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Nutrient Budgets for Waikato Dairy and Sheep, Beef and Deer Farms

1997/98 – 2006/07

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1. Executive Summary

- This project involved the use of the OVERSEER nutrient budget model (version 5.4.3.0) to estimate nutrient budgets and environmental emissions from farms in the Waikato region over time.

Dairy farms:

- Ten years data from 1997/98 to 2007/08 was supplied by DairyNZ from their DairyBase database for Waikato dairy farms for the average milksolids production/ha, the average for the top 25% of milksolids production, and the average for the lower 25% of milksolids production.
- Overall trends on the dairy farms over the time period showed increasing use of nitrogen (N) fertiliser and imported feed, and increasing stocking rates and milksolids produced across all farm categories.
- N leaching per hectare increased over time across all dairy farm categories, as did the concentration of N in drainage water from grazed farm areas.
- Nitrogen surplus increased while N conversion efficiency and farm P surplus decreased over time across all dairy farm categories.
- Greenhouse gas emissions/ha increased by about 20% over the 10 years. Increased greenhouse gas emissions were correlated with increased N leaching, indicating that management or mitigations to reduce N leaching would also reduce GHG emissions.

Sheep, beef and deer farms:

- Twelve years data from 1995 to 2006 was supplied by Meat and Wool New Zealand from their database for Waikato sheep, beef and deer farms. This represented the average of Class 3, Class 4 and Class 5 (steep low fertility, easy hill and rolling high intensity) land as determined by slope, stocking intensity and farm system.
- The sheep, beef and deer farms showed no change in overall stocking rate over time across all farm classes. N fertiliser use increased over time, particularly on the more intensive Class 5 farms.
- Total greenhouse gas emissions/ha remained relatively constant over time, with a slight decrease in methane and increase in CO_2 from sheep, beef and deer farms.
- Nitrogen farm surplus increased slightly over time while N conversion efficiency decreased across all classes of sheep, beef and deer farms.

- N leaching and P runoff showed no changes over time. An exception was on Class 5 farms where P runoff reduced after 1998 when deer were no longer farmed and corresponds with higher P runoff risk from farm systems with deer.
- Greenhouse gas emissions/ha increased with farm intensity between farm classes 3 to 5 but within each farm class there was no change in emissions over time.

Report comparison:

- Results produced from this report compared with those obtained in a similar report in 2004 showed similar values for N leaching, N concentration in drainage water from grazed farm areas and P runoff for the same assessment years. Greenhouse gas emissions, particularly on the dairy farms, were higher with the current model which can be partially attributed to changes in the OVERSEER nutrient budget model which have occurred between the version used in 2004 and that used in this report.

Rainfall scenarios:

- Model scenarios of the effects of increasing rainfall on each farm category for the latest year's data showed increased atmospheric inputs and outputs, N leaching and P runoff. The dilution effect of increased drainage with increased rainfall corresponded to a decrease in the N concentration in drainage water from grazed farm areas.
- Factors that are determined largely by stocking rate and production, such as greenhouse gas emissions, showed no change with increasing rainfall.

2. Background information

Environment Waikato's monitoring data indicate that some important aspects of soil and water quality are deteriorating across the intensively farmed areas of the region (EW, 2009). Nutrient budgets are seen by the primary industry as well as by regulatory authorities as a cost-effective means to identify major nutrient imbalances that not only affect farm profitability, but can also adversely affect soil and water quality as well as contributing to greenhouse gas emissions. Time series of nutrient budgets based on reliable, consistent and representative data allow potential trends in nutrient losses and nutrient conversion efficiencies on typical Waikato farms to be detected.

3. Objective

To determine annual nutrient budgets for six "farm types" representing:

- Average, upper and lower quartiles of dairy farms in the Waikato Region (based on kg milksolids/ha/year), and
- Three types of Waikato sheep, beef and deer farms (hard hill country through to intensive finishing farms).

A time series of data between about 1995 and 2007 was used to develop environmental indicators for 'Farm Nutrient Losses' that describe average losses for these Waikato pastoral farm types over time.

3.1 Services

The services agreed to for this project were:

- To obtain the required dairy farm data for the period 1997/98 to 2006/07 from DairyNZ (ProfitWatch and DairyBase) and sheep and beef farm data from MWNZ. Should it prove impossible to obtain data for the total period specified, modified periods can be agreed upon.
- Run OVERSEER for the six 'farm types' specified above for the whole period for which data becomes available.
- To investigate three rainfall scenarios for all six farm types on the example of the last year for which data becomes available (presumably 2006/07). Low, average, and high rainfall to be defined for the six farm types taking their spatial distribution within the Waikato Region into account.
- Prepare a report on the input data and OVERSEER results.
- Comment where appropriate on time series of input data and OVERSEER results.

4. Methodology

The OVERSEER nutrient budget model (hereafter called OVERSEER) (version 5.4.3) was used on farm data for three classes of sheep, beef and deer farms from 1995/96 to 2006/07, and three categories of dairy farms from 1997/98 to 2007/08, excluding 1998/99.

Data from farms was summarised for soil tests, production, fertiliser inputs and nutrient and greenhouse gas losses to the environment.

4.1 Input data sources

4.1.1 Waikato Dairy Farms

Data for Waikato dairy farms was supplied by DairyNZ. Data was for all business types (owners and sharemilkers) for the Waikato region from Franklin in the north to Taupo in the south, excluding the Rotorua district, but including Waitomo, Otorohanga and Ruapehu.

Three categories of Waikato dairy farm data were provided; the Average of all Waikato farms, the average of Upper and Lower Quartile farms based on milksolids production per hectare.

Data was supplied for all years from 1996/97 to 2007/08, with the exception of 1998/99 due to the change over from Profit Watch to DairyBase databases making previous data difficult to access. Data for the Average farm was derived from between 55 and 144 farms (Appendix 1).

4.1.1.1 Assumptions and deficiencies in the input data for dairy farms

- Only the effective area was used to model farms; agroforestry, forestry and undeveloped land were not included
- The average long term rainfall value of 1250 mm for the Waikato region was used for all years and for all farm categories.
- As per best practice, it was assumed that dairy effluent was applied to 15% of the farm area. Effluent blocks were assumed to receive the same rates of fertiliser application as the rest of the farm.
- The pasture development status of developed was assumed for all farms.
- It was assumed that the soil group was Volcanic and the topography rolling. Where no soil test data was provided, typical soil test values for Volcanic soils were used from the OVERSEER model database based on means for an average farm obtained from aggregated data from soil samples submitted to NZ Labs and its predecessors.

- It was assumed that the stock comprised Friesian x Jersey cows, with replacements being grazed off the farm after 9 months age, and all milking dairy cows wintered on the farm.
- Distance from the coast was assumed to be 50 km. The model is relatively insensitive to this parameter after this distance.
- Where nitrogen (N) and phosphorus (P) fertiliser was applied, it was assumed that none was applied during the at-risk winter months as per best practice.
- No information was provided on application of lime on any farms
- No wetland or DCD data was provided, so these categories were not entered in OVERSEER
- Supplementary feed was assumed to be of average quality, and was separated into hay and silage, and maize silage.
- It was assumed that no cropping occurred on farms.

4.1.2 Waikato Sheep, Beef and Deer Farms

Sheep, beef and deer farm data was supplied by Meat and Wool New Zealand Limited. The data is a time series from 1995/96 to 2006/07 (September year), and includes class averages for Class 3, 4, and 5 for the Waikato region. These averages were taken from the Meat & Wool New Zealand Farm Survey and the sample number ranged from 67 farms in 1995/96 to 76 in 2006/07 (Appendix 1).

- A Class 3 farm is defined as North Island Hard Hill Country, which is steep hill country and low fertility soils with most farms carrying six to ten SU/ha. While some stock are finished a significant proportion are sold in store condition.
- Class 4 is North Island Hill Country, which is easier hill country and more fertile soils than Class three, mostly carrying between eight and thirteen SU/ha. A high proportion of sale stock sold is in forward store or prime condition.
- Class 5 is North Island Intensive Finishing farms, which is easy contour farmland with the potential for high production and most carry between eight and fourteen SU/ha. A high proportion of stock is sent to slaughter and replacements are often brought in.

4.1.2.1 Assumptions and deficiencies in the input data for sheep, beef and deer farms

- Only the effective area was used to model farms; agroforestry, forestry and undeveloped land were not included

- Soil groups of Sedimentary for Class 3 farms, and Volcanic for class 4 and 5 farms were assumed. Soil test data was only provided for the latest year (2006/07). Where no soil test data was provided, typical soil test values for Volcanic soils were used from the OVERSEER model based on means for an average farm obtained from aggregated data from soil samples submitted to NZ Labs and its predecessors.
- It was assumed that all stock was grazed on farm during winter months.
- Distance from the coast was assumed to be 50 km. The model is relatively insensitive to this parameter after this distance.
- Where N and P fertiliser was applied, it was assumed that none was applied during the at-risk winter months as per best practice.
- No wetland or DCD data was provided, so these categories were not entered in OVERSEER.
- The pasture development status of developed was assumed for all farms.
- No supplementary feed information was given except for 2006/07 year, where it was assumed that supplements were fed to beef animals on paddocks.
- After discussions with I Power (AgResearch) about previous work with average Waikato sheep and beef farms, it was assumed that 20% of cattle were male.
- Not enough information was provided to use the advanced stock calculation form in OVERSEER, but stock units (SU) were supplied for each animal type, so these were used.
- The topography was assumed to be that of the largest category for each farm class type, namely: Class 3 – steep, Class 4 – easy hill and Class 5 – rolling. OVERSEER does not provide estimates of N concentration in drainage for easy hill and steep categories.

5. Description of OVERSEER nutrient budget report

5.1 Basis of the OVERSEER nutrient budget model

OVERSEER uses farm and block specific data to prepare nutrient budgets, showing nutrient inputs and outputs on a block or whole farm basis (Wheeler et al. 2003). Information reports show nutrient use efficiency and potential environmental effects.

OVERSEER includes a greenhouse gas (GHG) emission accounting tool (Wheeler et al. 2008). The GHG emission model is based on models and algorithms used for the NZ GHG national inventory, modified to include a range of on farm management practices. The model estimates methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions and presents the results as CO_2-equivalents.

5.2 Input requirements for the model

The following lists the key input data required for use of the OVERSEER nutrient budget model:

Block Information

Site Information

- Region
- Area (ha)
- Slope (flat, rolling, easy hill, steep hill)
- Distance from coast (km)
- Rainfall and irrigation (mm/yr)
- Soil drainage (well, moderately well, imperfect, poor, very poor)
- Soil group (Sedimentary, Volcanic, Pumice, Podzols, Sands, Peats, Recent)

Soil test information

- Olsen P
- Quick-test K, Ca, Mg and Na
- Organic S test
- pH

Fertiliser

- Sulphate-S applied last year
- Rate of nutrients or fertilisers for current 12 months
- N and P applied in high risk months

Farm Information

System information

- Product yield (milksolids, wool, velvet)
- Pasture development status (developing, developed, highly developed)

Management Information

- Stocking rate and animal type
- Feed brought-in or sold (t DM/ha, type)
- Dairy effluent management
- Winter management practices

6. Results

Tables of OVERSEER input, output and summary data are provided in Appendices 2-10 for dairy and 11-19 for sheep, beef and deer farms. Fluctuations in values across the years are a reflection of a series of factors such as the variable number of farms, climatic conditions, dairy payout etc.

6.1 Farm Input data

6.1.1 Soil and Fertiliser Inputs

6.1.1.1 Dairy farms

Soil Olsen P levels increased overall through time for the Average farms from 36 to 47 ppm while the Lower Quartile increased from 31 to 35, between 1997/98 and 2007/08, with a peak of 52 in 2005/06, while the Upper Quartile farms remained relatively constant at 41 (Figure 1, Appendices 2-4).

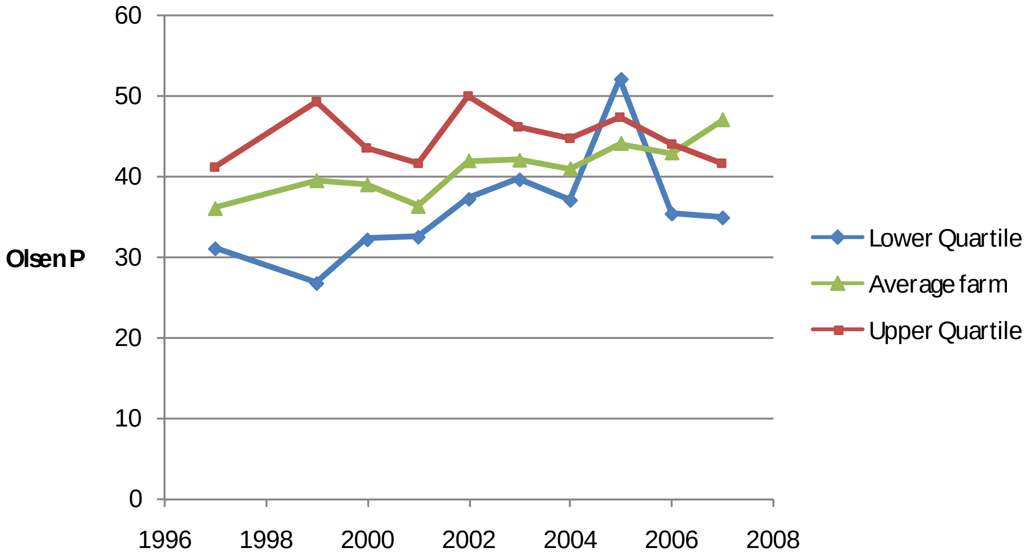

Figure 1: Soil Olsen P levels in Waikato dairy farms

While phosphorus (P), potassium (K) and sulphur (S) fertiliser usage decreased over time across all categories (Appendices 2-4), nitrogen (N) fertiliser use increased significantly (Figure 2). Lower Quartile dairy farms showed the greatest increase in N usage with a 310% increase (37 to 115 kg/ha) between 1997/98 and 2007/08, while Average and Upper Quartile farms increased by 190% (68 to 129 kg/ha) and 156% (92 to 144 kg/ha) respectively.

Upper Quartile farms showed more variability in N fertiliser usage, particularly in the last three years (2005/06-2007/08).

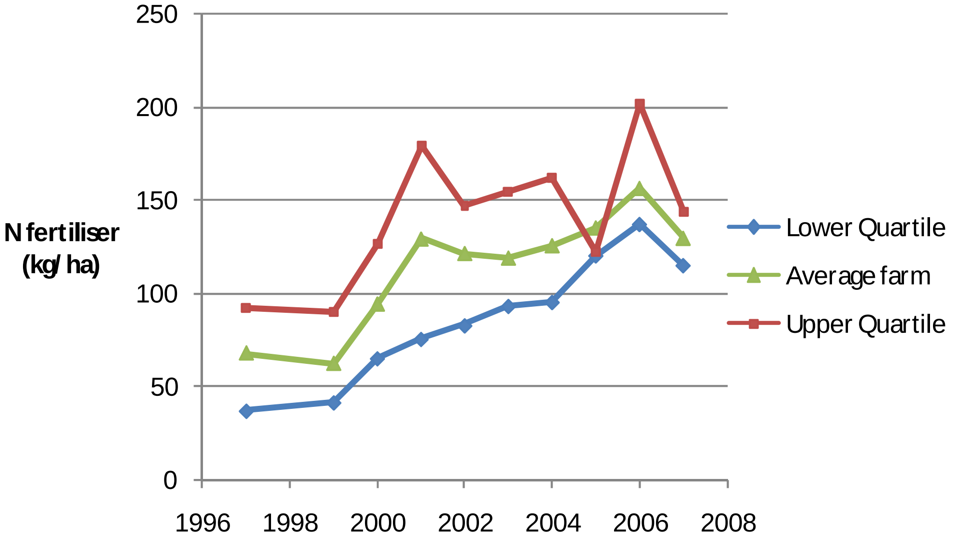

Figure 2: N fertiliser applied to Waikato dairy farms

6.1.1.2 Sheep, beef and deer farms

Class 3: Fertiliser N, P, K and S inputs remained reasonably constant over time while lime applications peaked in 2001/02 before dropping off and peaking again in 2006/07 (Figure 3, Appendices 11-13).

