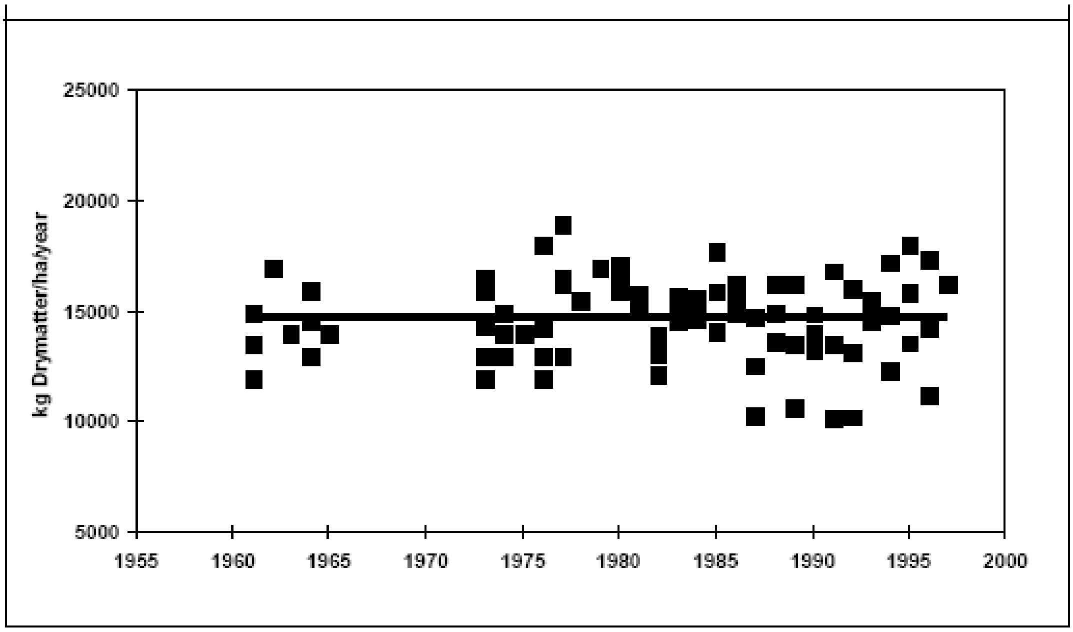

Figure 2. Annual pasture production on research stations and top farms since 1960 (from Deane, 1999).

17. The conclusion reached by Hodgson (1989) and Deane (1999) is reinforced by a recently study (Crush *et al*., 2006) that completed for the first time a comprehensive evaluation of the merits of different age-classes of perennial ryegrass (bred in the 1980s and 1998) and white clover (bred in the 1960s and 1998) cultivars. Crush *et al*. (2006) found no differences in annual pasture dry matter yield between the different age-classes of perennial ryegrass and white clover pastures. Yields averaged 17.2± 0.9 t DM/ha over years 2-4 of the trial. To compare values with Figure 2, subtract 1.0-1.5 t DM/ha to compensate for the yeild increase attributable to the addition of up to 100 kg N/ha. Crush *et al*. (2006) concluded annual pasture production from well managed ryegrass-white clover pastures is very close to the practical limit achievable in Waikato and close to the theoretical Waikato Regional upper limit for ryegrass pastures calculated by Mitchell (1963).

18. On that basis, the estimates of the potential productive capacity of a legume-based pasture, fixing N biologically under a "typical sheep and beef farming system", for each Land Use Capability (LUC) unit in New Zealand listed under "attainable potential carrying capacity" in the extended legend of the Land Use Capability are still very relevant today. They are not dated, as suggested by some and as a consequence, do provide an excellent proxy for the soil natural capital, before the introduction of other technologies.

19. Use of the extended legend of the LUC worksheets for calculating the natural capital of soils is a new application of the information. It reflects the evolving nature of sustainable land management, with the necessity to set limits on emissions from land to both air and water (in this case emissions to water and specifically nitrogen from farming systems). An attraction of the approach is already established as the basis for land development and evaluation, with the information available throughout New Zealand.

