Client Report

Prepared for Environment Waikato

March 2006

A simple sensitivity analysis of nitrogen leaching for three Taupo farming systems, estimated using the Overseer nutrient budget model

Ian Power, Amanda Judge, Stewart Ledgard

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1. Executive Summary

A previous report "Implementing regulations restricting nitrogen leaching from pastoral land in the Taupo Catchment: December 2005" (Ledgard *et al.* 2005), included estimation of N leaching for the farms in the catchment and in this report three of those farms were used for a simple sensitivity analysis of N leaching.

Of the list of variables which are inputted into the Overseer® nutrient budget model version 5.2.6 (Overseer) (Wheeler *et al.* 2003), it is possible to group them according to the effect they have on changes in nitrogen leaching losses into high, medium and low effect categories as given below. For variables having potentially large effects (high and medium impact), it is important that these are a required input from farmers. For some variables it is recommended that single default values are used (see below).

Table 1: List of variables input into Overseer in categories of their impact on N leaching and recommendations.

High Impact:	**Recommendation**
Nitrogen fertiliser applied	Good records critical
Winter application of N fertiliser	Good records critical
Stocking rate	Good records critical
Winter management practices (e.g. grazing animals off over winter) (Dairy system)	Good records critical
Detailed stock records (Sheep and beef systems)	Good records critical
Annual rainfall	Use rainfall map
Pasture development status	Use default = developed
Clover content	Use default = medium
Medium Impact:	
Replacements grazed off or on farm (Dairy system)	Good data/records important
Irrigation	Good data/records important
Breed of animal (Dairy system)	Good data/records important
Milksolids production (Dairy system)	Good data/records important
Supplements brought onto farm – quantity and type (Dairy system)	Good data/records important
Percentage of male cattle (Beef)	Good data/records important
Low Impact:	
Contour	Qualitative comment
Pasture species	Use default = ryegrass/clover
Type of N fertiliser used	Okay if unavailable
P application rates	Can be ignored
Drainage class	Records not needed
Supplements removed	Records not needed
Effluent application rate (Dairy system)	Records not needed
Effluent disposal system (Dairy system)	Important at block level

It is important to note that this report is largely based on altering single variables only. In practice, changes in some variables (e.g. milksolids production/ha) are associated with changes in other variables (e.g. inputs such as N fertiliser or purchased feed), which influences the sensitivity.

Indeed, there are many interactions between variables within the model, particularly linked to animal production and so care is needed to avoid over-interpretation of data presented in tables or figures in this report.

The sensitivity analysis was not done in a strict statistical manner and therefore the relative scales of changes to variables differed. Nevertheless it did clearly highlight the importance of obtaining good animal and N fertiliser data, with some 'low impact' factors being relatively unimportant

It is also important to note that the degree of impact that the variables have, are in the case of this report, specific to the farms studied (Armer dairy system, Reeves low input system and Martin intensive farm system) and the management practices which were used at the time of the data collection. Any changes in the farm system will affect the magnitude of impact of the variables and this information should be treated in only a general way.

2. Introduction

As an outcome from the report "Implementing regulations restricting nitrogen leaching from pastoral land in the Taupo Catchment: December 2005" (Ledgard *et al.* 2005), commissioned by Environment Waikato (EW), further information has been requested. EW wishes to further understand the implications of changes to estimated N leaching from Overseer as input variables are ignored or removed, with the view to easing data collection and interpretation issues. Thus the focus of this report is on the impacts of removing some of the variables used in the Overseer® nutrient budget model, version 5.2.6 (Overseer) (Wheeler et al 2003), on three farming systems, namely a dairy system (Armer property), a low input sheep and beef system (Reeves property) and an intensive beef system (Martin property), from the original report. Deer farming systems were not considered in this study.

3. Method

Changes to the input variables most likely to impact on nitrogen outputs were made in Overseer on three of the farms used in the report "Implementing regulations restricting nitrogen leaching from pastoral land in the Taupo Catchment: December 2005".

These farms were

(a) A dairy farm: Armer property

(b) A low input beef and sheep farm: Reeve property

(c) An intensive beef/dairy grazing farm: Martin property

Individual farm details were listed in the initial report "Implementing regulations restricting nitrogen leaching from pastoral land in the Taupo Catchment, December 2005".

The model variables changed for the appropriate farming systems were:

i. Those currently required to be supplied by farmer:

Nitrogen fertiliser applied, winter application of N fertiliser, stocking rate, winter management (e.g. grazing animals off over winter), dairy replacements grazed off or on farm, detailed stock records, irrigation, breed of animal, milksolids production, supplements brought onto farm – quantity and type, percentage of male cattle, contour, type of N fertiliser used, P application rates, supplements removed, effluent disposal system, effluent application.

ii. Those currently determined and set by the Overseer operator

Rainfall, pasture development status, clover content, pastures species, drainage class.

All results from this project are specific to these three farms, as per the "status quo" farm system. All results reflect the management practices used on the "status quo" farm. Any alterations to these management practices may alter the sensitivity of various factors used in Overseer.

It should be noted that this report used a simplistic approach of changing only one variable and examining the effects, whereas in practice a change in one variable (especially for production) is typically associated with changes in other variables. Thus, care is needed in interpretation of results.

4. Results

In the following sections, the effects of altering different single model variables (separated into those of high, medium and low impact) are presented for each of the three farm systems.