Class 4: Application rates of all fertilisers and lime were variable over time with use trending upwards.

Class 5: Fertiliser P, K and S use remained reasonably constant over time. Lime use peaked dramatically in 2000/01, and by 2006/07 had returned to near 1995/96 levels. Of the 3 farm classes, Class 5 is the only one where a very noticeable increase in N fertiliser occurred over time from 7 kg N/ha/yr in 1995/96 to 45 kg N/ha/yr in 2006/07, an increase of 642% (Figure 4).

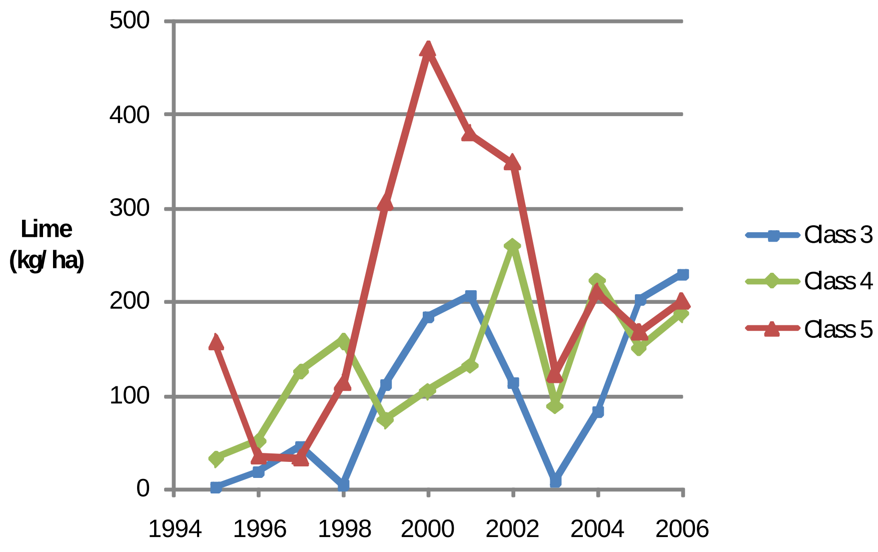

Figure 3: Lime applied to Waikato sheep, beef and deer farms

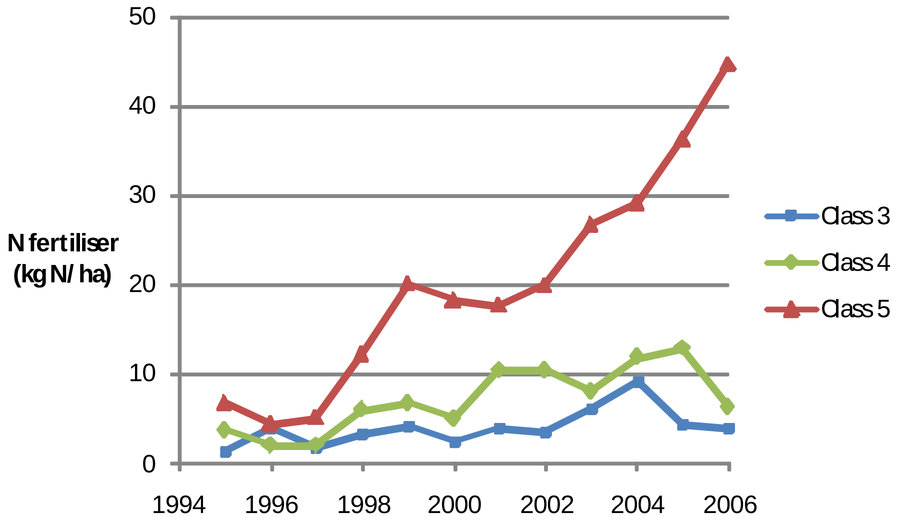

Figure 4: N fertiliser applied to Waikato sheep, beef and deer farms

6.1.2 Stock numbers, production and supplementary feed

6.1.2.1 Dairy farms

All farm categories showed an increase in the effective farm size, and in the production, stocking rate and imported supplementary feed on a per hectare basis (Appendices 2-4).

i. Lower Quartile Farms

Stocking rate increased from 2.3 to 2.7 cows/ha from 1997/98 to 2007/08 (Figure 5), with production increasing from 627 to 699 kg MS/ha (Figure 6), and imported supplementary feed increasing from 0.2 to 1.2 T/ha (Figure 7).

With overall farm size increasing from 94 to 167 ha, this led to an apparent nearly doubling in milksolids produced overall on the Lower Quartile farms.

ii. Average Farms

Stocking rates increased from 2.8 to 3.1 cows/ha from 1997/98 to 2007/08, while production increased from 854 to 940 kg MS/ha, and imported supplementary feed from 0.4 to 2.4 T/ha. Again, overall farm size increased in this class from 90 to 120 ha, leading to an apparent 85% increase in milksolids produced between the averages of the first and last three year periods on Average Waikato farms.

iii. Upper Quartile Farms

Stocking rates in this class increased the most over time from 3.2 to 3.7 cows/ha. Production increased from 1080 to 1345 kg MS/ha and imported supplementary feed increased dramatically from 0.8 to 4.6 T/ha. While farm size only increased by 18%, overall farm production increased between the averages of the first and last three year periods by 62%, due to the increased stocking rate and increasing use of imported supplementary feed.

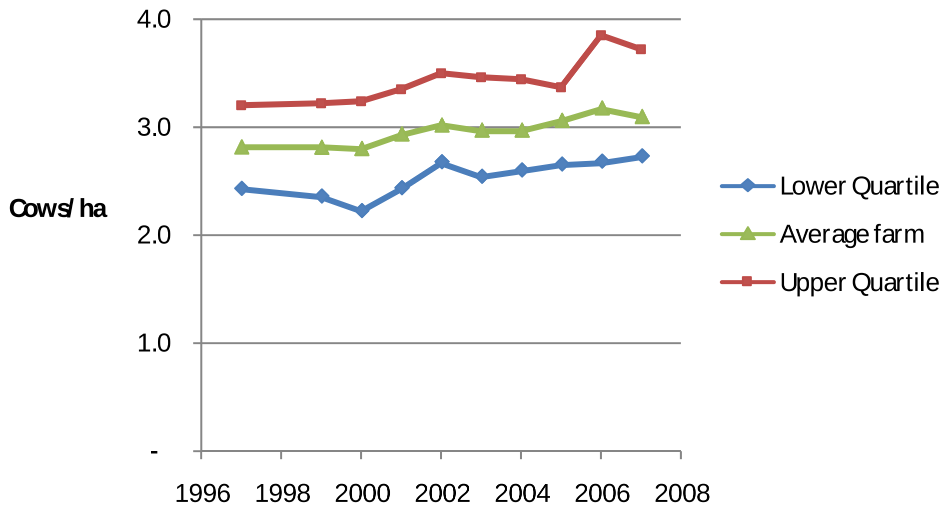

Figure 5: Stocking rate on Waikato dairy farms

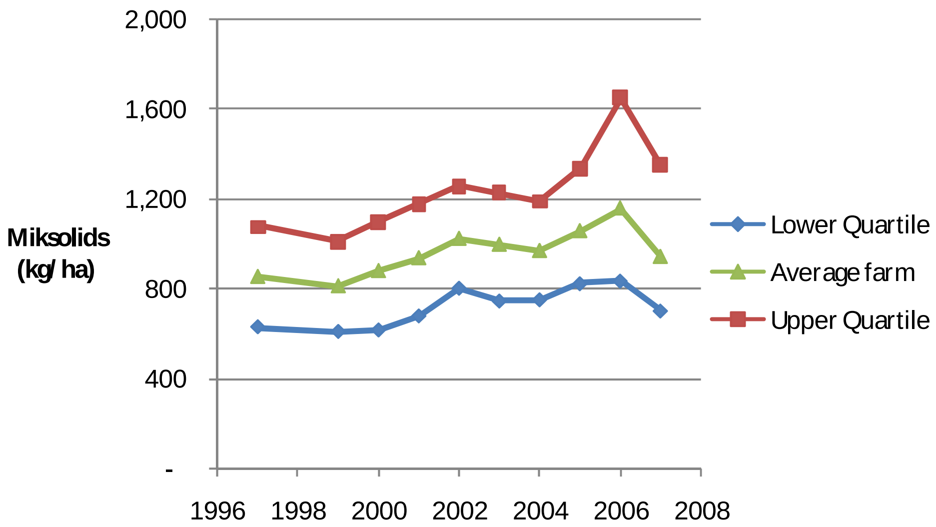

Figure 6: Milksolids production on Waikato dairy farms

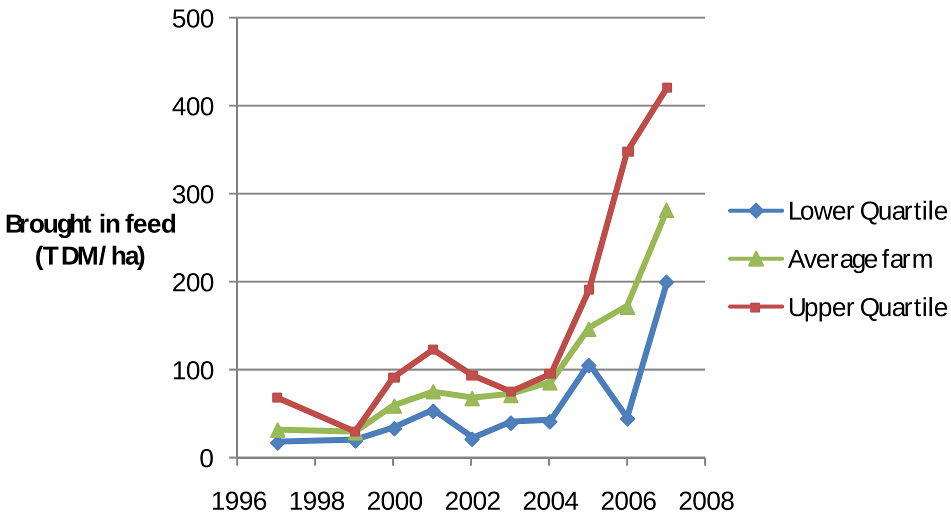

Figure 7: Supplementary feed brought onto Waikato dairy farms

6.1.2.2 Sheep, beef and deer farms

i. Class 3

This class comprised sheep and beef farms only. While overall stock numbers dropped from 1995/96 to 2006/07 (Figure 8, Appendices 11-13), this followed a drop in effective area of the farms, resulting in only a small decrease in SU/ha, from 5.6 to 5.5 for sheep and 3.9 to 3.6 SU/ha for beef and a subsequent decrease of wool sold from 30 to 27 kg/ha/yr.

ii. Class 4

This class comprised sheep, beef and deer. All animal classes showed an increase in overall animal numbers, but only beef and deer numbers increased from 5.3 to 5.8 and 0.05 to 0.1 SU/ha respectively. Sheep numbers declined from 5.6 to 4.9 SU/ha, with an associated decrease in wool sales from 30 to 23 kg/ha/yr between 1995/96 and 2006/07.

iii. Class 5

This class comprised sheep, beef and deer until 1999/2000 year when deer were no longer farmed. Sheep numbers dropped from 4.4 to 3.3 SU/ha with an associated drop in wool sold from 27 to 20 kg/ha/yr between 1995/96 and 2006/07. While beef numbers peaked in 2003/04, the overall stocking rate decreased returning to the initial 8.5 SU/ha. Deer numbers were highest in this class farm being 0.5 SU/ha in 1995/96 with 0.2 kg/ha/yr deer velvet sold, dropping to 0.16 SU/ha in 1998/99 with 0.07 kg/ha velvet sold. Deer ceased to appear in this farm class in 1999/2000.

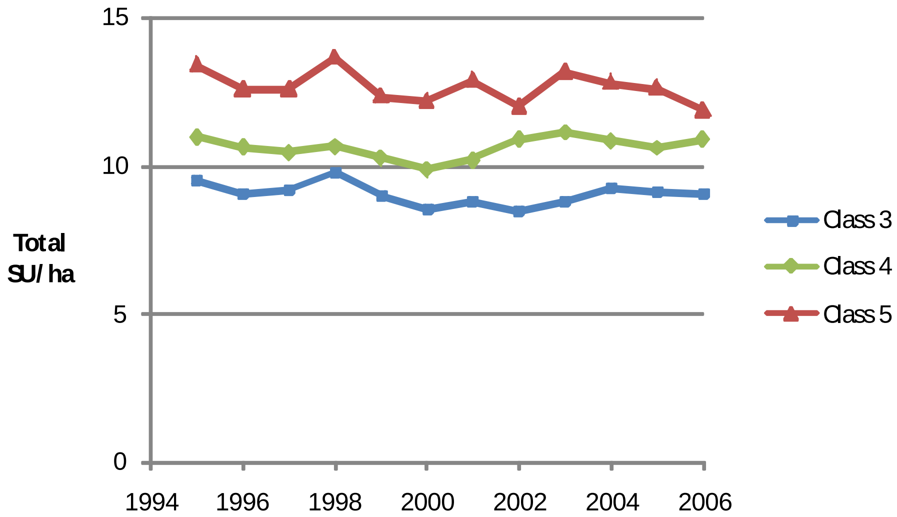

Figure 8: Stocking rate for Waikato sheep, beef and deer farms

6.2 OVERSEER N and P Budget Data

6.2.1 Dairy Farms

6.2.1.1 Supplementary feed N and P inputs

Supplementary feed use has increased dramatically over time for all farm classes. This has lead to a large increase over time in the amount of N inputs into the farm systems from 3 to 14, 5 to 28 and 11 to 54 kg N/ha/yr for Lower Quartile, Average and Upper Quartile farms respectively. The increase in the amount of P inputs was less at 1 to 3, 1 to 5 and 2 to 10 kg P/ha/yr.

6.2.1.2 Atmospheric N Inputs

Atmospheric N inputs from clover and rain decreased in all three farm categories over time from 94 to 67, 105 to 76 and 117 to 91 kg N/ha/yr for Lower Quartile, Average and Upper Quartile farms respectively (Appendices 5-7). The decrease in Atmospheric N inputs was expected because of the feedback effect from increasing fertiliser N usage.

6.2.1.3 N Outputs

Overall there were increases over time across all N output categories; N in product, atmospheric N losses (loss of N to the atmosphere by ammonia volatilisation and denitrification), N lost in leaching and N immobilisation, across the three farm categories (Appendices 5-7).

i. Nitrogen leaching

OVERSEER estimates the amount of N that leaches below the plant rooting depth and is thus lost for plant production. This estimate represents the total amount of N leached from grazed areas and farm lanes in various forms (usually predominantly nitrate, but with some ammonium and dissolved organic N), although most model validation research did not include data on dissolved organic N. Not all N leached out of the root zone necessarily reaches the underlying aquifer and surface water bodies linked to the aquifer, as attenuation processes (mainly denitrification) may occur below the root zone (Stenger *et al*, 2008). N leaching increased between 1997/98 and 2007/08 from 26 to 33, 32 to 38 and 39 to 47 kg N/ha/yr for Lower Quartile, Average and Upper Quartile farms, respectively (Figure 9).