Farm productivity

20. In sharp contrast to the lack of any increase in the production levels of legume based pastures, farm productivity continues to increase. Evidence of M. Newman for Fonterra and Neild & Rhodes (2010) for Horizons provides data on the the productivity gains in the dairy sector in the Region over the last 10 years. On average that has been 3% per year. The sheep and beef sector has shown similar productivity gains (1-4%) per year (Neild, 2005).

21. Submitters are correct in their assertion that the Natural Capital based approach does not reflect farm productivity of our more intensive pastoral systems and hence

underestimates N leaching losses when technological advances that increase productivity beyond that of a legume based pasture are included.

22. Increases in farm productivity in recent years have come from the increasing use of N fertilisers (S42A evidence of Dr Parfitt), irrigation, imported feeds in the dairy industry (palm kernel, maize), off-farm grazing for both replacement heifers and dairy cows, animal genetics (ie. increased fecundity in ewes), plant genetics (ie. cool season activity), improved pasture management and utilisation through grazing management, the better matching of feed supply with animal demand, through to the use of N inhibitors to reduce N losses that have the potential to translate to increases in pasture growth.

23. The Horizons test farms provide examples of the contribution these technologies are now making to dairy farm producivity in the Region (Figure 3). The contribution from the legume pasture based varies from 50% to more than 80% of milk solids production.

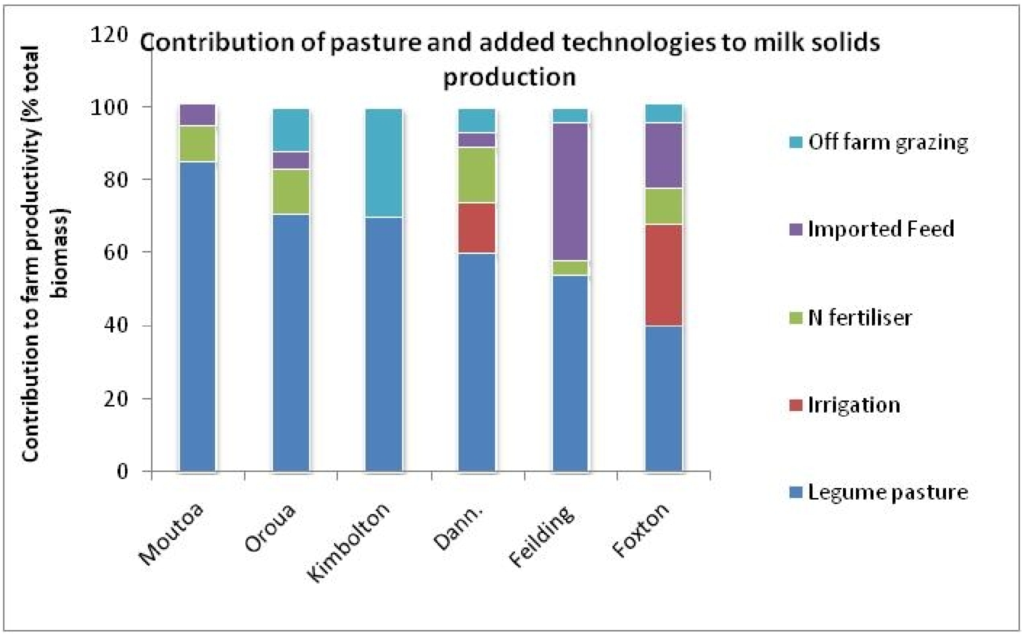

Figure 3. Breakdown of the proportional contribution of the legume pasture base, irrigation, N fertiliser, imported feeds and off-farm grazing (includes the run-off) to total farm dry matter. Note: the calculation does not include the feed requirements of replacement heifers. This would increase the contribution from the off-farm grazing significantly, reducing further the contribution from the legume pasture base to milk soilds production. The data were not always complete so some assumptions have been made.