4.1 Dairy Farm

4.1.1 High Impact Variables:

4.1.1.1 Nitrogen fertiliser applied

Increasing the annual amount of Nitrogen applied as N fertiliser has large effects on N leaching losses (figure 1). This does not account for associated increases in milk production.

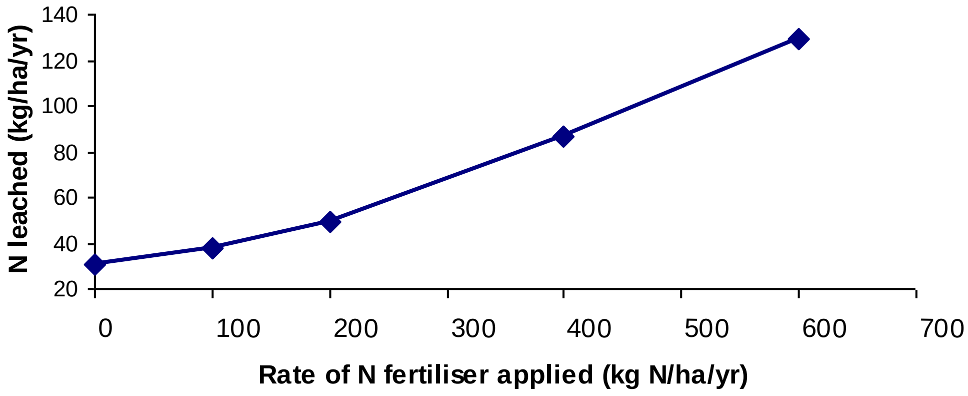

Figure 1: Effect of increasing application of fertiliser N on N leaching losses for the dairy farm example

4.1.1.2 Winter application of N fertiliser

Timing of applications of N fertiliser is also important, with N applied during winter months being more susceptible to direct leaching losses. Increasing the proportion of N applied in winter increased in leaching (figure 2).

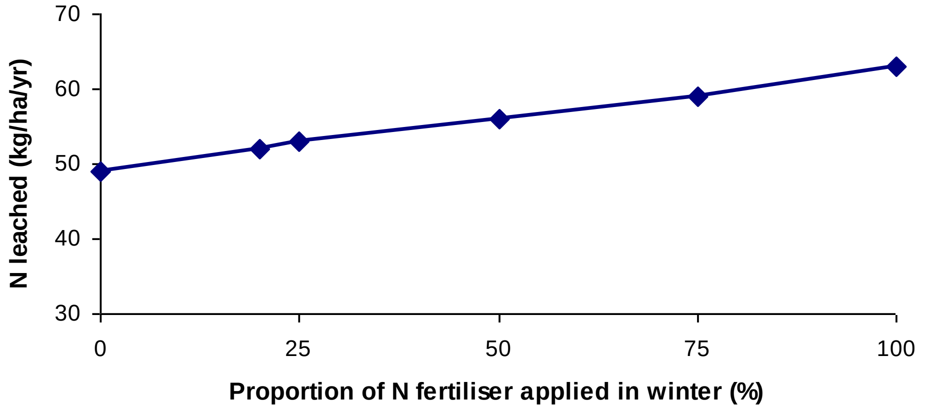

Figure 2: Effect of increasing the proportion of total fertiliser N applied during the at-risk winter months on N leaching losses for the dairy farm example

4.1.1.3 Grazing animals off over winter

Winter grazing off has large impacts on N leaching losses. As more animals are grazed off for longer periods, leaching losses decrease (figure 3). There is also a moderate effect on N leaching by hard grazing the farm prior to removal of animals.

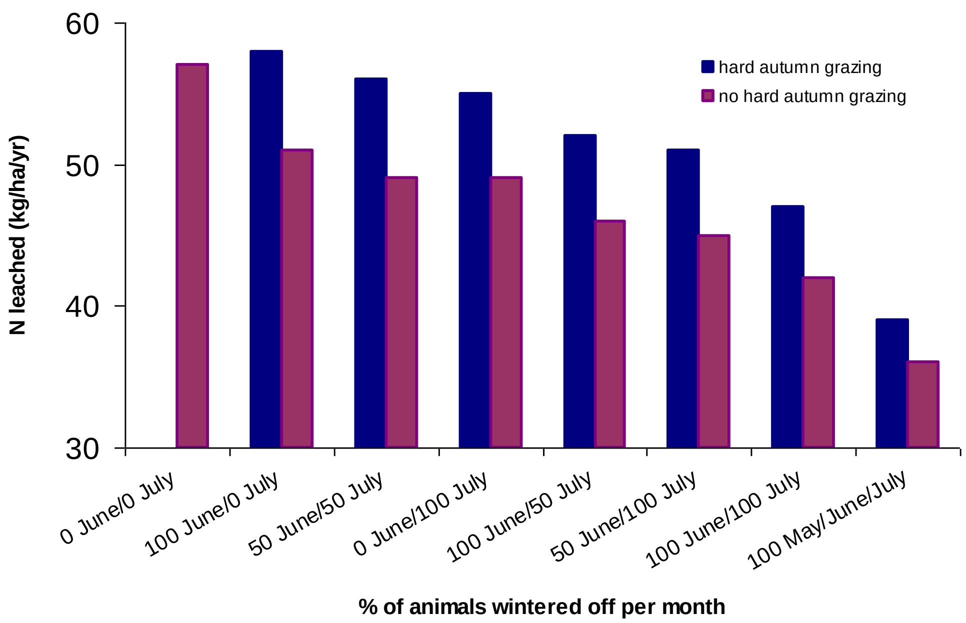

Figure 3: Effect of grazing animals off during winter months on N leaching losses for the dairy farm example

4.1.1.4 Stocking rate

As stocking rate increases, so does the N leaching losses (figure 4) due to greater pasture intake (and N excretion) needed to maintain more animals. Increasing the stocking rate can also have an effect on other variables such as Milksolids production and pasture intake, which will consequently have further effects on leaching losses.

