

MANAGEMENT OF GRAZED DAIRY PASTURE TO MINIMISE IMPACTS ON LAKE WATER QUALITY

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Introduction

In New Zealand there are 14741 dairy farms with an average herd size of 208 cows per farm. For the last couple of decades whilst the number of herds have reduced substantially, the increasing stocking rate and the increasing effective grazing area per farm have resulted in approximately 50% increase in total cow numbers. Increasing number of sheep and beef cattle farms have been converted in the Invercargill, Canterbury and Waikato Regions to make room for such increase. Moreover, increasing knowledge in farm production techniques have also led to an increase in milk production per cow. For example the current milkfat production per cow is 173 kg/cow/season whilst in 1974/75 it was 128 kg/cow/season.

Table 1. Summary of New Zealand herd statistics since 1974/75

<i>Season</i>	<i>Herds</i>	<i>Total cows</i>	<i>Average herd size</i>	<i>Average effective hectares</i>	<i>Average cows per hectare</i>
1974/75	18540	2079886	112	<60	<2.0
1996/97	14741	3064523	208	86	2.5

Dairy Statistics 1996-1997

Increasing intensity of dairy farming places an enormous amount of pressure on natural resources, particularly on water. Arguably, the soil quality under dairying is not a major issue due mainly to good soil management and nutrient recycling under grazed dairy pasture. However, both the ground water and surface water quality have been affected by dairying land use. In some cases regardless of farmers adopting best management practices the water quality is affected adversely. The issue of dairy land use is more serious in lake catchments where the water body is more susceptible to dairying impacts. The paper links certain dairying activities with water quality issues and recommends methods to improve water quality.

Water quality issues related to dairy farming

The following dairy farming activities are likely to cause adverse effects on water quality:

- Stock access to waterways
- Poor nutrient management

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- Poor farm dairy effluent management
- Poor grazing and soil management
- Pasture irrigation

Stock access to waterways

Direct stock access to waterways could cause serious problems to water quality. Stock access waterways to drink water, to wallow or to cross. Consequently, faeces and urine are deposited into water and lake or riverbeds are damaged through trampling. A water sample obtained in the Coromandel Peninsula from 10 metres downstream of the point where dairy cows crossed the stream showed a faecal coliforms count of 80,000 cfu per 100 mL (unpublished data). This is more than twice as many faecal coliforms detected (35,000 cfu per 100 mL) in an effluent discharged from a two pond farm dairy effluent treatment system (Selvarajah, 1996a).

Poor nutrient management

Nitrogen

There is a common confusion among many in the fertiliser industry that fertiliser nitrogen use does not contribute to nitrate leaching in soils. Soil and fertiliser research in New Zealand and overseas clearly reveals that unless there is a heavy rainfall or irrigation following fertiliser nitrogen application, and providing appropriate amounts are applied, there is little or no *direct* leaching of applied fertiliser nitrogen in most pastoral soils. This is because pastoral soils contain a significant pool of biologically available organic carbon and apart from the rapid plant uptake of applied nitrogen, a major proportion of the applied nitrogen is converted to microbial biomass. In contrast, continuously cultivated soils for cropping or vegetable growing contain relatively small amounts of biologically available organic carbon and hence microbial immobilisation of applied nitrogen is low. Consequently, in cultivated soils applied fertiliser nitrogen is at greater risk of being *directly* leached. In such cases leaching losses of nitrogen can be in excess of 200-300 kg N/ha/year. In contrast, a grazed pasture system without fertiliser nitrogen input could sustain a leaching loss of 60 kg N/ha/year (Selvarajah *et al.*, 1994).

Many years of research indicate that in a dairy pasture system the driving force for nitrate leaching is urine voided by animals. Indeed, such research indicates that among the several nitrogen loss pathways (e.g. denitrification, ammonia volatilisation, nitrogen transfer to unproductive areas, milk protein and nitrate leaching) in a grazed pasture system, nitrate leaching is the major nitrogen loss pathway (under the Canterbury soil and climatic conditions volatilisation may cause high N loss from the grazed pasture systems). It is well known that in dairy pasture systems nitrogen removal through milk is relatively minor (in most cases it is 10% of the nitrogen ingested by dairy cows). Thus whilst *direct* leaching of applied fertiliser nitrogen could be minimised through good fertiliser management practices, any nitrogen input into the system be it clover-N or fertiliser-N will contribute to the overall *indirect* leaching (*indirect* leaching is defined here as nitrate leaching from nitrification of urine-N and mineralisation of organic-N in soil).