24. Nitrogen fertiliser, imported feeds and off-farm grazing enable farm productivity gains beyond that possible with a legume based pasture system alone. To sustain the current annual growth these technologies will become increasingly important.

25. Whereas a legume based pasture system is self regulated with a ceiling yeild and associated N leaching loss that is reflective of the soil's underlying natural capital and local climate (Figure 3), a number of these other technologies (eg. imported feeds and off-farm grazing) remove the soil and and climate limitations, allowing annual farm productivity gains to continue regardless of the soil's underlying productive capacity and ability to assimilate and retain nutrients. **There are no limits to the farm productivity gains possible or the environmental impact without N loss limits**. Our success in developing production technologies to overcome production constraints has created an environmental problem.

Recognition of technological advances

26. To address the lack of recognition of technological advances and their impact on pasture and farm production Dr Roberts makes the suggestion in his submission that: "*a more equitable system would be to assess each property with WMZ in terms of their current estimated N loss and adopt an individualised staged process of achievable reductions in N loss." (paragraph 23.)* This also appears to be the approach favoured by G. Sneath from Fert Research and would address the concerns raised by S. Newland for Fonterra: "*N loss limit for LUC Class 2-6 are too low", and "Recognition of existing land use decisions";* D. Smeaton for Fonterra: *"N loss in Table 13.2 for LUC Classes 3-7 should be increased to better reflect the NC approach";* N. Sadlier for Ballance Agri-nutrients: *"Over the long-term values must be adapted to land use and technology changes"; and* C. Hansen on behalf of Ravensdown Fertiliser Co-operative Ltd: *"subdivisions and changes in land use and value over recent years means the LUC data may not be accurate" and "Current land uses are unlikely to reflect the old LUC data".*

27. My S42A evidence (page 28-29) shows that grand-parenting, which is essentially what Dr Roberts is suggesting, has a number of serious faults. Grand-parenting as an allocation mechanism fails to recognise that land is a finite resource and fails to assess land use options in the catchment against the desired water quality outcomes. It puts the future viability of all farms at risk, by failing to allow growth options and flexibility in land use. It recognises landowners with the largest N leaching losses and disadvantages landowners who have been actively conserving N, for example by using Best Management Practices. It also potentially rewards the greatest polluters and penalises those who have already included mitigations in their farming systems.

28. To achieve the necessary reductions under Dr Roberts' suggested approach, in addition to managing down N losses from intensive farming practices to some agreed N loss limits, which are not specified, restrictions would have to be placed on the activity of all

other landowners with the Water Management Zone. This action would appear to be at odds with the assertion *that recognising technologies contributing to production and N losses over and above that of a legume based pasture systems "is more equitable".* Equity would only be achieved if landowner were allowed to intensify to the same level of production or use the same quantities of inputs. This would create a host of challenges, not only within, but also across land uses.

3. ADJUSTMENT TO LUC ASSESSMENT FOR SAND COUNTRY WHERE PERMANENT IRRIGATION HAS BEEN INSTALLED

29. Concern has been expressed by a number of submitters over the reclassification of sand country where permanent irrigation has been installed to overcome the moisture limitation. The concern is that the reclassification does not recognise the productivity improvements.

30. There is a robust and well developed process for examining and making changes in the event a limitation is removed (LUC Survey Handbook, pp 86-87). In the sand country where permanent irrigation has been installed, the classification is made on the basis that the soil mositure limitation has been permanently removed.