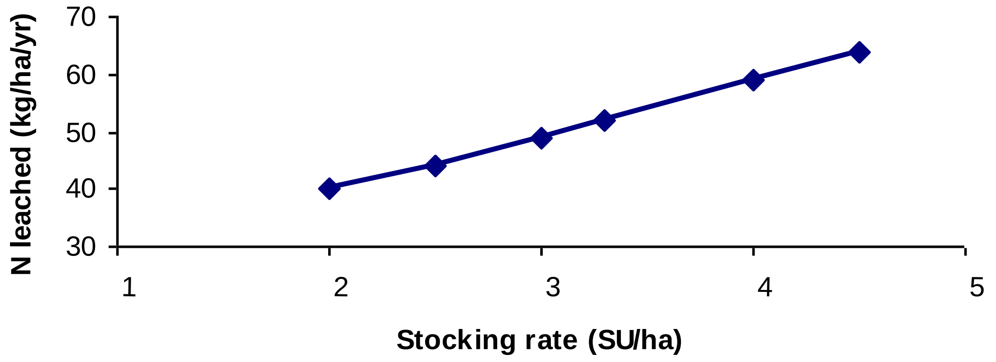

Figure 4: Effect of increasing stocking rate on N leaching losses for the dairy farm example

4.1.1.5 Annual rainfall

The long-term annual average amount of rainfall has a large effect on nitrogen leaching (figure 5). For consistency it is recommended that this is based on a rainfall map of long-term average values (e.g. using long-term NIWA met. data from sites around the catchment with lines of common rainfall delineated). This does not change over time so a defined value can be used for a specific farm or block.

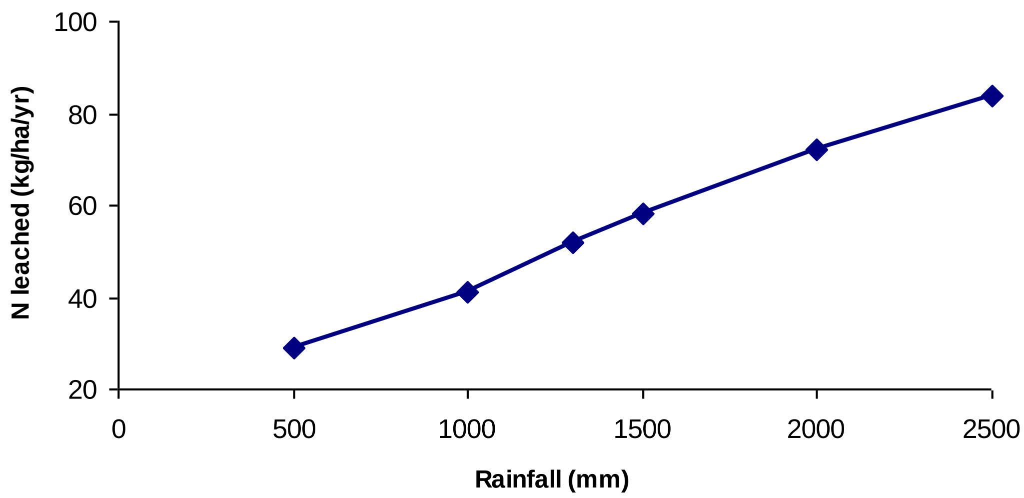

Figure 5: Effect of increasing long-term average annual rainfall on N leaching losses for the dairy farm example

4.1.1.6 Pasture Development Status

The stage of pasture development has a large effect on N leaching (figure 6), with highly developed pastures having much greater leaching losses than developed, and with the other categories (developing, recently cultivated and dairy conversion) all having similar lower leaching losses. It is recommended that "developed" status (the standard default in the model), be used for farms since the developing or conversion farms will move into the developed category within roughly a decade.

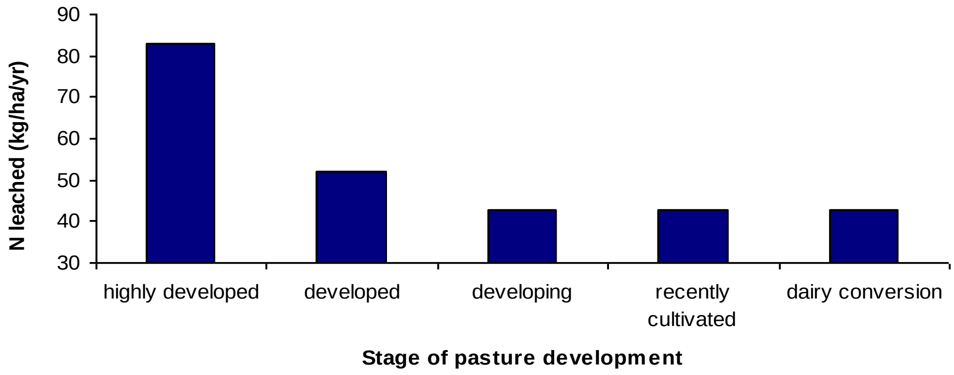

Figure 6: Effect of stage of pasture development on N leaching losses for the dairy farm example

4.1.1.7 Clover content

The clover content of a pasture (long-term annual average) has a large effect on leaching losses with the very high clover content contributing nearly double that of the very low content (figure 7). A standard farm system will usually have medium clover content in its pasture in the long-term in order to maintain its productivity. It is recommended that the default setting be fixed at medium clover content (the standard default in the model), unless there is some major atypical factor e.g. long term severe clover root weevil infestation.