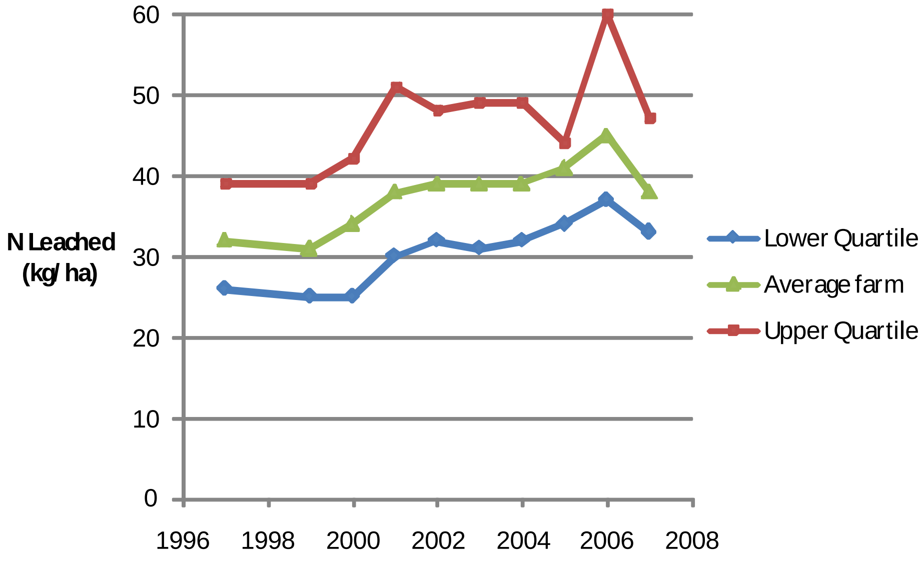

Figure 9: Annual N leached from Waikato dairy farms

ii. N concentration in drainage water

The calculated N concentration in drainage water from grazed farm areas increased over time in all farm categories, from 4.1 to 5.5, 5.3 to 6.5 and 6.6 to 8.2 mg N/L for Lower Quartile, Average and Upper Quartile Farms, respectively. In the 2006/07 year on the Upper Quartile dairy farms, the N concentration in drainage peaked at 10.7 mg N/L. If this was assumed to be all nitrate-N it would be close to the recommended level for drinking water set by the World Health Organisation (WHO) of 11.3 mg NO_3-N/L (Figure 10). This coincided with a peak of 202 kg/ha fertiliser-N applied in this year. The ecological criteria are more stringent than the WHO drinking water criteria, with the ANZECC trigger for the protection of lowland streams being 0.44 mg NO_3-N/L (MFE, 2009).

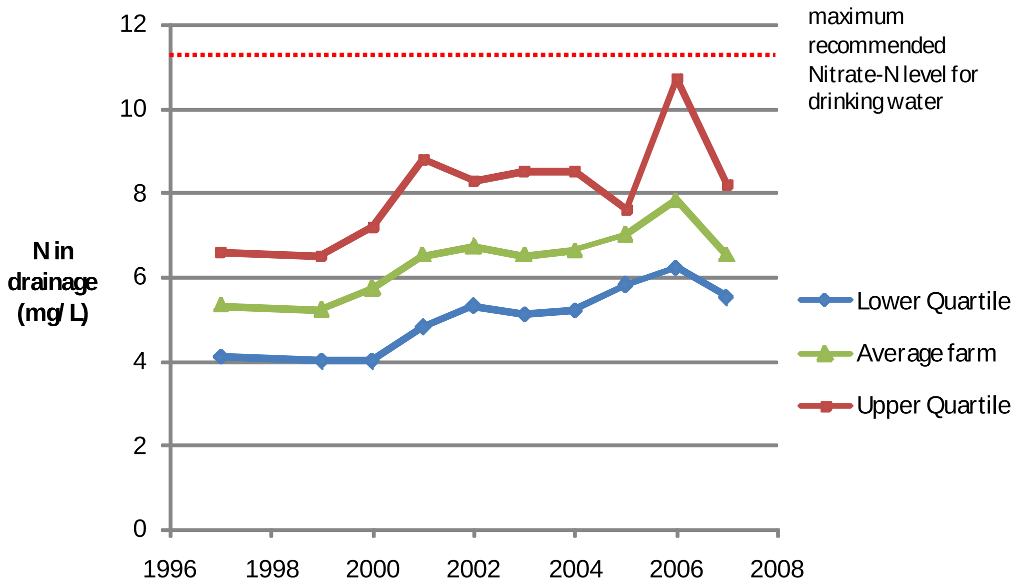

Figure 10: Calculated N concentration in drainage water from Waikato dairy farms

6.2.1.4 P Outputs

Phosphorus is lost to waterways largely by surface runoff and even though values are relatively small, it can be significant for increasing algae and plant growth in waterways. P lost in runoff remained relatively constant over time at 0.7, 0.8 and 0.9 kg P/ha/yr for Lower, Average and Upper Quartile farms (Figure 11). For Lower Quartile and Average Farms, P exported in product increased slightly over time from 7 to 8 and 10 to 11 kg P/ha respectively, and P immobilisation/absorption increased from 32 to 35 and 37 to 44, respectively. In the Upper Quartile farms, P exported in milk and meat increased over time from 12 to 15 kg P/ha.

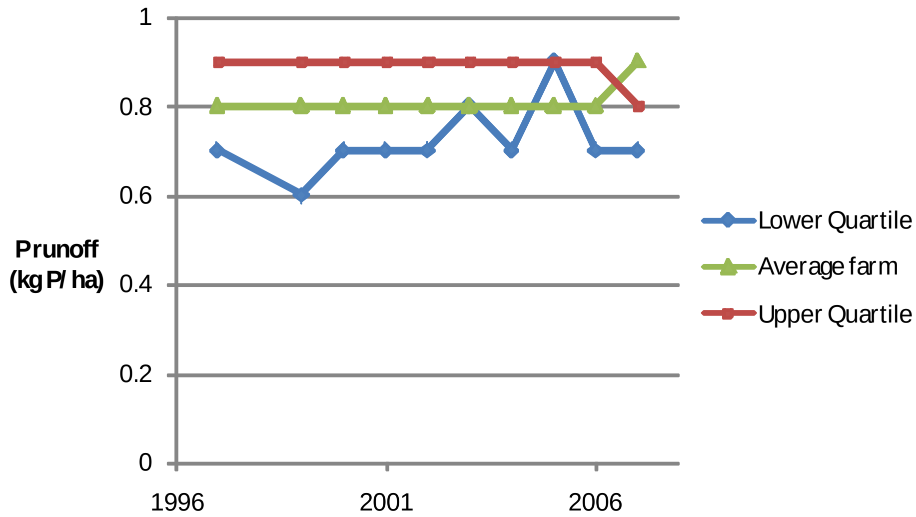

Figure 11: P runoff from Waikato dairy farms

6.2.2 Sheep, Beef and Deer farms

6.2.2.1 Atmospheric N Inputs

Atmospheric N inputs from clover and rain decreased over time in all three classes of farms, with only small decreases in the Class 3 and 4 farms. The largest decrease was in the Class 5 farms with a drop from 74 to 51 kg N/ha/yr between 1995/96 and 2006/07. This correlated with a 640% increase in N fertiliser use over the same period (Appendices 14-16).

6.2.2.2 N Outputs

Overall, each of the N outputs increased progressively over time in moving from the steeper Class 3 land with lower stocking rates, through to the flatter Class 5 land with more intensive stocking rates (Appendices 14-16).

i. Class 3 Farms

These showed fairly stable levels of N outputs, with exporting of product and losses through atmospheric, leaching and immobilisation averaging 12, 9, 10 and 35 kg N/ha/yr respectively from 1995/96 to 2006/07.

ii. Class 4 farms

These showed fairly stable levels of N removal in product and atmospheric losses of 12 and 12 kg/ha respectively. N losses through leaching increased slightly from 13 to 14 kg N/ha/yr (Figure 12) and N immobilised increased from 32 to 35 kg/ha/yr.

iii. Class 5 Farms

These showed a decrease in N removed in product from 17 to 14 kg N/ha, while atmospheric N losses and N immobilised increased from 16 to 21 and 32 to 47 kg N/ha, respectively. N lost in leaching remained fairly constant over time at 16 kg N/ha/yr. N concentration in drainage from grazed farm areas is only produced by OVERSEER for rolling or flat topography farms, so there are no values for Class 3 and 4 farms, but the rolling Class 5 farms had levels remaining fairly constant at 2 mg N/L in drainage water. If this was assumed to be all nitrate-N it is well below the recommended level in drinking water by the WHO of 11.3 mg NO_3-N/L, but still above the ANZECC trigger of 0.44 mg NO_3-N/L.

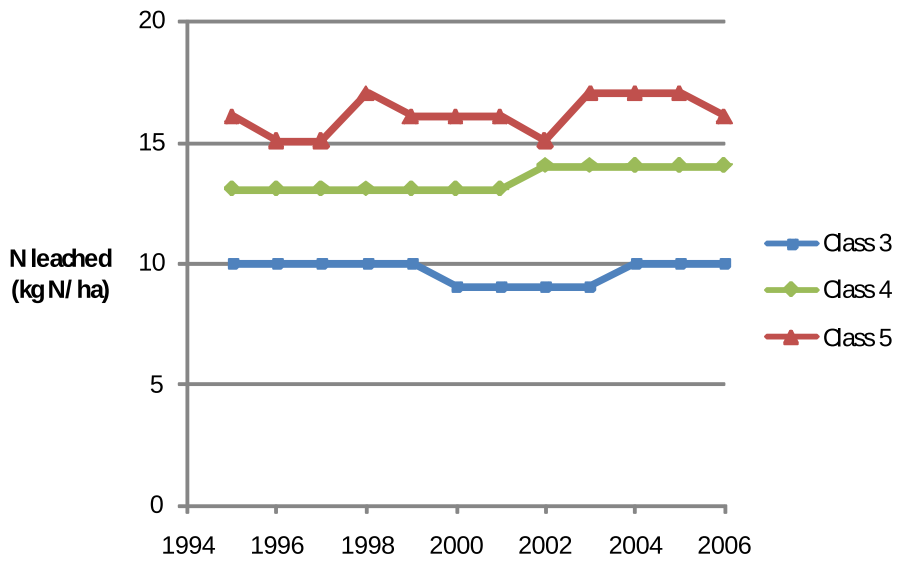

Figure 12: N leached from Waikato sheep, beef and deer farms

6.2.2.3 P Outputs

i. Class 3 and 4 Farms

P lost in product and in runoff remained constant over time at 2 and 2 kg/ha between 1995/96 and 2006/07, respectively (Figure 13). Soil P immobilisation/absorption increased from 13 to 16 kg/ha in Class 3 farms and 16 to 20 kg/ha in Class 4 farms.

ii. Class 5 Farms

P lost in product remained constant over time while P in runoff dropped from 2 to 1 kg P/ha in 1999/2000. The only major continued change in farming practices on Class 5 farms over this period was deer farming ceasing in 1999/2000. Deer have a higher P runoff factor in the model. Soil P immobilisation/absorption remained relatively constant around 17 kg/ha from 1995/96 to 2006/07.

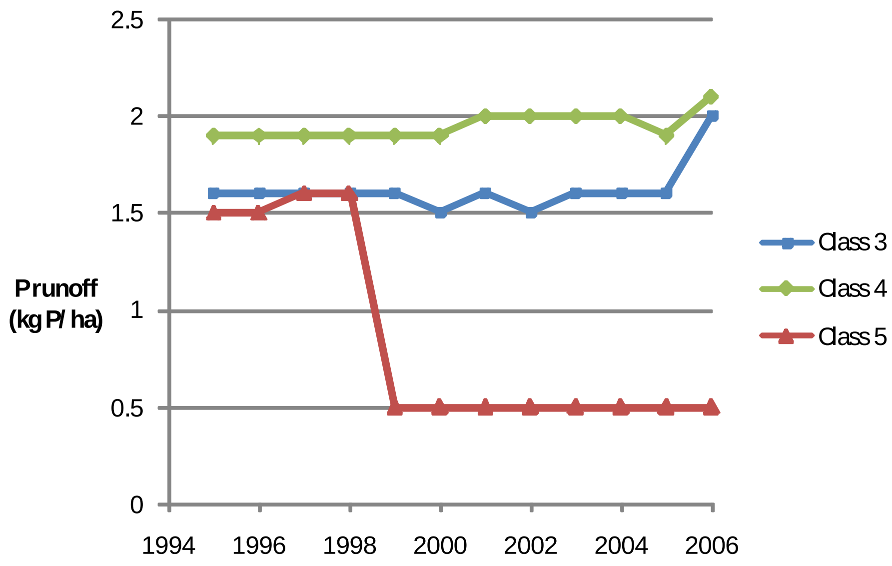

Figure 13: P runoff from Waikato sheep, beef and deer farms

6.3 OVERSEER Nutrient Loss Indices

6.3.1 Dairy Farms

Tables for OVERSEER Nutrient Loss Indices for the dairy farms can be seen in Appendices 8-10.

From 1997/98 to 2007/08 there was an overall increase in farm N surplus from 90 to 146, 118 to 166 and 144 to 195 kg N/ha/yr for Lower Quartile, Average and Upper Quartile farms, respectively (Figure 14). This coincided with an increase in inputs in fertiliser and brought-in feed and was associated with an estimated increase in immobilisation of N in soil organic matter.

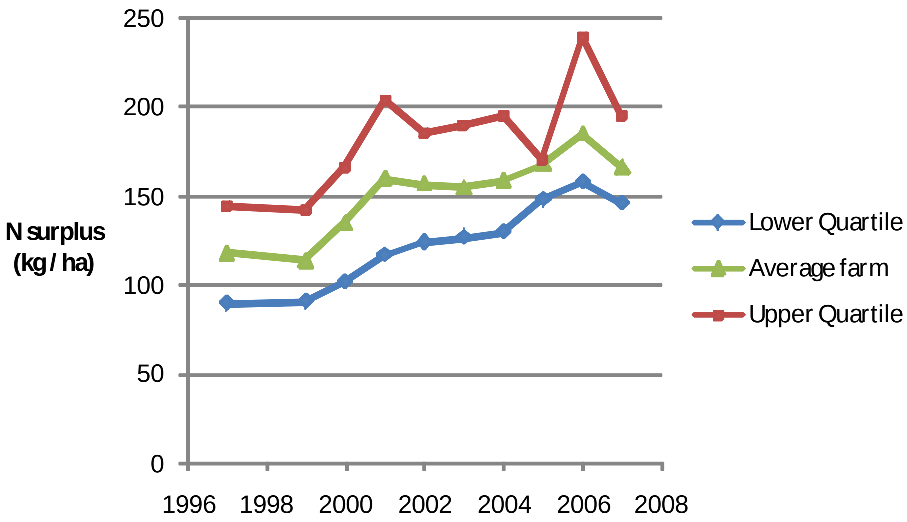

Figure 14: N Surplus in Waikato dairy farms

N conversion efficiency is the amount of N in product/total N inputs. The N conversion efficiency decreased from 32 to 25, 33 to 28 and 34 to 32%, respectively (Figure 15).