31. In the test farms on the sand country (Foxton) in addition to irrigation, N fertiliser, imported feed and off-farm grazing contribute significantly to the farms productivity (Figure 3). From discussions with fertiliser company representatives and farm consultants, more N fertiliser is used on the irrigated sand country blocks than in dairy operations on landscapes fed only by rain. There are some questions about the economics of irrigation on the sand without N fertiliser. The "increased pasture production" is from a combination of water and added N fertiliser, and the increased "farm productivity" also includes the contribution from off-farm grazing and imported feed. Lifting the LUC classification by one class to reflect the permanent removal of the moisture limitation does reflect the shift in pasture production from water alone, but not that of the other technologies.

32. The water holding capacity, anion and cation exchange capacity, and filtering ability of the soil will not change. Irrigation will result in greater drainage volumes, and in combination with fertiliser inputs (both P and N) the increased animal production will result in higher nutrient losses. My S42A evidence (Figure 6; page 44) points out that for the same level of production, emissions (eg. N leaching) will be higher on soils with less natural capital. For example, using the Overseer nutrient budget model and as inputs a sandy loam under dairying receiving 400 mm of irrigation water (800 mm

rainfall), 200 kg N/ha as fertiliser N, producing 900 kg MS/ha, would leaching 28 kg N/ha. A silt loam under dairying, under a rainfall of 1,000 mm, would require less fertiliser N (100 kg N/ha) to achieve the same level of production and would leach less N (22 kg N/ha). The soil with the high natural capital requires fewer inputs and has less of a footprint.

Identifying differences between LUC Classes

33. A number of submitters point to the difficultly of identifying differences between LUC Classes (S. Newland for Fonterra: *Allocation of LUC classes to land;* D Smeaton for Fonterra: *Lack of skilled operators, slightly different results*; and N. Sadlier for Ballance Agri-nutrients: *"We do not believe LUC classes and associated N leaching/run-off values can be practically applied in a fair and equitable manner".* I suspect they are talking more about the difficulties in identifying differences between LUC units, not LUC classes where there is little debate. For more information on LUC classes, LUC subclasses and LUC units see the evidence of Drs Douglas & Roygard.

4. ANTHROPOGENIC FACTORS AND SOIL DEVELOPMENT

34. It is very difficult to change the inherent properties of the soil, but land use and farm practices have major influences on the manageable attributes. The properties of a soil and their relationship to soil services are listed in Figure 4.