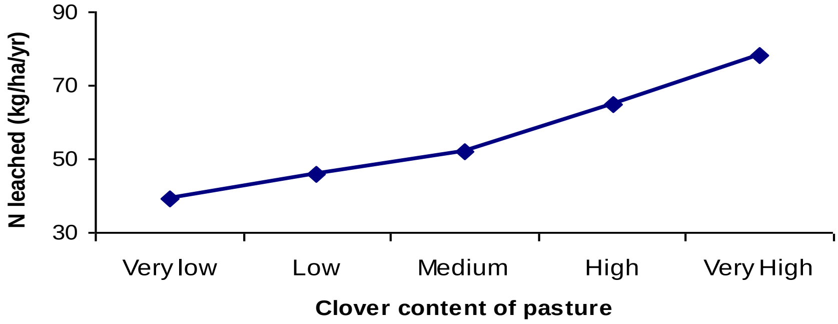

Figure 7: Effect of changes in long-term average clover content in pasture on N leaching losses for the dairy farm example.

4.2 Medium Impact Variables

4.2.1.1 Replacements grazed off or on farm

Grazing replacement animals on the farm has larger impacts on N leaching than the age of replacement animals grazing off the farm. This variable could be simplified to either "on or off farm" (Table 2)

Table 2: Effect of grazing off of replacements on N leaching.

Grazed off age	Overall Farm Nitrate leached (kg N/ha/yr)
Weaners	52
9-21 months	52
never (on farm)	62

4.2.1.2 Irrigation:

Irrigation has an effect on leaching through the volume of extra water applied above that received as rainfall and the assumed increase in drainage (Table 3).

Table 3: Effect of irrigation on a Dairy farm on N leaching.

Amount Irrigated (mm/yr)	Overall Farm Nitrate leached (kg N/ha/yr)
0	52
100	53
200	54
300	56
400	57
800	63

4.2.1.3 Breed of animal:

The breed of animal has an effect with the larger animals having higher feed maintenance requirements producing more urine and consequently higher N leaching losses (Table 4).

Table 4: Effect of dairy cow breed on N leaching.

Breed of animal	Overall Farm Nitrate leached (kg/ha)
Friesian	55
Friesian x jersey	52
Jersey	48
Ayrshire	50

4.2.1.4 Production (Milksolids):

Leaching losses increase with increasing MS production, as this also requires an increase in pasture intake of the animals to produce the higher kg MS. It should be noted that to increase production, other variables are also often changed such as fertiliser inputs, stocking rate etc, which will all have impacts on increasing N leaching losses (Table 5).

Table 5: Effect of milk solids production on N leaching.

Production (kg MS/ha/yr)	Overall Farm Nitrate leached (kg/ha)
700	50
800	50
900	51
1000	52
1200	54
1400	55

4.2.1.5 Supplements brought onto farm – Quantity and Type:

At levels below 500 tonnes DM of silage (equivalent to 2.5 t DM/ha), there is little impact of bringing supplements onto the farm, but above this level the amounts of N leaching increase for the higher N content grass silage, and decrease for the lower N content maize silage. Since milksolids (MS) production was not changed, the model assumes less intake from pasture with increasing supplement use. In practice this would not typically occur to any great extent and associated increases in MS/ha would also be expected (Table 6).

Table 6: Effect of increasing supplements brought on to the farm on N leaching.

Supplements t DM/yr	Overall Farm Nitrate leached (kg/ha) **Grass Silage**	Overall Farm Nitrate leached (kg/ha) **Maize Silage**
0	52	52
100	53	52
200	53	51
500	55	49
1000	59	46
1500	63	43

4.2.2 Low Impact Variables

Contour

Pasture species

Effluent application rate

Effluent disposal system

Type of N fertiliser used

Increase in P application

All of these variables had little or no effect on the amount of N leaching for the overall farm.

Pasture species has little effect except for Kikuyu grass which is not present in the Taupo region because of cold winter conditions. However, it should be noted that there is little research on this factor and it may alter in future model updates with new research.

The type of effluent disposal system used had a large effect within the block that the effluent is applied to, but had little effect on the overall farm N leaching.

P fertiliser rate has no effect on N leaching, although if this is linked to increased pasture and animal production it could have an indirect effect. Thus, there is no need to collect this unless information on P runoff (which requires this variable) is useful additional data because of potential implications to water quality.

4.3 Sheep and Beef Farms

4.3.1 High Impact Variables

4.3.1.1 Increasing Nitrogen Fertiliser

Increasing the rate of N applied increases N leaching for both the intensive (high) and low input (low) farming systems (figures 8a, b). However, increasing N application will result in more pasture growth. This will increase the stock carrying capacity of the farm resulting in greater N leaching than keeping the animal stocking rate unchanged (figures 8a, b).