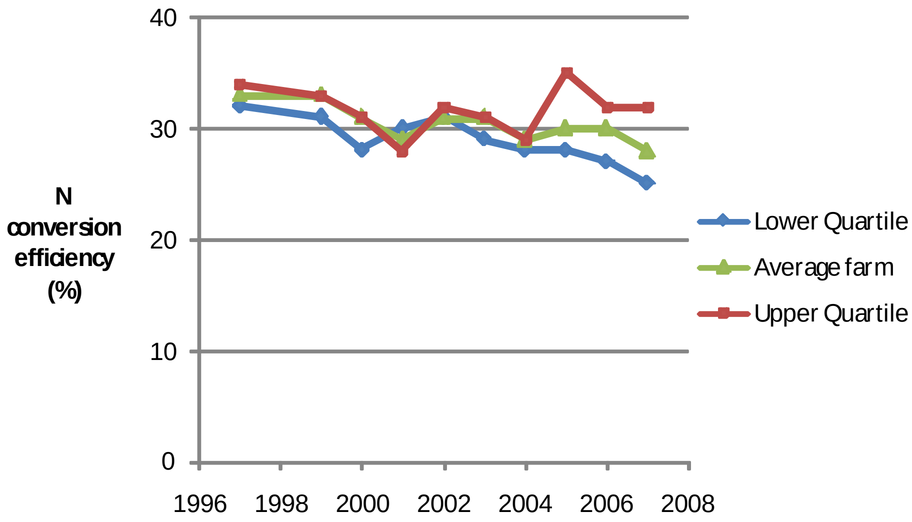

Figure 15: N conversion efficiency for Waikato dairy farms

Farm P surpluses decreased from 52 to 34, 55 to 43 and 56 to 35 kg P/ha/yr for Lower Quartile, Average and Upper Quartile farms, respectively (Figure 16).

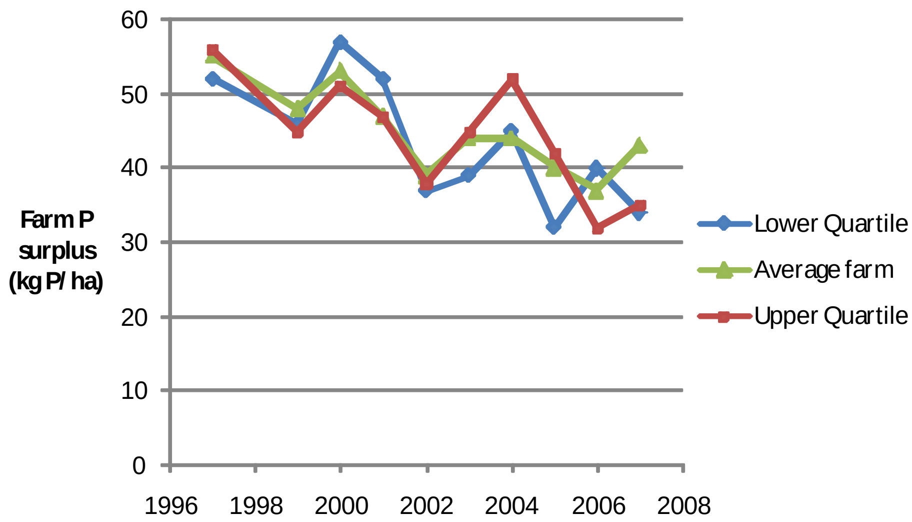

Figure 16: Farm P surplus for Waikato dairy farms

6.3.1.1 Rainfall and drainage

The average long term rainfall of 1250 mm was used giving an annual drainage value of 508 mm across all farm categories.

6.3.2 Sheep, Beef and Deer Farms

Tables for OVERSEER Nutrient Loss Indices for the sheep, beef and deer farms can be seen in Appendices 17-19.

Farm N surplus remained constant at 54 kg/ha/yr for Class 3 farms, but increased in Class 4 and 5 farms from 58 to 61 and 65 to 85 kg/ha/yr, respectively (Figure 17).

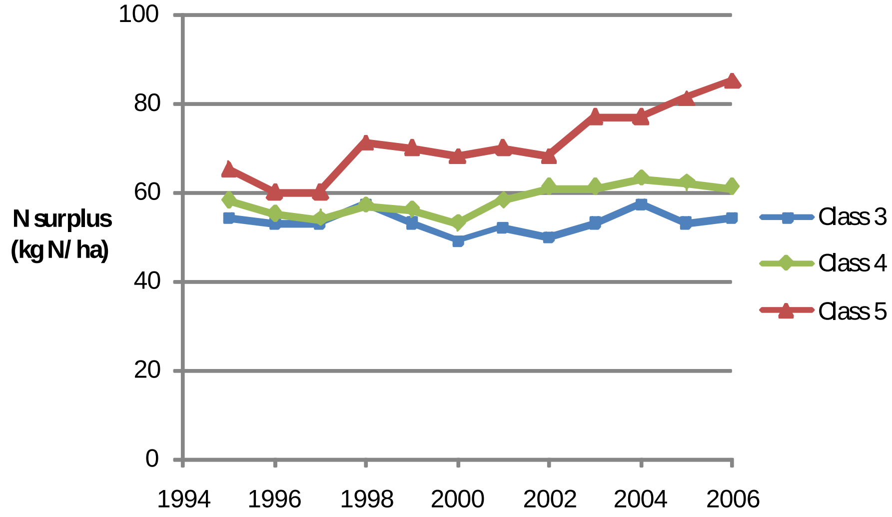

Figure 17: N surplus in Waikato sheep, beef and deer farms

The N conversion efficiency decreased across all categories over time, from 20 to 19, 20 to 18 and 20 to 14% for Class 3, 4 and 5, respectively (Figure 18).

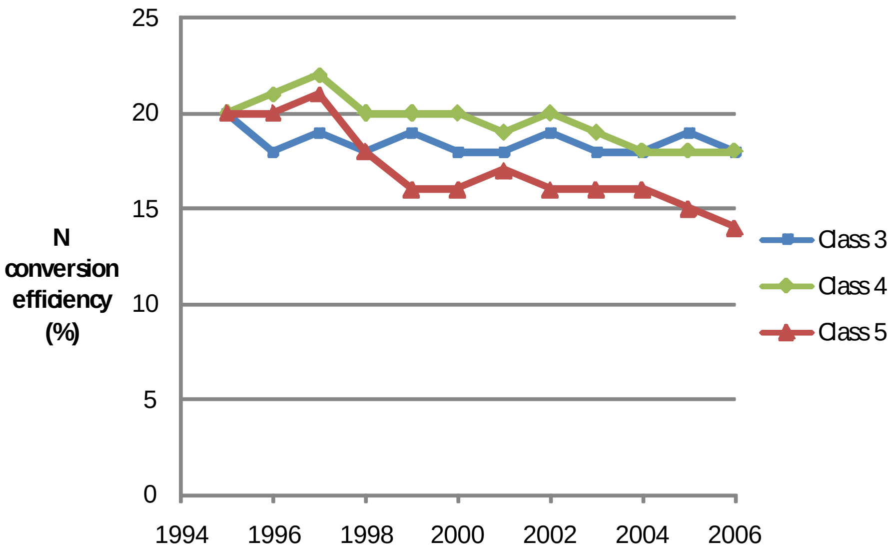

Figure 18: N conversion efficiency (%) for Waikato sheep, beef and deer farms.

Farm P surplus decreased over time in Class 3 and 5 farms from 20 to 18 and 35 to 30 kg/ha, respectively, but increased from 24 to 29 kg/ha in Class 4 farms (Figure 19).

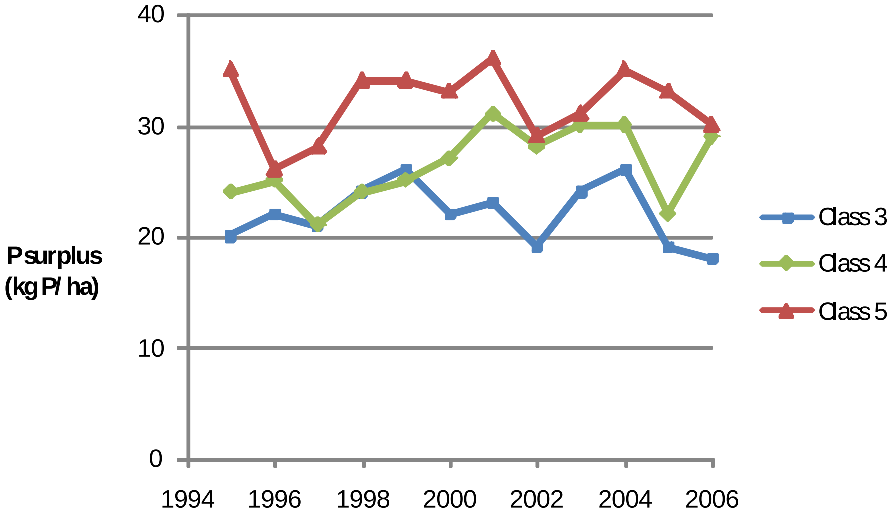

Figure 19: Farm P surplus for Waikato sheep, beef and deer farms

6.3.2.1 Rainfall and drainage

Rainfall data reflecting the spatial distribution of the three Sheep, Beef and Deer classes was provided by MWNZ. Rainfall remained relatively constant over time, with expected yearly fluctuations, averaging 1720 mm for Class 3, 1585 mm for Class 4, and 1422 mm for Class 5 farms. Consequently, drainage also remained fairly constant at 488, 553 and 598 mm for Class 3, 4 and 5 farms respectively (Figure 20).

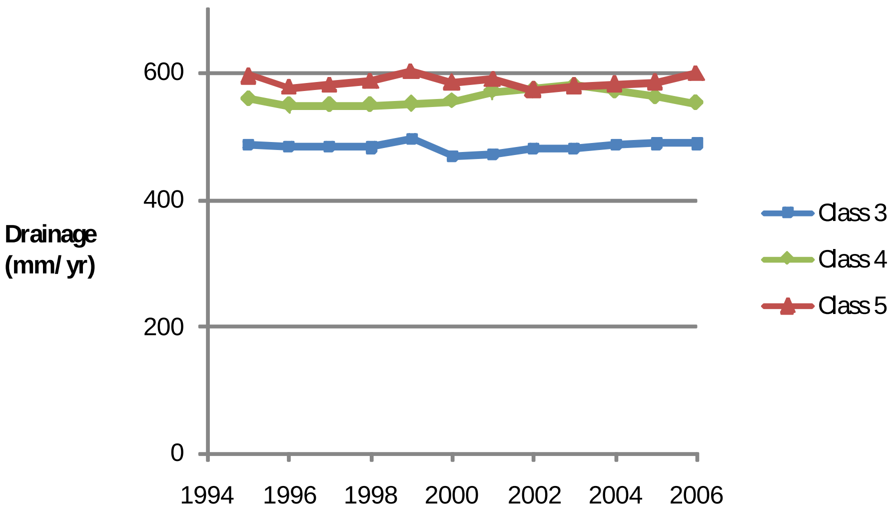

Figure 20: Annual drainage for Waikato sheep, beef and deer farms

6.4 Greenhouse Gas Emissions

The OVERSEER model produces an estimate for total greenhouse gas emissions, and also the individual components; methane (CH_4), nitrous oxide (N_2O), carbon dioxide (CO_2) and Capital. For this report, Capital, which is the CO_2-equivalents associated with infrastructure on the farm for items such as tractors, implements, buildings, fences, races etc, is not included with the total greenhouse gas emission values.

The main component of GHG emissions is methane loss from animals. The main source of N_2O emission is from excreta, effluent and fertiliser N. The amount of N lost as N_2O is relatively small, but can have a large effect on the total GHG emissions in terms of CO_2-equivalents. CO_2 emissions come from the dissolution of lime (particularly when capital dressings are applied), N fertiliser, fuel and electricity use on the farm.

6.4.1 Dairy farms

Between 1997 and 2007, the total greenhouse gas emissions increased from 9144 to 10707 kg CO_2-equivalents/ha/yr for Average farms, 11048 to 13693 for Upper Quartile farms and 7183 to 8829 for Lower Quartile farms (Appendices 8-10). All components increased, but the CO_2 increase was the greatest at around 170% across all categories. Approximately 60% of the total greenhouse gas emissions occurred as methane across all farm categories (Figure 21).

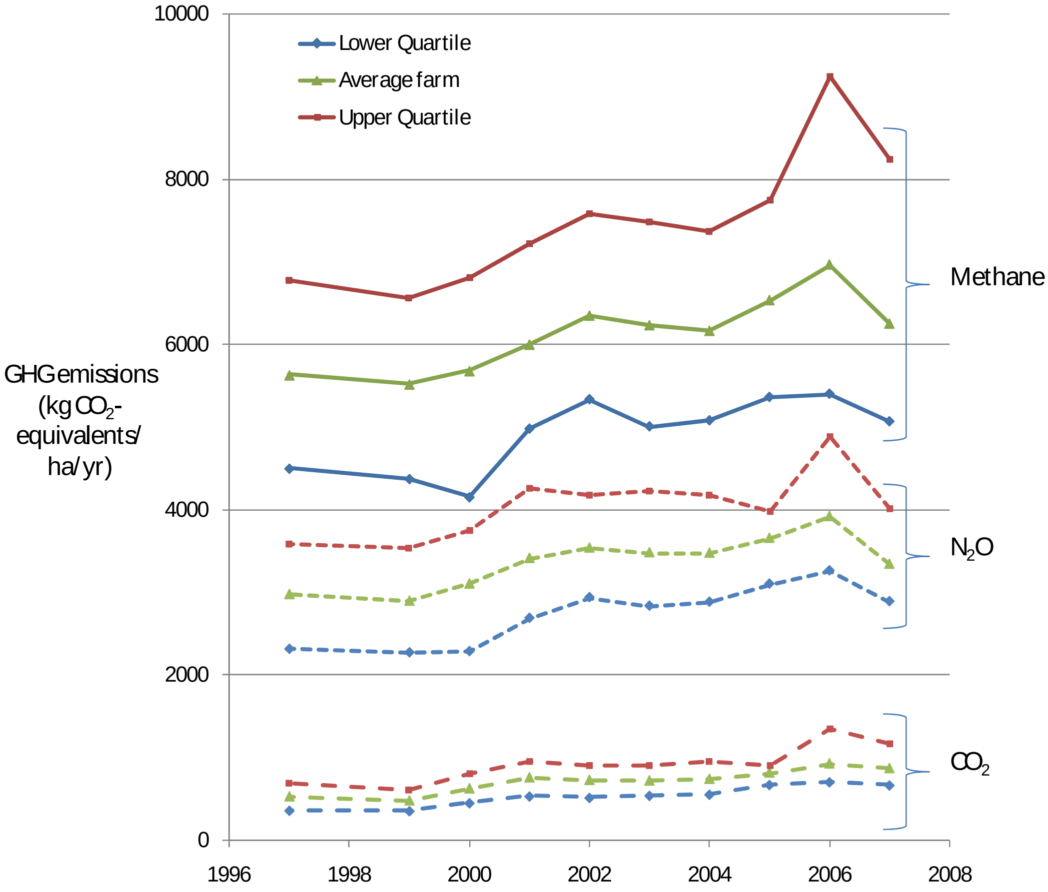

Figure 21: Greenhouse Gas emissions for Waikato dairy farms

6.4.2 Sheep, Beef and Deer farms

The total greenhouse gas emissions remained fairly constant from 1994 to 2006 for Class 3 farms at around 3300 kg CO_2-equiv/ha/yr, whereas Class 4 farms showed a slight increase from 3878 to 4000, and Class 5 farms a decrease from 4828 to 4678 kg CO_2-equivalents/ha/yr (Appendices 17-19). Both methane and N_2O emissions/ha either remained constant, or had small decreases, while CO_2 increased by between 175% (187 to 329 kg CO_2-equivalents/ha/yr) and 370% (43 to 159 kg CO_2-equivalents/ha/yr) from Class 5 to Class 3 farms across the same time period (Figure 22).