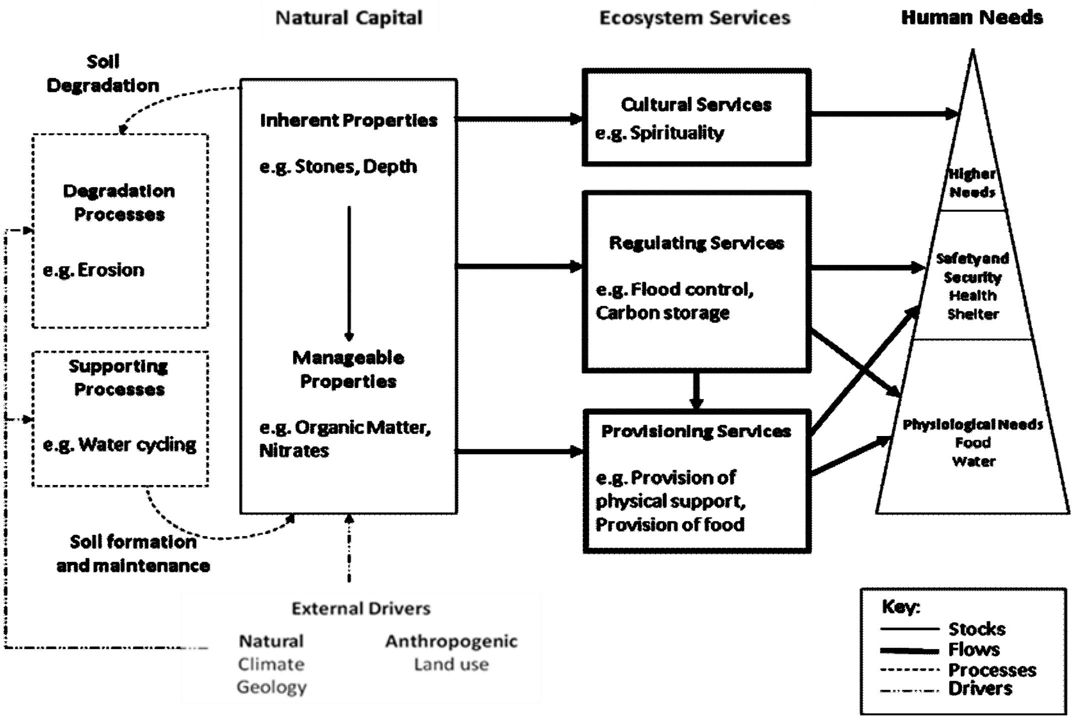

Figure 4. Relationship between the soil's natural capital and ecosystems services.

35. In the long-term irrigation trial at Winchmore Research Station near Ashburton in South Canterbury, established in 1949, the irrigated pastures carry 18 sheep su/ha compared with the dryland pasture which carries only 6 sheep su/ha. Despite the three-fold difference in primary production and associated litter return to the soil ecosystem over an extended period of time, in a recent study Srinivasan & McDowell (2009) could find no measurable effect of irrigation on the soil moisture holding capacity or the hydraulic conductivity of the soil, indicating little or no "soil development" of attributes linked to the inherent properties of the soil.

36. Schon *et al*. (2010) found that to a large extent the soil invertebrate community in the long-term irrigation trial at Winchmore was more characteristic of a dryland soil than of a soil in a higher rainfall zone. They attributed the lack of difference between the dryland and irrigated sites to the fact, that apart from earthworms which could burrow to depth, the invertebrate community had few strategies to survive the moisture deficit between irrigation events.

37. The findings of these two studies highlight that despite more than 50 years of irrigation, fertiliser inputs, grazing and nutrient cycling which has lifted livestock production three-fold and organic N and P levels in the soil, the inherent properties of the soil have not been altered in a measurable way.

38. In the sand country, some increases in soil organic matter content might be expected with increased pasture growth, but this is not a given as the losses of carbon (C) through increased cycling and respiration will also be higher. For example, in the long-term irrigation study at Winchmore, organic carbon levels in the soil have not increased, despite the substantial increase in pasture and animal production. A change in soil organic matter content will not change the water holding capacity of the soil significantly or the soil's ability to filter and prevent the losses of nutrient. There will be some colour development in the soil profile associated with organic matter. To change water holding capacity in these soils, the texture of the soil would need to be changed from sand to finer textural classes. Addition of large quantities of organic matter will increase pasture growth by providing nutrients from a fraction that is less vulnerable to leaching and may increase the soil's organic matter levels. It will not change the inherent properties of the soil.

39. Land development to date has largely been about removing limitations to plant growth. For example, irrigation, drainage, slope angle, etc are technologies that remove a limitation and might contribute to changes in the manageable properties of the soil, but

do not change the inherent attributes of that soil. Little thought and effort has been given to developing technologies that change the inherent properties of a soil and add to the soil's natural capital and ecosystems services. That may be what land development into the future will need to tackle.

5. CATCHMENT OUTCOME FROM WINTERING DAIRY COWS OFF-FARM AS PART OF THE NITROGEN MITIGATION STRATEGY

40. The effectiveness of N mitigation scenarios involving wintering off of dairy cattle within the same catchment to reduce overall catchment N losses has been questioned by submitters. To investigate this a case study was assembled to explore the impact of wintering dairy cows on a sheep and beef unit from a dairy farm within the same catchment on the overall losses from that operation. The benefits of wintering dairy cows off farm was explored using the Overseer nutrient budget model.

Question

What impact do 400 dairy cows wintered for six weeks on a sheep and beef farm have on the N leaching losses?