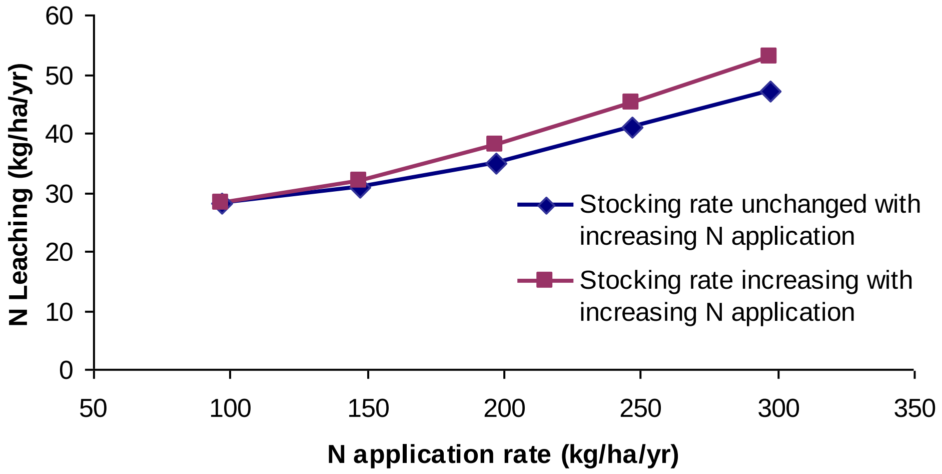

Figure 8a: Effect of increasing application of Nitrogen fertiliser N on N leaching losses for the intensive (high) beef farm example

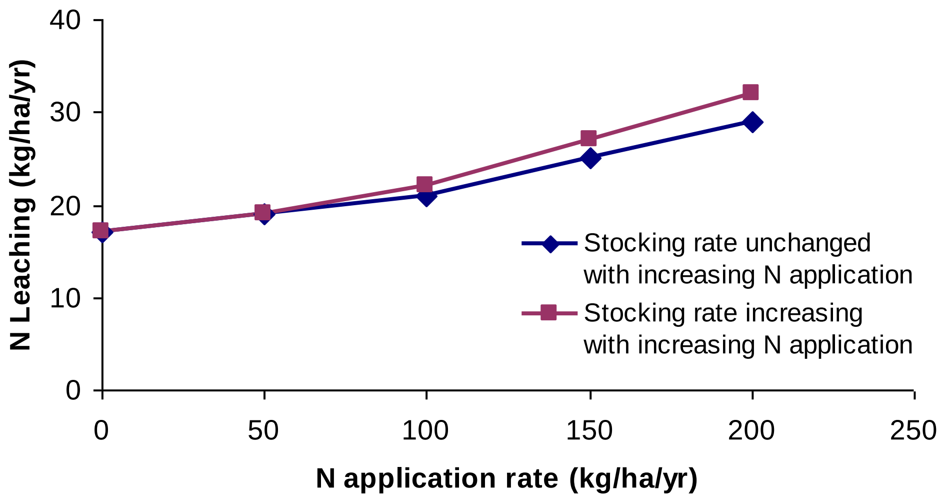

Figure 8b: Effect of increasing application of Nitrogen fertiliser N on N leaching losses for the low input sheep and beef farm example

4.3.1.2 Winter application of N fertiliser

Timing of applications of N fertiliser is also important, with N applied during winter months being more susceptible to direct leaching losses. The greater the percentage of total N applied in winter, the greater the N leaching losses. The higher N application rates have higher N leaching losses (figure 9a, b).

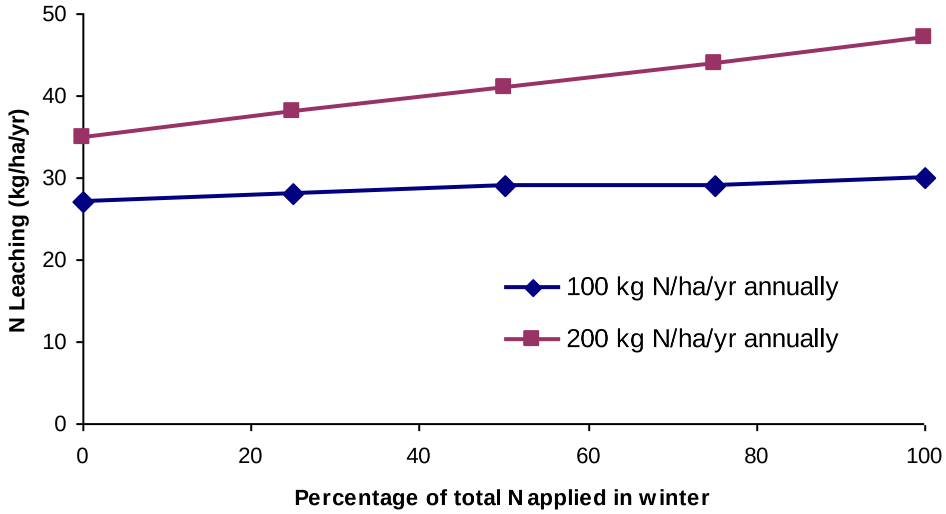

Figure 9a: Effect of increasing the proportion of total N fertiliser N applied during the at-risk winter months on N leaching losses for the intensive beef farm example for annual application rates of 100 and 200 kg N/ha/yr.