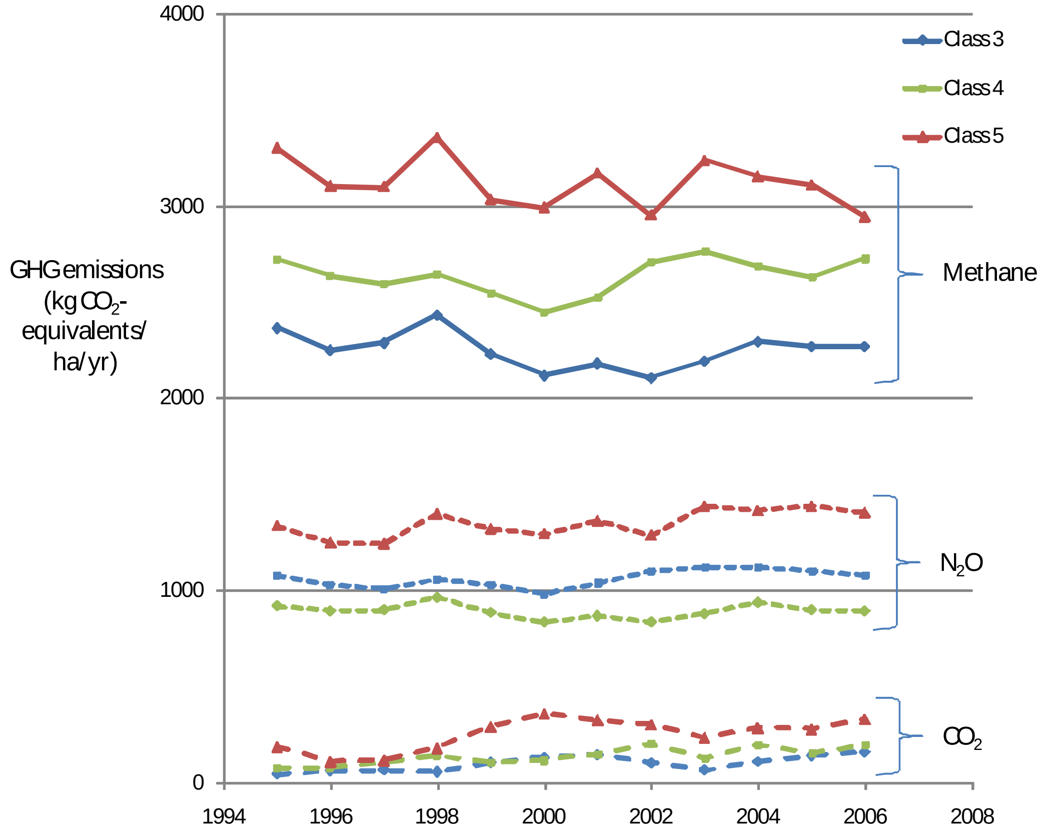

Figure 22: Greenhouse Gas emissions for Waikato sheep, beef and deer farms

6.5 Caution in data interpretation

No individual farm data has been used in this summary. The data provided for both the dairy farms from DairyNZ's DairyBase, and sheep, beef and deer farms from Meat and Wool New Zealand's' data base was provided on an average basis for each of the farm categories or classes based on a survey of farms. On an individual farm basis, farm practices will vary. For example, animals may be grazed off over winter, feed pads and standoff pads may be used, crops may be grown, effluent ponds may be used, and fertiliser may be applied during at-risk months. All these factors will affect both the inputs and outputs from OVERSEER.

The total number of dairy farms from DairyBase for the 2007/08 year was 93 (including 23 Upper Quartile and 23 Lower Quartile farms). This is only a small fraction of the 4000 plus farms in the Environment Waikato catchment (LIC, 2008). This also applies to the sheep, beef and deer farms. Some caution therefore needs to be used as results in this summary, while averages for each category or class, still only represent a small fraction of the overall land area.

7. Comparison with previous report

In 2004, a report was prepared for Environment Waikato comparing data from two years, being 1997/98 and 2002/03, for MAF Sheep and Beef, MAF dairy and Dexcel ProfitWatch dairy farms (Judge and Ledgard, 2004). Data from that report was provided on an individual farm basis. The output data for the report was obtained using the OVERSEER nutrient budget model (version 5.0.10). The change in model version between the previous report and this current one will account for some variation between data as upgrades have been made to OVERSEER in the interim, and there have been slight modifications to the program which may result in subtle differences between the two versions.

7.1 Dairy Farms

Table 1: Summary table of the main environmental emissions for dairy farms from the current 2009 report and the previous 2004 report. Values in brackets represent the Lower and Upper Quartiles for milk production (except MAF dairy data which represents ranges).

	Year	N leached (kg N/ha)	Average N in drainage (mg N/L)	P runoff (kg P/ha)	Total GHG (kg CO_2-equivalents/ha/yr)
Waikato dairy farms	1997/98	32 (26-39)	5 (4-7)	0.8 (0.7-0.9)	9144 (7183-11048)
2009 report	1999/2000	31 (25-39)	5 (4-7)	0.8 (0.6-0.9)	9178 (7272-10990)
	2000/01	34 (25-42)	6 (4-7)	0.8 (0.7-0.9)	9676 (7159-11649)
	2001/02	38 (30-51)	7 (5-9)	0.8 (0.7-0.9)	10444 (8477-12711)
	2002/03	39 (32-48)	7 (5-8)	0.8 (0.7-0.9)	10881 (9060-12952)
	2003/04	39 (31-49)	7 (5-9)	0.8 (0.8-0.9)	10697 (8638-12891)
	2004/05	39 (32-49)	7 (5-9)	0.8 (0.7-0.9)	10641 (8764-12778)
	2005/06	41 (34-44)	7 (6-8)	0.8 (0.9-0.9)	11239 (9342-12896)
	2006/07	45 (37-60)	8 (7-11)	0.8 (0.7-0.9)	12048 (9594-15739)
	2007/08	38 (33-47)	7 (6-8)	0.9 (0.7-0.8)	10707 (8829-13693)
Dexcel ProfitWatch	1997/98	32 (24-39)	5 (4-7)	1.3 (1.0-1.3)	7530 (5925-8956)
2004 report	2002/03	40 (31-51)	7 (5-9)	1.3 (1.4-1.5)	8635 (6967-10276)
MAF dairy	1997/98	33 (18-68)	6 (2-12)	1.0 (0.1-2.3)	8628 (5643-13029)
2004 report	2002/03	42 (30-53)	10 (5-14)	1.0 (0.2-1.8)	8878 (7006-11148)

Summary results for all years for this report and the two years for the previous report can be seen in Table 1 (based on using OVERSEER versions 5.4.3 and 5.0.10, respectively). Comparison of the same years covered by both reports show similar values for the N leached per hectare and the average N concentration in drainage water.

The GHG part of the OVERSEER model has had more modifications than other parts, and hence there is a bigger variation between the two versions.

7.2 Sheep, Beef and Deer farms

Summary results for all years for this report and the two years for the previous report can be seen in Table 2. In the 2004 report, around 20 sheep and beef farms were evaluated, while in this report sheep, beef and deer farms numbered around 70 in all farm classes (Appendix 1). All values for N leaching, average N concentration in drainage, P runoff and total GHG are similar between the two years of the 2004 report and those obtained in this report.

Table 2: Summary table of the main environmental emissions for sheep, beef and deer farms. Values represent Class 3, Class 4, Class 5 farms (only Class 5 farms have average N concentration values). Values in brackets from the 2004 report are ranges.

	Year	**N leached (kg N/ha)**	**Average N in drainage (mg N/L)**	**P runoff (kg P/ha)**	**Total GHG (kg CO_2-equivalents/ha/yr)**
sheep, beef and deer	1995/96	10, 13, 16	2	2, 2, 2	3327, 3878, 4828
2009 report	1996/97	10, 13, 15	2	2, 2, 2	3207, 3750, 4461
	1997/98	10, 13, 15	2	2, 2, 2	3253, 3712, 4459
	1998/99	10, 13, 17	2	2, 2, 2	3453, 3843, 4937
	1999/2000	10, 13, 16	2	2, 2, 1	3221, 3681, 4646
	2000/01	9, 13, 16	2	2, 2, 1	3081, 3548, 4645
	2001/02	9, 13, 16	2	2, 2, 1	3195, 3712, 4858
	2002/03	9, 14, 15	2	2, 2, 1	3046, 4008, 4542
	2003/04	9, 14, 17	2	2, 2, 1	3139, 4008, 4908
	2004/05	10, 14, 17	2	2, 2, 1	3341, 4002, 4854
	2005/06	10, 14, 17	2	2, 2, 1	3308, 3881, 4825
	2006/07	10, 14, 16	2	2, 2, 1	3323, 4000, 4678
MAF Sheep and Beef	1997/98	8 (4-19)	2 (1-3)	1.0 (0.2-1.8)	3214 (1179-5857)
2004 report	2002/03	10 (5-19)	1 (<1-2)	2.0 (0.8-3.3)	3594 (2322-4557)

8. Rainfall Scenarios

Three rainfall scenarios were investigated for all farm types on the last year for which data was available (2007/08 for dairy and 2006/07 for sheep, beef and deer). Low, average and high rainfall regimes were defined for the farm types taking their spatial distribution within the Waikato Region into account.

8.1 Dairy Farms

Each farm category had three rainfall scenarios carried out on the most recent years farm data, that being 2007/08. These were the average of 1250 mm for Waikato dairy farms, and what was deemed to be upper and lower limits for the region of 1500 and 1000 mm/yr, respectively (Appendices 20 and 21).

While increasing rainfall will impact on various inputs and outputs from OVERSEER, on others such as greenhouse gas emissions it will have no effect as this is largely determined by the stocking rate, production and farm inputs. N and P lost in product removal, and farm N surplus also show no changes with increasing rainfall.

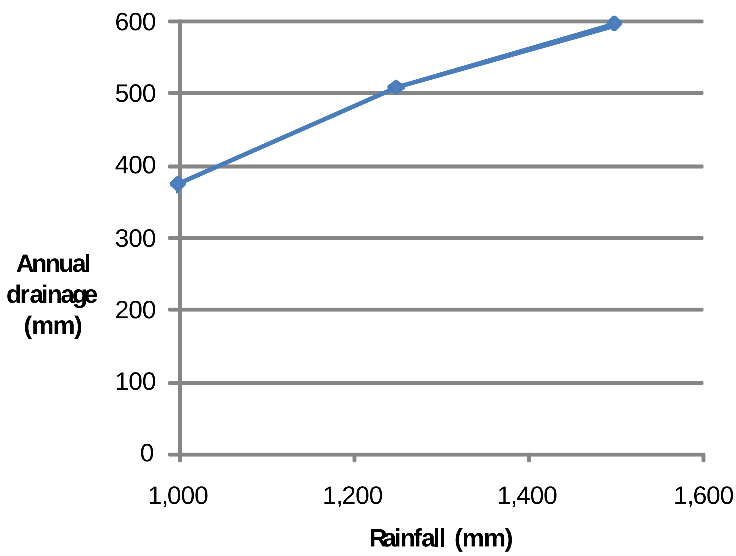

Figure 23: Effect of annual rainfall scenarios on drainage for dairy farms

Atmospheric inputs and outputs of N both increased with increasing rainfall. The annual drainage increased from 374 to 597 mm/yr with increasing rainfall (Figure 23). This led to an increase in N leaching from 28 to 37, 33 to 43 and 41 to 53 kg N/ha/yr for Lower Quartile, Average and Upper Quartile farms, respectively (Figure 24). Increasing the drainage led to a dilution effect causing a decrease in N concentration in drainage water from grazed farm areas (Figure 25).

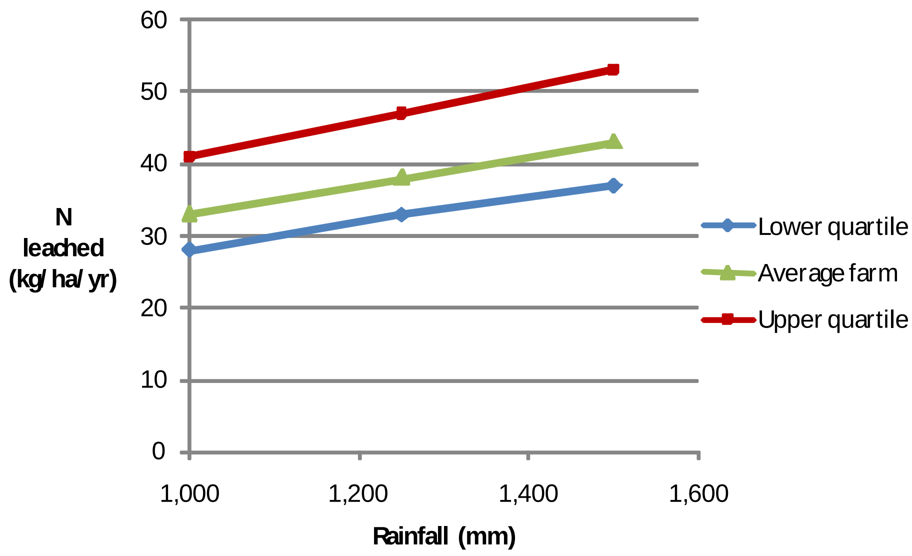

Figure 24: N leached with increasing rainfall for dairy farms

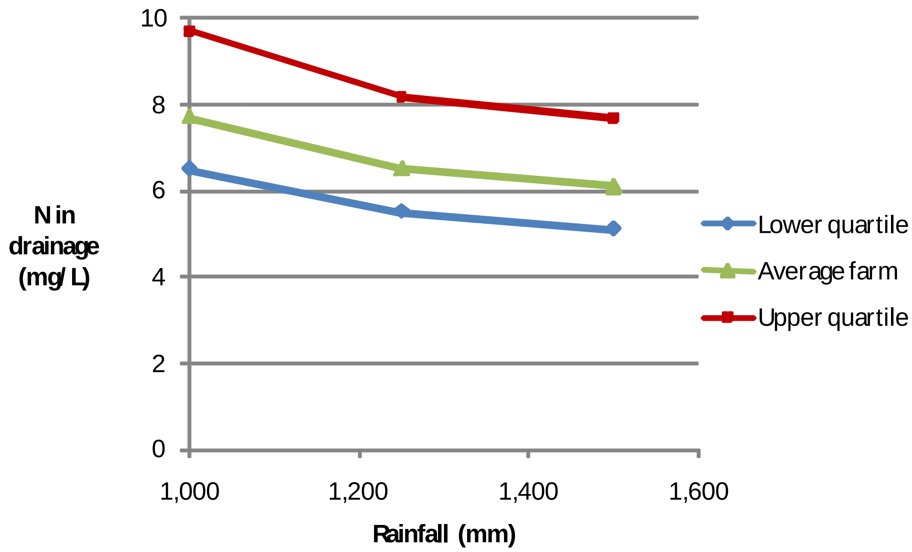

Figure 25: Calculated N concentration in drainage water with increasing rainfall for dairy farms

The P runoff from the farms also increased with increased rainfall, from 0.4 to 1.0, 0.5 to 1.3 and 0.5 to 1.2 kg P/ha/yr for Lower Quartile, Average and Upper Quartile farms, respectively (Figure 26).