Characteristics of the sheep and beef operation

- Sheep and beef farm on 500 ha effective
- Carrying 9 su/ha (4,500 su) 65:35 sheep cattle ratio (Including cows)
- Docking 135%
- Rolling 30%, hill 40%, steep 30%
- Sedimentary soils
- Olsen P 12-15.
- Developing
- 1,100 mm rainfall
- N leaching loss of 6kgN/ha

Assessment of feed required for dairy cows

- 400 dairy cow grazers, with a grazing period of six weeks
- Daily intake of 10 kg DM/cow/day (typical dairy farmer demand)
- No forage crops grown for cows

Feed required: 168,000 kg DM

Assuming

- Pre-grazing pasture cover of 2,500 kg DM/ha and a residual dry matter pasture cover of 1,100 kg DM/ha
- An average pasture growth rate of 8 kg DM/ha/d over the grazing period and pasture utilisation of 80%

41. Using a feed budget, the area required by the dairy cows adds up to 197.5 ha. On a “feed-in feed-out basis”, the number of sheep and beef stock units that would need to be displaced to make room for the dairy cows amounts to approximately 1,940 su.

42. It is important to note that the area to be grazed by dairy cows will need to be “shut up” for a considerable period prior to the cows arriving to ensure sufficient pasture cover accumulates. If pasture growth rates of 30 and 20 kg DM/ha are realised in April and May respectively, the cows would need to be removed from the sheep and beef system by April 10. It must be noted that upon removal of the dairy cows the farm may be considered to be significantly under-stocked from mid to late July onwards. Therefore, changing the autumn and spring management would be essential to undertake dairy cow grazing in a financially rewarding way. It must be acknowledged that there are many different factors that could be considered when completing this analysis which may drive significantly different results.

43. The N leaching losses from the sheep and beef operation with a dairy cow grazing operation did not change but remained at 6 kg N/ha (Appendix 1). In this case study, the comparison was limited to the impact of substituting sheep and beef stock units with dairy cow grazers. The impact of additional inputs (eg. N fertiliser, imported feeds) was not explored.

6. REFERENCES

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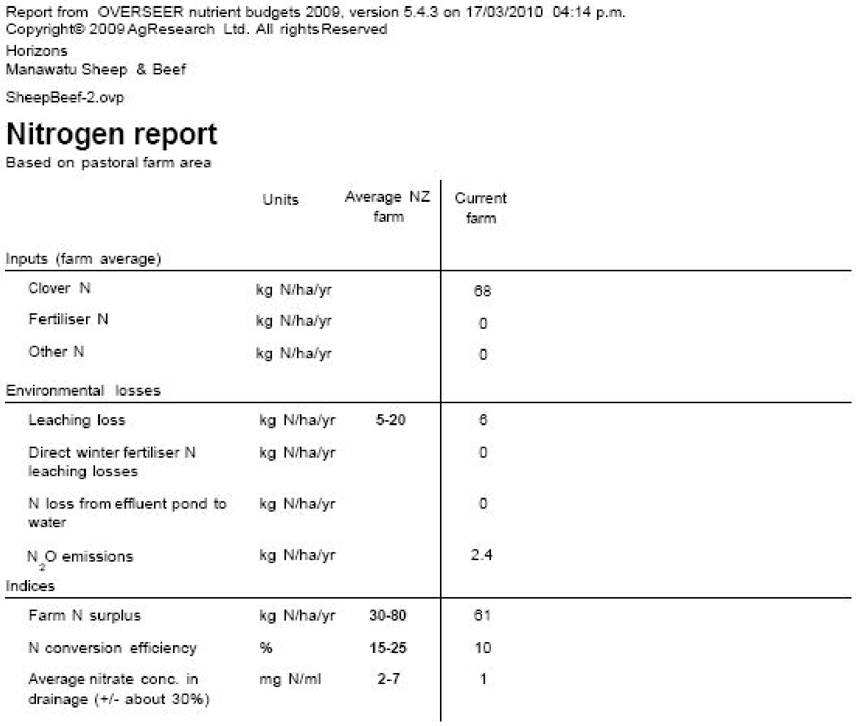
7. APPENDIX 1: OVERSEER NUTRIENT BUDGET OUTPUTS FOR THE SHEEP AND BEEF AND SHEEP AND BEEF PLUS WINTER DAIRY COW SYSTEMS