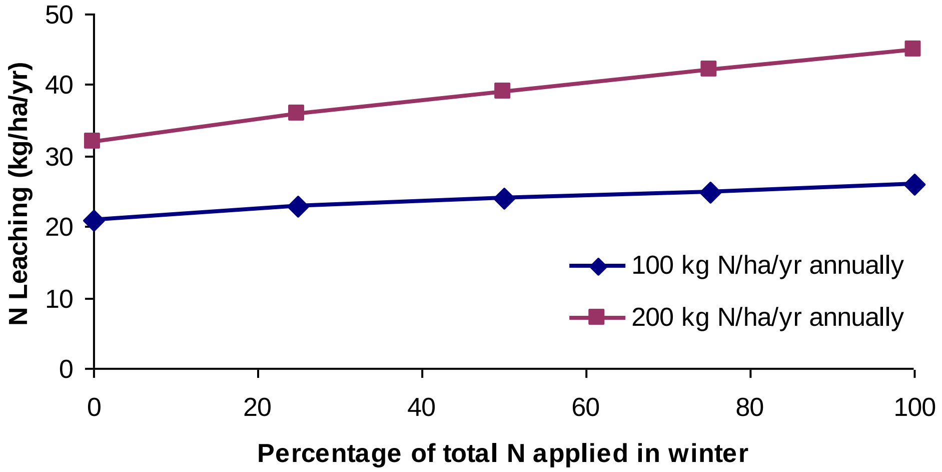

Figure 9b: Effect of increasing the proportion of total N fertiliser N applied during the at-risk winter months on N leaching losses for the low input sheep and beef farm example for annual application rates of 100 and 200 kg N/ha/yr.

4.3.1.3 Stocking rate

Changing stocking rate has a major impact on N leaching rates. As stocking rate increases, so does the N leaching losses (figure 10). Often this will be associated with other changes (e.g. increased inputs of N fertiliser or feed) which impact further on N leaching.

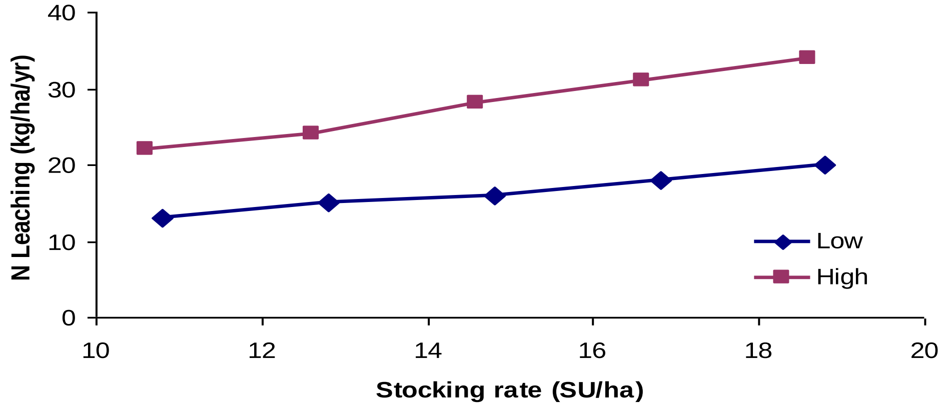

Figure 10: Effect of increasing stocking rate on N leaching losses for the low input and high intensity sheep and beef farm examples

4.3.1.4 Annual rainfall

Nitrogen leaching (kg N/ha/yr) increases approximately linearly with increasing long-term average annual rainfall over the range examined on both the intensive (high) and low input (low) farming systems (figure 11). For consistency it is recommended that this is based on a rainfall map (e.g. using long-term NIWA met. data from sites around the catchment with lines of common rainfall delineated). This variable should remain unchanged for a farm or block.

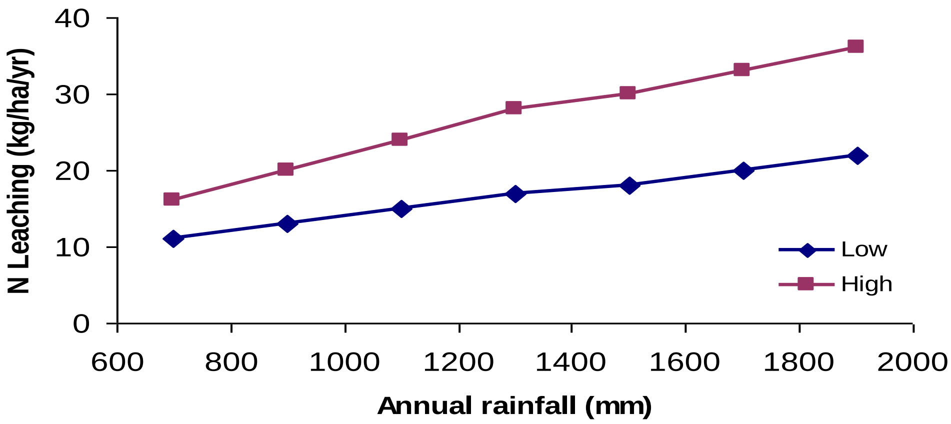

Figure 11: Effect of increasing long-term average annual rainfall on N leaching losses for the low input and high intensity sheep and beef farm examples

4.3.1.5 Pasture Development Status

The stage of pasture development has a large effect on N leaching (figures 12 a, b) for both the intensive (high) and low input (low) farming systems. The highly developed pastures have greater leaching losses than developed, and the other categories (developing or recently cultivated) all having similar lower leaching losses. It is recommended that "developed" status (the standard default) be used for all farms.