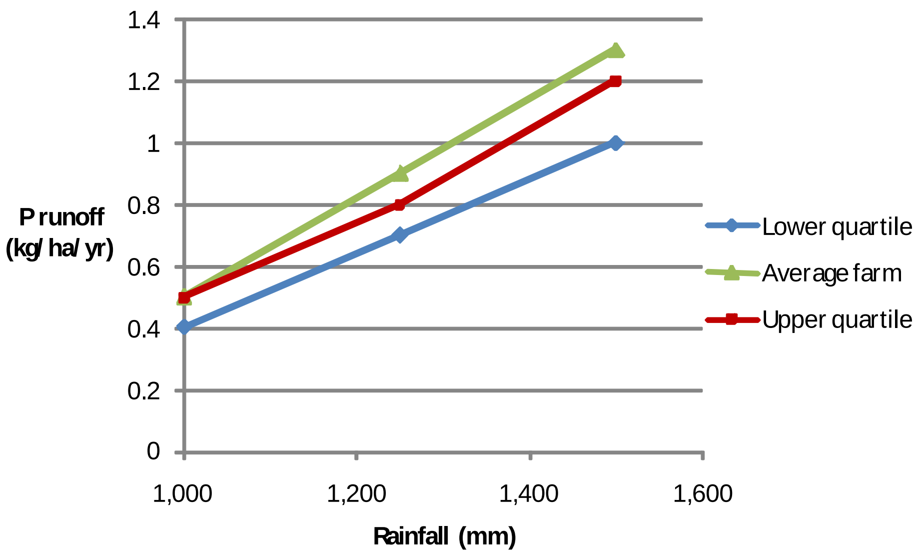

Figure 26: P runoff with increasing rainfall for dairy farms

8.2 Sheep, Beef and Deer Farms

Each farm class had three rainfall scenarios carried out on the most recent years farm data, that being 2006/07. These scenarios were; the rounded value of the most recent year's rainfall and 300 mm lower and 300 mm higher for each class i.e. 1400, 1700 and 2000 for Class 3, 1300, 1600 and 1900 for Class 4 and 1100, 1400 and 1700 for Class 5 farms. These were deemed to be likely upper and lower limits of rainfall that would occur in each farm class (Appendices 22 and 23).

Many of the OVERSEER results showed no change with increasing rainfall such as GHG emissions, and N and P outputs in product (meat, wool and velvet). The most obvious change is the increase in annual drainage across all the farm classes (Figure 27), which in turns leads to an increase N leaching (Figure 28), and an increase in Farm N surplus. The P runoff (Figure 29) also increased with increased rainfall for all farm classes.

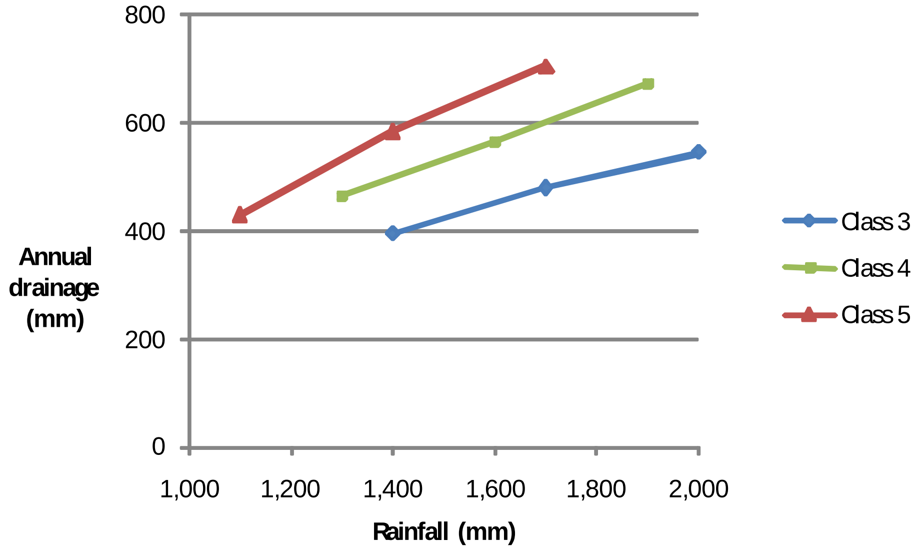

Figure 27: Rainfall scenarios showing increasing rainfall effects on drainage for sheep, beef and deer farms

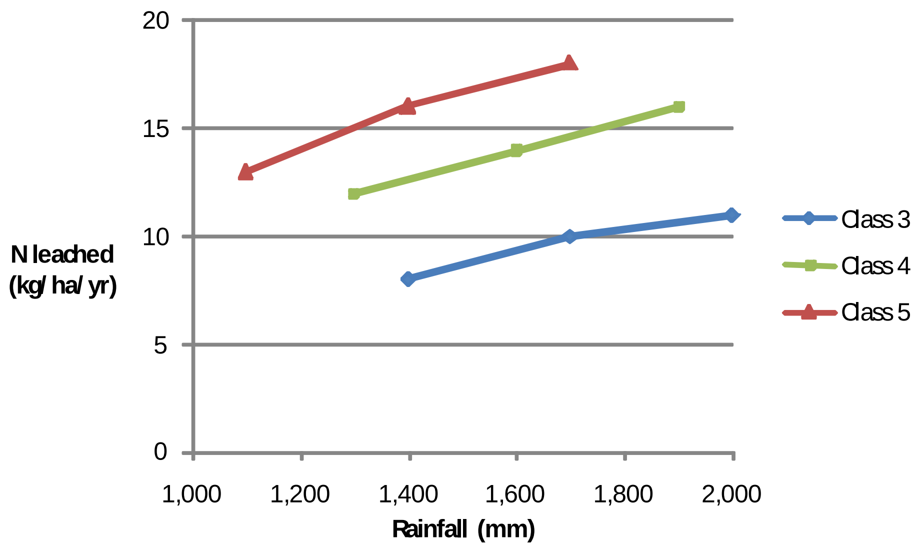

Figure 28: N leached with increasing rainfall for sheep, beef and deer farms

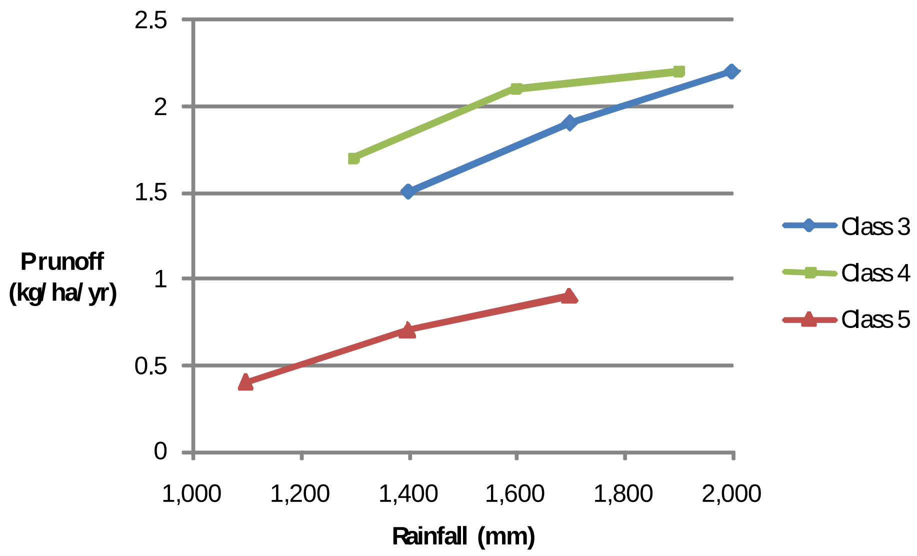

Figure 29: P runoff with increasing rainfall for sheep, beef and deer farms

9. Discussion

9.1 N Leaching

9.1.1 Dairy Farms

N leaching increased across all farm categories over time. This corresponded to increasing inputs such as in fertiliser and imported supplementary feed and increased stocking rate. These all led to increased production which can in turn lead to increased N leaching and increased N in drainage water from grazed farm areas.

9.1.2 Sheep, Beef and Deer Farms

Rainfall, drainage and N leaching have all remained relatively constant over time. This reflected small changes in stocking rate and N fertiliser inputs (except in farm class 5)

9.2 P Runoff

9.2.1 Dairy Farms

P runoff remained relatively constant over time despite a decrease in rate of fertiliser-P application illustrating the more dominating effect of other factors such as land slope and soil P status.

9.2.2 Sheep, Beef and Deer Farms

Default values for soil test values, including Olsen P, were used in the OVERSEER modelling (Appendices 11-13). These may be lower than actual values, and this would lead to an underestimate of the P runoff and subsequent P losses from the farm.

The major change in P runoff can be seen in the 1999/2000 year for the Class 5 farms when deer were no longer present. This reflects the impact of erosion caused by fence-line pacing of deer which can lead to increased P runoff (McDowell et al., 2005).

9.3 Greenhouse Gas Emissions

9.3.1 Dairy Farms

The Waikato dairy farms showed increases in methane, N_2O and CO_2 over time. These increases resulted directly from increases on the farms over time in stocking rate, milksolids produced, fertiliser-N usage and increasing supplementary feed being brought onto the farm allowing higher stocking rates and productivity.

Figure 30 shows the close relationship between greenhouse gas emissions and nitrogen leaching for Waikato dairy farms. Both GHG emissions and nitrogen leaching are affected by stock numbers, animal production and fertiliser-N use. This indicates that the implementation of farm practices or mitigations to reduce N leaching are also likely to have a synergistic effect on reducing GHG emissions.

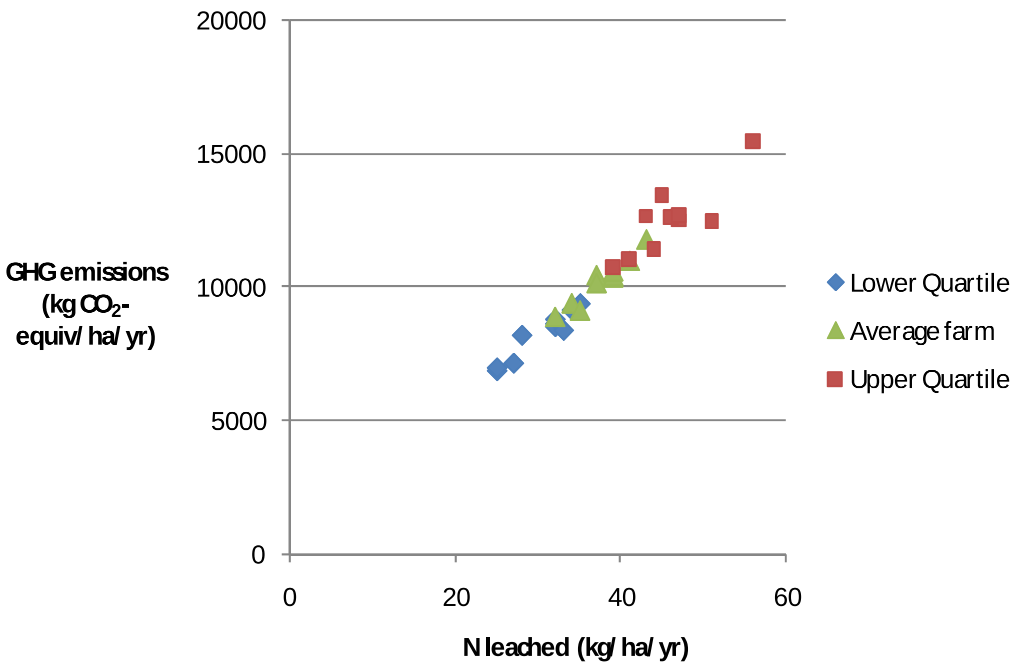

Figure 30: Relationship between GHG emissions and N leaching for Waikato dairy farms

Environmental efficiency can be shown by the level of emissions (GHG or N leaching) per kg of milk production. In general, the efficiency of both GHG emissions and N leaching per kg milksolids decreased with increasing milksolids/ha in moving from lower to upper quartile farms (Figure 31). Thus, the upper quartile farms generally showed the lowest GHG emissions/kg milksolids <u>and</u> the lowest N leaching/kg milksolids, while the opposite occurred with lower quartile farms.

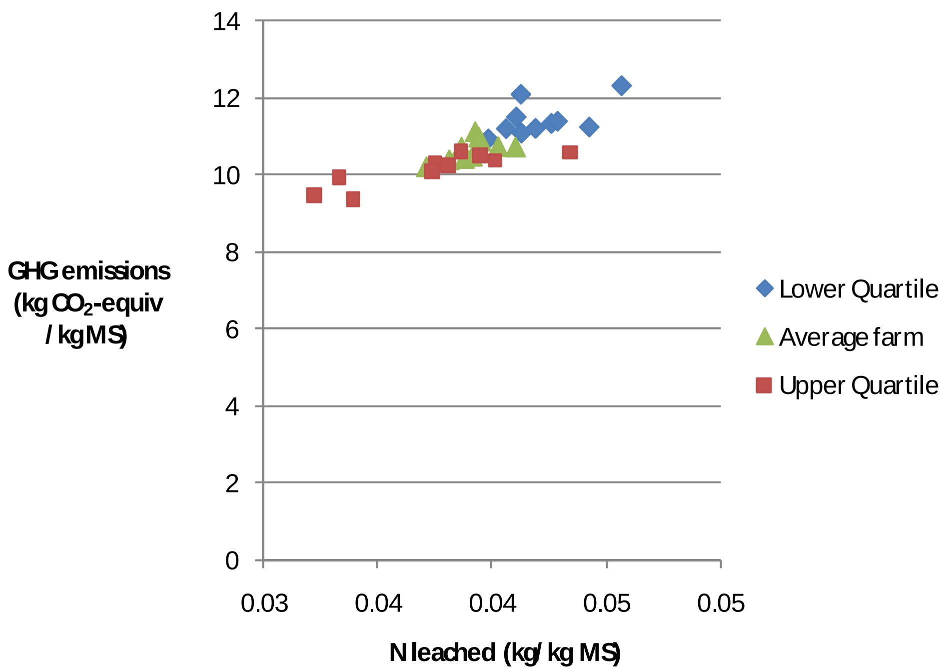

Figure 31: Relationship between GHG emissions/kg milksolids and N leaching/kg milksolids for Waikato dairy farms.

9.3.2 Sheep, Beef and Deer Farms

Although total GHG emissions remained relatively constant over time, methane decreased slightly, N_2O remained fairly constant and CO_2 increased over time. The increase in CO_2 levels over time corresponded to increases in lime being applied over the same period, as the dissolution of lime contributes significant amounts of CO_2 emissions.

Figure 32 shows the impact of increasing farming intensity of Waikato sheep, beef and deer farms across the three farm classes with the more intensive, higher fertiliser usage Class 5 farms showing the highest N leaching and GHG emissions per hectare.