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Horizons
Manawatu Sheep & Beef

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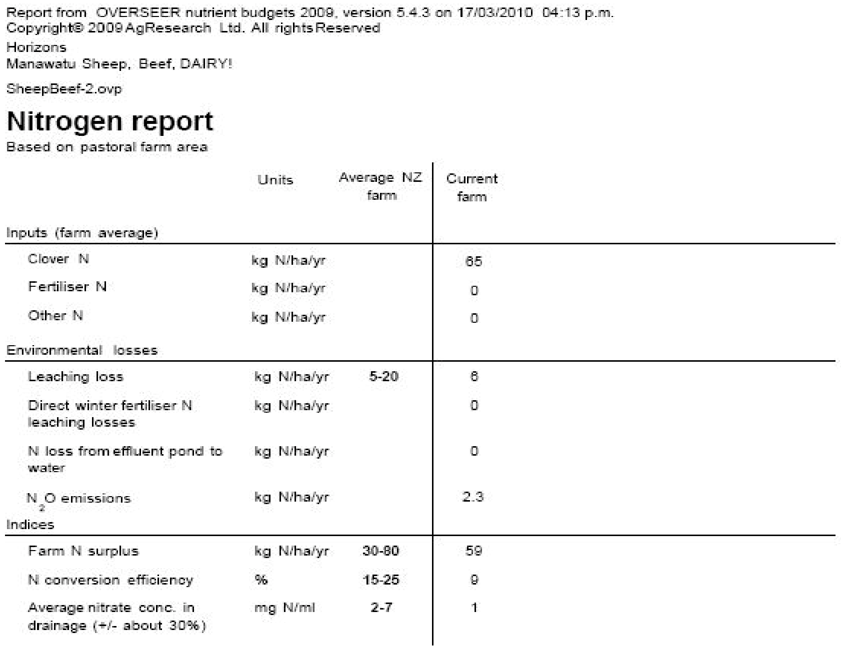
Nitrogen report

Based on pastoral farm area

	Units	Average NZ farm	Current farm
Inputs (farm average)			
Clover N	kg N/ha/yr		68
Fertiliser N	kg N/ha/yr		0
Other N	kg N/ha/yr		0
Environmental losses			
Leaching loss	kg N/ha/yr	5-20	6
Direct winter fertiliser N leaching losses	kg N/ha/yr		0
N loss from effluent pond to water	kg N/ha/yr		0
N_2O emissions	kg N/ha/yr		2.4
Indices			
Farm N surplus	kg N/ha/yr	30-80	61
N conversion efficiency	%	15-25	10
Average nitrate conc. in drainage (+/- about 30%)	mg N/ml	2-7	1



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Nitrogen report

Based on pastoral farm area

	Units	Average NZ farm	Current farm
Inputs (farm average)			
Clover N	kg N/ha/yr		65
Fertiliser N	kg N/ha/yr		0
Other N	kg N/ha/yr		0
Environmental losses			
Leaching loss	kg N/ha/yr	5-20	6
Direct winter fertiliser N leaching losses	kg N/ha/yr		0
N loss from effluent pond to water	kg N/ha/yr		0
N_2O emissions	kg N/ha/yr		2.3
Indices			
Farm N surplus	kg N/ha/yr	30-80	59
N conversion efficiency	%	15-25	9
Average nitrate conc. in drainage (+/- about 30%)	mg N/ml	2-7	1