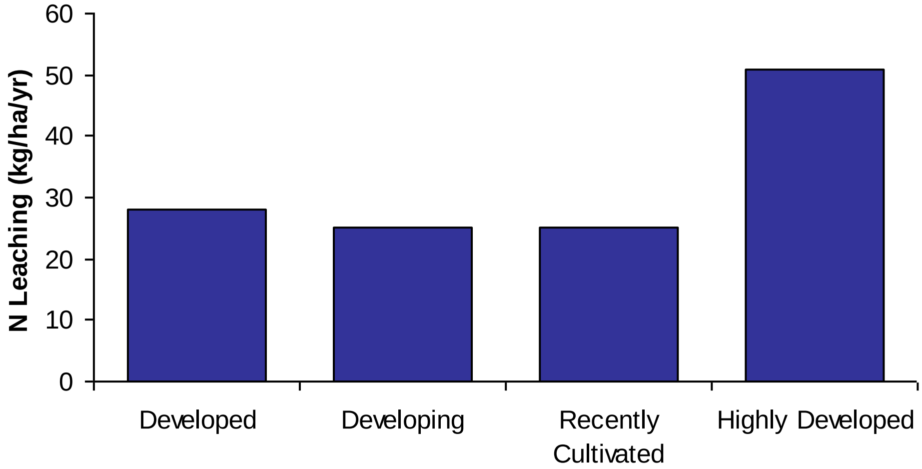

Figure 12a: Effect of stage of pasture development on N leaching losses for the high intensity beef farm example

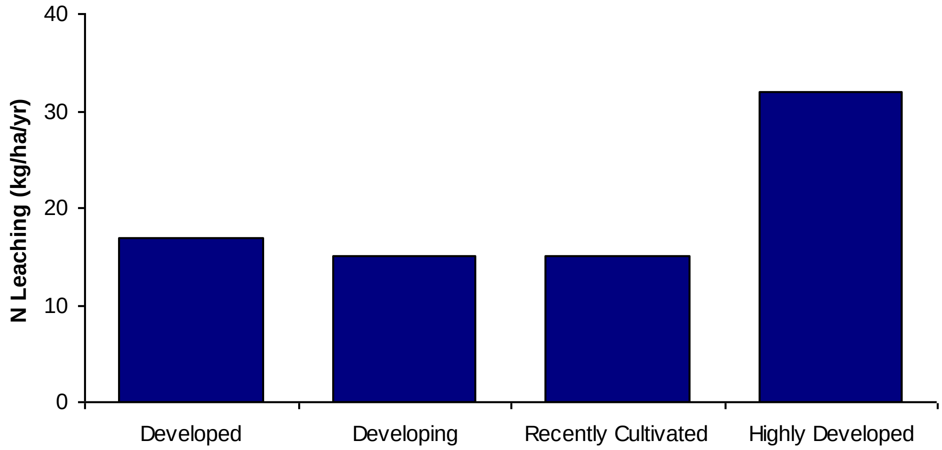

Figure 12b: Effect of stage of pasture development on N leaching losses for the low input sheep and beef farm example

4.3.1.6 Clover content

Nitrogen leaching (kg N/ha/yr) increases with increasing long-term average clover content on both the intensive (high) and low input (low) farming systems (figure 13). A standard farm system will usually have medium clover content in its pasture unless there are significant recurring atypical conditions, which will also significantly affect long-term production. It is recommended that the default setting be fixed at medium clover content. This is currently the default in the model unless specifically selected otherwise.

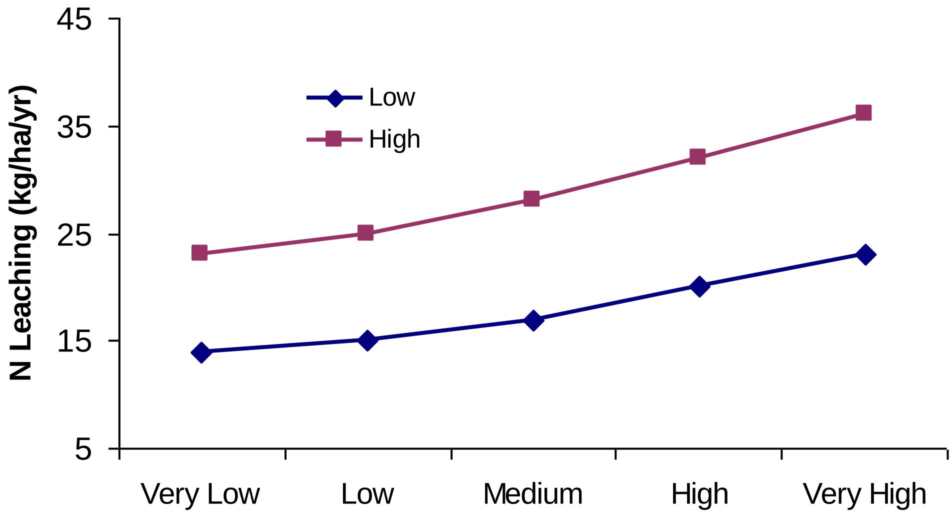

Figure 13: Effect of stage of long-term average clover content in pasture on N leaching losses for the low intensity and the high intensity sheep and beef farm examples

4.3.1.7 Detailed stock records

The effect of specific animal production on N leaching for a high versus low animal growth rate beef farm and a high (160%) versus low (100%) lambing sheep farm are given in table 7:

Table 7: Effect of growth rate on N leaching.