Data on animal outputs (e.g. meat and wool production) was unavailable to examine environmental efficiency. However, an estimate of this can be obtained from emissions/stock unit. In general, the GHG emissions and N leaching per stock unit increased with increased intensity in moving from farm class 3 to farm class 5 (Figure 33). This suggests that farm class 3 is more environmentally efficient. However, this may not be the case for animal productivity (e.g. emissions/kg meat) and actual data is required before this can be evaluated.

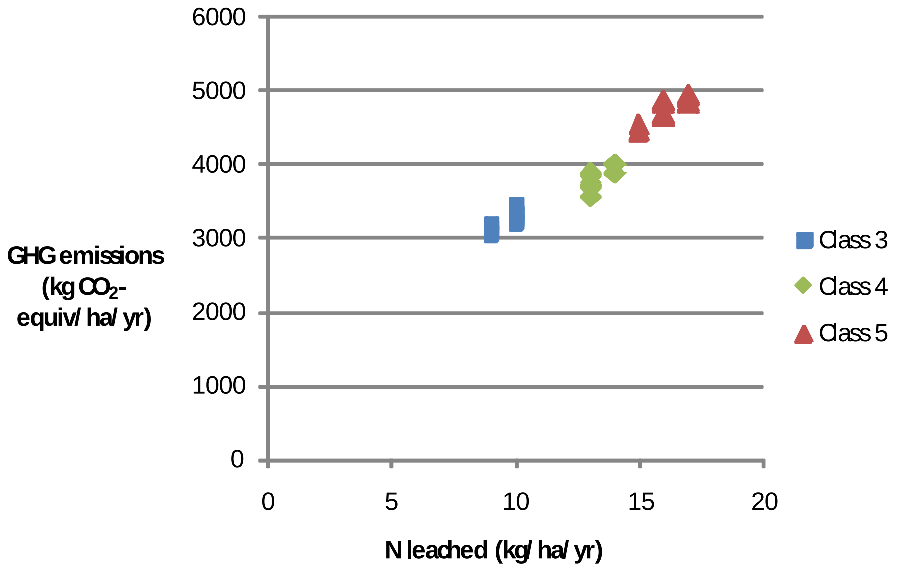

Figure 32: Relationship between GHG emissions and N leaching for Waikato sheep, beef and deer farms

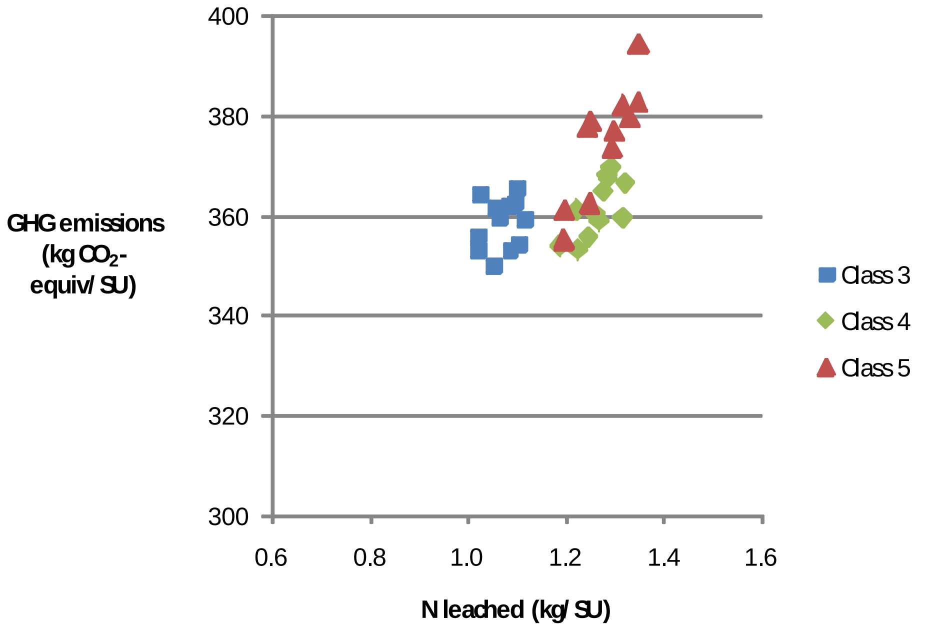

Figure 33: Relationship between GHG emissions/SU and N leaching/SU for Waikato sheep, beef and deer farms

9.4 Rainfall Scenarios

Scenario analyses of the effect of changes in annual rainfall showed increased N leaching and P runoff with increased rainfall. This illustrates model sensitivity to rainfall with a 25% increase in rainfall giving a similar increase in N leaching and an approximately 60% increase in P runoff.

Assumptions were made that the farm systems were the same for each rainfall scenario for each farm type. This may not be the case in reality. The higher rainfall scenarios could be associated with more pasture being produced and an increase in production. This would not only lead to an increase in N and P losses, but also to an increase in greenhouse gas emissions per hectare.

The lower rainfall scenarios may produce less pasture growth, which may require either extra supplementary feed to be brought in to keep production up to actual levels for that year, or stock numbers or productivity/animal may need to be reduced, with a consequent loss in production. The former could result in higher N leaching losses and the later in lower N leaching losses.

10. References

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11. Appendix

Appendix 1: Number of farms used in this evaluation

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Dairy Farms Lower Quartile			36		13	29	20	23	36	33	16	19	23
Dairy Farms Average			144		53	118	80	92	144	130	64	75	93
Dairy Farms Upper Quartile			37		13	34	20	20	36	33	16	19	23
Sheep, beef and deer Class 3	11	12	12	11	12	14	12	13	13	13	11	11	
Sheep, beef and deer Class 4	38	35	35	36	39	37	36	34	33	40	37	46	
Sheep, beef and deer Class 5	18	20	21	19	20	19	18	20	20	19	20	19	

Note that in all cases the year defined represents the first 6 months e.g. 1997 refers to the period 1 July 1997 to 30 June 1998 for dairy farms, and 1 September 1997 to 31 August 1998 for sheep, beef and deer farms.

Appendix 2: Dairy; Lower Quartile farms – Farm input data

Region: Waikato
Slope: Rolling
Rainfall: 1250 mm
Distance from Coast: 50 km
Soil group: Volcanic

		Production		Soil Test	Fertiliser inputs				
	Farm size (ha)	MS (kg)	cows/ha	Olsen P	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Supplements (T)
1997	94	58967	2.4	31	37	56	67	59	18
1999	91	55466	2.3	27	41	50	47	60	20
2000	97	59576	2.2	32	65	61	60	60	34
2001	90	61261	2.4	32	75	56	64	64	53
2002	88	71062	2.7	37	83	43	50	44	22
2003	110	82065	2.5	40	93	44	43	45	40
2004	118	88604	2.6	37	95	50	44	47	42
2005	161	132619	2.6	52	120	38	62	52	105
2006	138	115102	2.7	35	137	47	64	50	45
2007	167	116778	2.7	35	115	37	52	36	200

Appendix 3: Dairy; Average farms – Farm input data

Region: Waikato
Slope: Rolling
Rainfall: 1250 mm
Distance from Coast: 50 km
Soil group: Volcanic

		Production		Soil Test	Fertiliser inputs				
	Farm size (ha)	MS (kg)	cows/ha	Olsen P	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Supplements (T)
1997	90	76892	2.8	36	68	62	75	67	33
1999	78	63600	2.8	39	62	54	52	57	29
2000	92	80470	2.8	39	94	59	61	65	60
2001	83	77411	2.9	36	129	53	60	58	76
2002	89	90670	3.0	42	121	47	52	51	69
2003	96	95390	3.0	42	119	51	56	52	72
2004	101	97816	3.0	41	125	51	53	55	86
2005	131	138400	3.1	44	135	47	60	62	147
2006	120	138601	3.2	43	156	45	65	54	172
2007	120	112830	3.1	47	129	46	52	45	283

Appendix 4: Dairy; Upper Quartile farms – Farm input data

Region: Waikato
Slope: Rolling
Rainfall: 1250 mm
Distance from Coast: 50 km
Soil group: Volcanic

		Production		Soil Test	Fertiliser inputs				
	Farm size (ha)	MS (kg)	cows/ha	Olsen P	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Supplements (T)
1997	85	91814	3.2	41	92	64	74	69	70
1999	74	75098	3.2	49	90	53	51	58	31
2000	84	91572	3.2	43	126	59	64	69	92
2001	79	92957	3.3	42	180	56	51	63	124
2002	72	89998	3.5	50	147	47	68	57	95
2003	75	91855	3.5	46	155	54	71	58	77
2004	76	90258	3.4	44	162	60	70	66	96
2005	94	125045	3.4	47	122	50	50	57	192
2006	96	157740	3.8	44	202	41	68	56	348
2007	92	123733	3.7	41	144	38	42	48	421

Appendix 5: Dairy; Lower Quartile farms - OVERSEER N and P budget (kg/ha/yr)

	N Inputs		P Inputs	N Outputs				P Outputs		
	Atmospheric N	Supplement N	Supplement P	Product (meat & fibre)	Atmospheric	Runoff /leaching	Immobilisation	Product (meat & fibre)	Runoff /leaching	Immobilisation /absorption
1997	94	3	1	43	33	26	32	7	0.7	32
1999	89	3	1	42	33	25	33	7	0.6	29
2000	73	5	1	40	35	25	41	7	0.7	33
2001	84	8	2	49	42	30	46	8	0.7	33
2002	94	3	1	55	46	32	46	9	0.7	36
2003	82	5	1	51	45	31	54	9	0.8	39
2004	83	5	1	51	46	32	52	9	0.7	37
2005	78	8	1	56	51	34	62	9	0.9	47
2006	77	4	1	57	55	37	67	10	0.7	35
2007	67	14	3	48	48	33	65	8	0.7	34

Appendix 6: Dairy; Average farms - OVERSEER N and P budget (kg/ha/yr)

	N Inputs		P Inputs	N Outputs				P Outputs		
	Atmospheric N	Supplement N	Supplement P	Product (meat & fibre)	Atmospheric	Runoff /leaching	Immobilisation	Product (meat & fibre)	Runoff /leaching	Immobilisation /absorption
1997	105	5	1	59	45	32	41	10	0.8	37
1999	104	5	1	56	43	31	40	9	0.8	38
2000	94	8	2	60	49	34	52	10	0.8	39
2001	86	11	2	64	56	38	66	11	0.8	36
2002	98	9	2	70	57	39	61	12	0.8	40
2003	97	9	2	68	56	39	60	11	0.8	41
2004	91	11	2	66	57	39	63	11	0.8	40
2005	94	13	3	72	60	41	67	12	0.8	42
2006	94	17	3	79	66	45	75	13	0.8	41
2007	76	28	5	64	55	38	73	11	0.9	44

Appendix 7: Dairy; Upper Quartile farms - OVERSEER N and P budget (kg/ha/yr)

	N Inputs		P Inputs	N Outputs				P Outputs		
	Atmospheric N	Supplement N	Supplement P	Product (meat & fibre)	Atmospheric	Runoff /leaching	Immobilisation	Product (meat & fibre)	Runoff /leaching	Immobilisation /absorption
1997	117	11	2	74	55	39	51	12	0.9	41
1999	117	5	1	70	54	39	49	12	0.9	46
2000	103	14	3	75	60	42	64	12	0.9	42
2001	96	12	2	81	72	51	81	13	0.9	41
2002	111	16	3	86	68	48	70	14	0.9	47
2003	109	13	2	84	70	49	72	14	0.9	44
2004	100	16	3	81	70	49	76	14	0.9	43
2005	117	24	5	91	63	44	63	15	0.9	45
2006	112	42	8	113	89	60	91	19	0.9	42
2007	91	54	10	92	65	47	83	15	0.8	40

Appendix 8: Dairy; Lower Quartile farms - OVERSEER summary data

	Nutrient loss indices						Greenhouse gas emissions			
	N leached	Farm N surplus	P runoff	Farm P surplus	N conversion efficiency	N in drainage	Methane	N_2O	CO_2	Total
	(kg/ha/yr)				(%)	(mg/L)	(CO_2 equivalents - kg/ha/yr)			
1997	26	90	0.7	52	32	4.1	4498	2320	365	7183
1999	25	91	0.6	46	31	4.0	4374	2278	359	7272
2000	25	102	0.7	57	28	4.0	4155	2293	455	7159
2001	30	117	0.7	52	30	4.8	4981	2693	537	8477
2002	32	124	0.7	37	31	5.3	5335	2943	519	9060
2003	31	127	0.8	39	29	5.1	5009	2840	544	8638
2004	32	130	0.7	45	28	5.2	5081	2888	557	8764
2005	34	148	0.9	32	28	5.8	5362	3105	674	9342
2006	37	158	0.7	40	27	6.2	5401	3265	707	9594
2007	33	146	0.7	34	25	5.5	5069	2894	669	8829

Appendix 9: Dairy; Average farms - OVERSEER summary data

	Nutrient loss indices						Greenhouse gas emissions			
	N leached	Farm N surplus	P runoff	Farm P surplus	N conversion efficiency	N in drainage	Methane	N_2O	CO_2	Total
	(kg/ha/yr)				(%)	(mg/L)	(CO_2 equivalents - kg/ha/yr)			
1997	32	118	0.8	55	33	5.3	5630	2981	533	9144
1999	31	114	0.8	48	33	5.2	5520	2901	485	9178
2000	34	135	0.8	53	31	5.7	5679	3108	629	9676
2001	38	160	0.8	47	29	6.5	6000	3416	760	10444
2002	39	157	0.8	39	31	6.7	6349	3540	730	10881
2003	39	155	0.8	44	31	6.5	6234	3484	723	10697
2004	39	159	0.8	44	29	6.6	6167	3479	743	10641
2005	41	168	0.8	40	30	7.0	6537	3657	818	11239
2006	45	185	0.8	37	30	7.8	6965	3920	927	12048
2007	38	166	0.9	43	28	6.5	6254	3345	872	10707

Appendix 10: Dairy; Upper Quartile farms - OVERSEER summary data

	Nutrient loss indices (kg/ha/yr)						Greenhouse gas emissions (CO_2 equivalents - kg/ha/yr)			
	N leached	Farm N surplus	P runoff	Farm P surplus	N conversion efficiency (%)	N in drainage (mg/L)	Methane	N_2O	CO_2	Total
1997	39	144	0.9	56	34	6.6	6780	3575	693	11048
1999	39	142	0.9	45	33	6.5	6570	3533	612	10990
2000	42	166	0.9	51	31	7.2	6822	3749	811	11649
2001	51	204	0.9	47	28	8.8	7222	4251	967	12711
2002	48	186	0.9	38	32	8.3	7585	4177	913	12952
2003	49	190	0.9	45	31	8.5	7482	4219	916	12891
2004	49	195	0.9	52	29	8.5	7367	4177	960	12778
2005	44	170	0.9	42	35	7.6	7744	3984	910	12896
2006	60	240	0.9	32	32	10.7	9246	4881	1356	15739
2007	47	195	0.8	35	32	8.2	8242	4009	1182	13693

Appendix 11: Sheep, beef and deer; Class 3 farms – OVERSEER inputs

Region: Waikato
Slope: Steep hill
Distance from Coast: 50 km
Soil group: Sedimentary
OVERSEER default soil test values: Olsen P=23, QT K=12, QT Ca=7, QT Mg=26, QT Na=8, Organic S=14.7