	Effective stocking rate SU/ha	N leached kg N/ha/yr
Low cattle growth rate	10	19
High cattle growth rate	18.3	33
Low lambing %	11.1	11
High lambing %	12.8	12

The effect of inputting specific animal information including levels of weight gains was assessed. For the cattle scenario 370 Rising 1 yr cattle were grown on farm at 0.2 (low growth rate) and 0.8 (high growth rate) kg/day for 12 months. The average annual stocking rate for the cattle grown at 0.2 kg/day was estimated at 10.0 SU/ha and at 18.3 SU/ha for the cattle grown at 0.8 kg/day (table 6). The increase in effective stock units was due to the increased cattle growth rates and associated increased pasture consumption. Nitrogen leaching was 19 kg N/ha/yr for the low growth rate cattle and 33 kg N/ha/yr for the high growth rate cattle, a 74% increase (table 6).

For the scenario where lambing percentage was increased from 100% to 160%, only small increases in annual stocking rate and N leaching were observed (table 6).

It is recommended that where trading of animals is a common farming practice then the monthly stock data and stock weights are important to achieve an accurate assessment on the N budget for a farm. Otherwise, conservative values for weight gain would need to be used for benchmarking. Where stock numbers and weight gains are more stable (e.g. as in a traditional breeding system) then average stocking rates may suffice. However it is more difficult to confirm accurate stocking rates if only annual data is given.

4.3.2 Medium Impact Variables

4.3.2.1 Irrigation:

Table 7: The effects of irrigation on N leaching for the low input (low) and intensive (high) sheep and beef farming systems (Table 8).

Table 8: Effect of irrigation use on a sheep and beef farm on N leaching.

Irrigation water (mm)	N Leaching (kg/ha/yr)	
	Low	High
0	17	28
100	17	28
300	18	30
500	19	31
700	21	33
900	22	34

Irrigation has an effect on leaching through increasing the volume of water applied above that received as rainfall. As the rate of irrigation increases the rate of N leached increases (Table 7.)

4.3.2.2 Percentage of male cattle

Table 8: The effects of the percentage (%) of male cattle on N leaching for the low input (low) and intensive (high) sheep and beef farming systems (Table 9).

Table 9: Effect of male cattle % on N leaching.

Male cattle %	N Leaching (kg/ha/yr)	
	Low	High
0	17	28
25	17	27
50	16	26
75	16	25
100	16	24

As the percentage of male cattle in the beef herd increases the amount of N leaching decreases (table 8). The decrease in N leached is greater on the intensive beef farm where there is 100% beef animals than the low input farm with 35% beef (and 65% of stock units as sheep) animals.

4.3.3 Low Impact Variables

Contour

Pasture species

Type of N fertiliser used

Increase in P fertiliser application

Drainage Class

Supplements removed

All of these variables had little or no effect on the amount of N leaching for the overall farm for either the low input or intensive farming systems. In particular, contour has only a small impact on N leached in an overall farm context but may have differences on a block by block basis. Pasture species has little effect except for Kikuyu grass which is not present in the Taupo region.

The type of N fertiliser used and increasing P application rates (or any other non-N containing fertiliser) had no effect on N leaching. Removing supplements from the farming system had nil or little effect on N leached unless an associated decrease in stocking rate occurs.

All soils in the catchment can be classified as pumice soils although the drainage status may vary. The latter was shown to have little effect and since the soil type remains unchanged it is unimportant to define drainage status.

5. Conclusions and Implications

Of the list of variables which are inputted into the Overseer® nutrient budget model, it is possible to group them according to the effect they have on changes in nitrogen leaching losses into high, medium and low effect categories as given below. For variables having potentially large effects (high and medium impact), it is important that these are a required input from farmers. For some variables it is recommended that single default values are used (Table 10).

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Annual rainfall	Use rainfall map
Pasture development status	Use default = developed
Clover content	Use default = medium
Medium Impact:	
Replacements grazed off or on farm (Dairy system)	Good data/records important
Irrigation	Good data/records important
Breed of animal (Dairy system)	Good data/records important
Milksolids production (Dairy system)	Good data/records important
Supplements brought onto farm – quantity and type (Dairy system)	Good data/records important
Percentage of male cattle (Beef)	Good data/records important
Low Impact:	
Contour	Qualitative comment
Pasture species	Use default = ryegrass/clover
Type of N fertiliser used	Okay if unavailable
P application rates	Can be ignored
Drainage class	Records not needed
Supplements removed	Records not needed
Effluent application rate (Dairy system)	Records not needed
Effluent disposal system (Dairy system)	Important at block level

A variable that has no impact on nitrogen leaching losses is the addition of Phosphorus fertilisers. This may still be a useful variable to collect to future proof the data, as at a later date it may be decided that it is important to P losses in the Taupo catchment.

It is important to note that the degree of impact that the variables have, are in the case of this report, specific to the farms studied and the management practices which were used at the time of the data collection. Any changes in the farm system will affect the impact of the variables and this information should be treated in only a general way.

It is important to note that this report is largely based on altering single variables only. In practice, changes in some variables (e.g. milksolids production/ha) are associated with changes in other variables (e.g. inputs such as N fertiliser or purchased feed), which influences the sensitivity.

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6. Reference

Stewart Ledgard, Bruce Binnie, Ian Power, Rex Webby, and Kevin Benge (2005): Implementing regulations restricting nitrogen leaching from pastoral land in the Taupo Catchment: A report prepared for Environment Waikato; December 2005; 97 pp

Wheeler, D.M., Ledgard, S.F., De Klein, C.A.M., Monaghan, R.M., Carey, P.L., McDowell, R.W., Johns, K.L. 2003: OVERSEER® nutrient budgets – moving towards on-farm resource accounting. Proceedings of the New Zealand Grassland Association 65: 191-194.