			Fertiliser					Stock Numbers			Animal production	
	effective area	rainfall	N	P	K	S	Lime	Sheep	Cattle	Deer	wool sold	velvet sales
	(ha)	(mm)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	SU	SU	SU	(kg/yr)	(kg/yr)
1995	539	1,737	1	19	1	11	2	3,018	2,103	0	16,239	0
1996	529	1,719	4	21	3	14	19	2,678	2,108	0	13,980	0
1997	528	1,719	2	20	2	10	45	2,663	2,198	0	13,886	0
1998	554	1,716	3	23	4	13	4	3,148	2,268	0	13,059	0
1999	530	1,773	4	25	3	10	111	2,825	1,923	0	14,417	0
2000	418	1,660	2	21	3	14	184	2,059	1,500	0	9,465	0
2001	440	1,673	4	22	1	14	207	2,261	1,596	0	11,236	0
2002	446	1,706	4	18	6	11	114	2,296	1,478	0	11,708	0
2003	444	1,706	6	23	4	12	9	2,312	1,601	0	12,393	0
2004	441	1,737	9	25	2	12	82	2,375	1,692	0	12,661	0
2005	423	1,744	4	18	2	9	203	2,261	1,596	0	12,181	0
2006	423	1,744	4	17	2	11	229	2,322	1,521	0	11,498	0

Appendix 12: Sheep, beef and deer; Class 4 farms – OVERSEER inputs

Region: Waikato
Slope: Easy hill
Distance from Coast: 50 km
Soil group: Volcanic
OVERSEER default soil test values: Olsen P=20, QT K=8, QT Ca=6, QT Mg=22, QT Na=7, Organic S=18.1

			Fertiliser					Stock Numbers			Animal production	
	effective area	rainfall	N	P	K	S	Lime	Sheep	Cattle	Deer	wool sold	velvet sales
	(ha)	(mm)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	SU	SU	SU	(kg/yr)	(kg/yr)
1995	289	1,580	4	23	12	20	31	1,619	1,534	14	8,672	1
1996	281	1,556	2	24	9	22	50	1,560	1,405	19	8,894	2
1997	290	1,558	2	20	9	19	124	1,568	1,439	19	9,674	2
1998	294	1,560	6	23	7	23	156	1,651	1,439	38	8,068	3
1999	290	1,562	7	24	7	25	72	1,511	1,412	51	7,910	10
2000	300	1,575	5	26	9	30	103	1,431	1,473	56	7,256	11
2001	307	1,609	10	30	13	19	130	1,515	1,564	44	7,551	12
2002	325	1,615	10	28	11	19	258	1,815	1,650	73	11,146	13
2003	310	1,635	8	30	14	28	87	1,720	1,655	72	8,606	15
2004	303	1,610	12	30	13	23	221	1,585	1,636	59	6,798	12
2005	295	1,589	13	21	13	16	149	1,515	1,564	44	7,647	12
2006	280	1,566	6	27	12	26	186	1,375	1,640	32	6,513	8

Appendix 13: Sheep, beef and deer; Class 5 farms – OVERSEER inputs

Region: Waikato
Slope: Rolling
Distance from Coast: 50 km
Soil group: Volcanic
OVERSEER default soil test values: Olsen P=16, QT K=7, QT Ca=6, QT Mg=20, QT Na=7, Organic S=8

			Fertiliser					Stock Numbers			Animal production	
	effective area	rainfall	N	P	K	S	Lime	Sheep	Cattle	Deer	wool sold	velvet sales
	(ha)	(mm)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	SU	SU	SU	(kg/yr)	(kg/yr)
1995	213	1,422	7	35	20	36	155	950	1,787	110	5,751	43
1996	212	1,458	4	26	18	33	33	848	1,702	112	4,333	50
1997	219	1,464	5	28	20	33	32	921	1,767	60	6,222	15
1998	197	1,478	12	34	15	37	112	730	1,921	32	3,832	13
1999	197	1,435	20	34	22	39	305	580	1,848	0	3,218	0
2000	209	1,402	18	33	22	42	469	598	1,943	0	2,990	0
2001	201	1,411	18	36	26	40	378	765	1,820	0	3,108	0
2002	210	1,379	20	29	19	32	348	634	1,884	0	3,396	0
2003	207	1,389	27	31	23	45	121	711	2,008	0	3,637	0
2004	206	1,396	29	35	28	48	209	768	1,866	0	3,525	0
2005	205	1,401	36	33	22	39	166	765	1,820	0	3,566	0
2006	191	1,429	45	29	19	39	199	644	1,622	0	3,799	0

Appendix 14: Sheep, beef and deer; Class 3 farms - OVERSEER N and P budget (kg/ha/yr)

	N Inputs	N Outputs				P Outputs		
	Atmospheric N	Product (meat & fibre)	Atmospheric	Runoff /leaching	Immobilisation /absorption	Product (meat & fibre)	Runoff /leaching	Immobilisation /absorption
1995	66	13	9	10	35	2	1.6	13
1996	61	12	9	10	34	2	1.6	13
1997	63	12	9	10	34	2	1.6	13
1998	66	12	9	10	37	2	1.6	13
1999	61	12	9	10	34	2	1.6	13
2000	58	11	8	9	32	2	1.5	13
2001	59	12	9	9	34	2	1.6	13
2002	58	11	8	9	33	2	1.5	13
2003	59	12	9	9	35	2	1.6	13
2004	61	13	10	10	37	2	1.6	13
2005	62	12	9	10	35	2	1.6	13
2006	61	12	9	10	35	2	2	16

Appendix 15: Sheep, beef and deer; Class 4 farms - OVERSEER N and P budget (kg/ha/yr)

	N Inputs	N Outputs				P Outputs		
	Atmospheric N	Product (meat & fibre)	Atmospheric	Runoff /leaching	Immobilisation /absorption	Product (meat & fibre)	Runoff /leaching	Immobilisation /absorption
1995	69	15	12	13	32	2	1.9	16
1996	67	15	11	13	31	2	1.9	16
1997	67	15	11	13	30	2	1.9	16
1998	66	14	12	13	33	2	1.9	16
1999	63	14	12	13	32	2	1.9	16
2000	61	13	11	13	30	2	1.9	16
2001	61	13	12	13	33	2	2	17
2002	66	16	14	14	34	2	2	17
2003	68	15	13	14	34	2	2	17
2004	64	14	13	14	35	2	2	17
2005	63	14	13	14	35	2	1.9	16
2006	60	14	12	14	35	2	2.1	20

Appendix 16: Sheep, beef and deer; Class 5 farms - OVERSEER N and P budget (kg/ha/yr)

	N Inputs	N Outputs				P Outputs		
	Atmospheric N	Product (meat & fibre)	Atmospheric	Runoff /leaching	Immobilisation /absorption	Product (meat & fibre)	Runoff /leaching	Immobilisation /absorption
1995	74	17	16	16	32	3	1.5	17
1996	71	15	15	15	30	3	1.5	17
1997	71	16	15	15	29	3	1.6	17
1998	74	15	18	17	36	3	1.6	17
1999	64	14	18	16	36	3	0.5	18
2000	64	13	17	16	35	3	0.5	18
2001	67	14	18	16	36	3	0.5	18
2002	62	13	17	15	36	3	0.5	18
2003	65	15	20	17	41	3	0.5	18
2004	63	14	20	17	41	3	0.5	18
2005	59	14	20	17	44	3	0.5	18
2006	51	14	21	16	47	2	0.5	18

Appendix 17: Sheep, beef and deer; Class 3 farms - OVERSEER summary data

	Nutrient loss indices (kg/ha/yr)				N conversion efficiency (%)	Greenhouse gas emissions (CO_2 equivalents - kg/ha/yr)				Annual drainage (mm/yr)
	N leached	Farm N surplus	P runoff	Farm P surplus		Methane	N_2O	CO_2	Total	
1995	10	54	1.6	20	20	2365	919	43	3327	488
1996	10	53	1.6	22	18	2250	895	62	3207	484
1997	10	53	1.6	21	19	2288	899	66	3253	484
1998	10	57	1.6	24	18	2432	965	56	3453	483
1999	10	53	1.6	26	19	2230	885	106	3221	496
2000	9	49	1.5	22	18	2118	834	129	3081	470
2001	9	52	1.6	23	18	2181	868	146	3195	473
2002	9	50	1.5	19	19	2107	837	102	3046	481
2003	9	53	1.6	24	18	2193	881	65	3139	481
2004	10	57	1.6	26	18	2295	938	108	3341	488
2005	10	53	1.6	19	19	2269	899	140	3308	489
2006	10	54	2	18	18	2269	895	159	3323	489

Appendix 18: Sheep, beef and deer; Class 4 farms - OVERSEER summary data

	Nutrient loss indices (kg/ha/yr)				N conversion efficiency (%)	Greenhouse gas emissions (CO_2 equivalents - kg/ha/yr)				Annual drainage (mm/yr)
	N leached	Farm N surplus	P runoff	Farm P surplus		Methane	N_2O	CO_2	Total	
1995	13	58	1.9	24	20	2721	1077	80	3878	559
1996	13	55	1.9	25	21	2638	1030	82	3750	549
1997	13	54	1.9	21	22	2592	1010	110	3712	550
1998	13	57	1.9	24	20	2644	1059	140	3843	550
1999	13	56	1.9	25	20	2548	1027	106	3681	551
2000	13	53	1.9	27	20	2449	981	118	3548	556
2001	13	58	2	31	19	2525	1039	148	3712	570
2002	14	61	2	28	20	2705	1099	204	4008	573
2003	14	61	2	30	19	2762	1118	128	4008	580
2004	14	63	2	30	18	2687	1118	197	4002	571
2005	14	62	1.9	22	18	2628	1096	157	3881	562
2006	14	61	2.1	29	18	2724	1077	199	4000	553

Appendix 19: Sheep, beef and deer; Class 5 farms - OVERSEER summary data

	Nutrient loss indices						Greenhouse gas emissions				
	N leached	Farm N surplus	P runoff	Farm P surplus	N conversion efficiency	N in drainage	Methane	N_2O	CO_2	Total	Annual drainage
	(kg/ha/yr)				(%)	(mg/L)	(CO_2 equivalents - kg/ha/yr)				(mm/yr)
1995	16	65	1.5	35	20	2	3305	1336	187	4828	594
1996	15	60	1.5	26	20	2	3104	1246	111	4461	577
1997	15	60	1.6	28	21	2	3101	1242	116	4459	580
1998	17	71	1.6	34	18	2.2	3358	1399	180	4937	586
1999	16	70	0.5	34	16	2	3035	1320	291	4646	601
2000	16	68	0.5	33	16	2	2993	1294	358	4645	584
2001	16	70	0.5	36	17	2.1	3172	1362	324	4858	589
2002	15	68	0.5	29	16	2	2954	1287	301	4542	573
2003	17	77	0.5	31	16	2	3237	1439	232	4908	578
2004	17	77	0.5	35	16	2.2	3154	1416	284	4854	581
2005	17	81	0.5	33	15	2.2	3110	1438	277	4825	584
2006	16	85	0.7	30	14	2	2944	1405	329	4678	598

Appendix 20: Dairy farms; Rainfall Scenarios - OVERSEER N and P budget (kg/ha/yr)

		N Inputs	N Outputs				P Outputs		
	Rainfall (mm)	Atmospheric N	Product (meat & fibre)	Atmospheric	Runoff /leaching	Immobilisation	Product (meat & fibre)	Runoff /leaching	Immobilisation /absorption
Lower Quartile	1,000	65	48	47	28	69	8	0.4	35
	1,250	67	48	48	33	65	8	0.7	34
	1,500	68	48	49	37	62	8	1	34
Average	1,000	73	64	54	33	77	11	0.5	44
	1,250	76	64	55	38	73	11	0.9	44
	1,500	78	64	56	43	70	11	1.3	44
Upper Quartile	1,000	89	92	63	41	88	15	0.5	40
	1,250	91	92	65	47	83	15	0.8	40
	1,500	95	92	66	53	79	15	1.2	39

Appendix 21: Dairy farms; Rainfall Scenarios - OVERSEER summary data

Farm Class	Rainfall (mm)	N leached (kg/ha/yr)	Farm N surplus (kg/ha/yr)	P runoff (kg/ha/yr)	Farm P surplus (kg/ha/yr)	N conversion efficiency (%)	N in drainage (mg/L)	Methane (CO_2 equivalents - kg/ha/yr)	N_2O (CO_2 equivalents - kg/ha/yr)	CO_2 (CO_2 equivalents - kg/ha/yr)	Total (CO_2 equivalents - kg/ha/yr)	Annual drainage (mm/yr)
Lower Quartile	1,000	28	144	0.4	34	25	6.5	5069	2894	669	8632	374
	1,250	33	146	0.7	34	25	5.5	5069	2894	669	8632	508
	1,500	37	148	1	34	25	5.1	5069	2894	669	8632	597
Average	1,000	33	164	0.5	43	28	7.7	6254	3345	872	10471	374
	1,250	38	166	0.9	43	28	6.5	6254	3345	872	10471	508
	1,500	43	169	1.3	43	28	6.1	6254	3345	872	10471	597
Upper Quartile	1,000	41	192	0.5	35	32	9.7	8242	4009	1182	13433	374
	1,250	47	195	0.8	35	32	8.2	8242	4009	1182	13433	508
	1,500	53	198	1.2	35	32	7.7	8242	4009	1182	13433	597

Appendix 22: Sheep, beef and deer farms; Rainfall Scenarios - OVERSEER N and P budget (kg/ha/yr)

		N Inputs	N Outputs				P Outputs		
Farm Class	Rainfall (mm)	Atmospheric N	Product (meat & fibre)	Atmospheric	Runoff /leaching	Immobilisation	Product (meat & fibre)	Runoff /leaching	Immobilisation /absorption
Class 3	1,400	60	12	9	8	36	2	1.5	16
	1,700	61	12	9	10	35	2	1.9	16
	2,000	62	12	11	11	35	2	2.2	15
Class 4	1,300	59	14	12	12	36	2	1.7	20
	1,600	60	14	12	14	35	2	2.1	20
	1,900	59	14	12	16	36	2	2.2	20
Class 5	1,100	50	14	21	13	50	2	0.4	30
	1,400	51	14	21	16	48	2	0.7	30
	1,700	51	14	21	18	46	2	0.9	29

Appendix 23: Sheep, beef and deer farms; Rainfall Scenarios - OVERSEER summary data

Farm Class	Rainfall (mm)	Nutrient loss indices (kg/ha/yr)				N conversion efficiency (%)	N in drainage (mg/L)	Greenhouse gas emissions (CO_2 equivalents - kg/ha/yr)				Annual drainage (mm/yr)
		N leached	Farm N surplus	P runoff	Farm P surplus			Methane	N_2O	CO_2	Total	
Class 3	1,400	8	53	1.5	18	19	-	2269	895	159	3323	394
	1,700	10	54	1.9	18	18	-	2269	895	159	3323	479
	2,000	11	55	2.2	18	18	-	2269	895	159	3323	545
Class 4	1,300	12	60	1.7	29	19	-	2724	1077	199	4000	466
	1,600	14	61	2.1	29	18	-	2724	1077	199	4000	567
	1,900	16	63	2.2	29	18	-	2724	1077	199	4000	673
Class 5	1,100	13	84	0.4	30	14	2.4	2944	1405	329	4678	429
	1,400	16	85	0.7	30	14	2	2944	1405	329	4678	583
	1,700	18	85	0.9	30	14	1.9	2944	1405	329	4678	703