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Regional or national fertiliser nitrogen loading rates cannot be determined *solely* on the basis of any one fertiliser trial. However, such a trial can be used to assist decision making. The fertiliser nitrogen work by AgResearch at Ruakura clearly demonstrated that at a 400 kg N/ha/year loading rate ground water nitrate levels far exceeded the New Zealand drinking water standard (11.3 mg nitrate-N/litre) (Ledgard *et al.*, 1996a). At 200 kg N/ha/year ground water nitrate levels stayed at or below the drinking water standard during most seasons except for winter 1995 when it exceeded the standard. Estimates on economical return from these trials by the Dairying Research Corporation (DRC) indicated that the 400 kg N/ha/year compared to 200 and 0 kg N/ha/year was uneconomical (Ledgard *et al.*, 1996b). Similar trials showed the paddocks that received 200 kg N/ha/year marginally but significantly outperformed the economical returns of that of the 0 kg N/ha/year loading rate. These trials clearly indicate that *high fertiliser-N loadings are not environmentally and economically sustainable and that fertiliser-N should be used as a strategic supplement to clover-N, not as a substitute for it.*

It must be emphasised that depending on the aquifer characteristics a similar *mass* of nitrate nitrogen discharged into ground water can result in varying levels of nitrate in ground water. This highlights the need to consider a mass loading approach to nitrate contamination. Ground water quality management is often narrowly focused on human health and market access. Such an approach may ignore the adverse impact of ground water quality on surface water quality. Like many other regions the Waikato has many spring fed or ground water fed streams or rivers.

Phosphorus

Volcanic soils need regular phosphorus input to maintain an available soil-P pool. Generally phosphorus is applied as super phosphate. Super phosphate can dissolve in water relatively rapidly, more so than other forms of P fertilisers. The high solubility of super phosphate can lead to surface runoff of P during a heavy rainfall. Surface water enriched with P can cause algal blooms. If N level is restricted in water in relation to P levels, blue-green algae can proliferate under warm weather conditions.

Pasture irrigation

Although the amount and distribution of rainfall in the Waikato Region is sufficient to sustain pasture production, an increasing number of dairy farmers in the Region are irrigating pasture to boost milk production. There is sufficient information to indicate that certain inappropriate uses of water can cause significant adverse effects on the environment. Particularly, poorly managed pasture irrigation systems can cause excessive nutrient leaching into ground water. This is because leaching in soils is influenced mainly by the amount and the rate of percolation. The greater the rate and amount of irrigation, the greater the percolation and leaching.

Grazed pasture systems recycle 90% of the nitrogen taken up by pasture through animal excreta breakdown in soil. Urea accounts for 70% of the animal excreta-N. When urea breaks down it rapidly releases ammonium which in turn is converted into nitrate. The rate of nitrogen application during a urination event is estimated as 1000 kg N/ha. Nitrate produced from this urine patch is in excess of pasture needs and hence available for leaching. Ledgard *et al.* (1996a) showed that during high rainfall seasons nitrate leaching is greater. This highlights that

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grazed pasture systems are susceptible to nitrate leaching under wet conditions such as conditions caused by high rainfall and irrigation.

Consequently, it is appropriate to regulate water uses that have the potential to cause adverse effects. It must be emphasised that even when extreme care is taken to match crop water requirements and irrigation, the potential for leaching is greater in irrigated soils than non-irrigated soils. This is because rainfall following an irrigation event can exceed the water holding capacity of soil resulting in more leaching and that irrigated soils have more percolating water than that of non-irrigated soils.

Poor farm dairy effluent management

High N loading combined with high hydraulic loading can lead to nitrate leaching and ground water contamination. Moreover, excessive effluent application could also result in surface runoff.

Poorly sealed ponds could leak a substantial amount of effluent into the ground and ground water. A study commissioned by Environment Waikato showed that farm dairy effluent ponds could leak more than 1 m³/d (Ray *et al.*, 1995). More recently Ray *et al.* (1997) indicated that when earth materials with clay content of >8% are used as pond liner and properly compacted, the pond seepage could be minimal. Evidently, despite the influent volume exceeding evaporation losses these ponds did not discharge from the discharge pipe from the second pond (Selvarajah, 1996a).

Poor grazing and soil management

Many farmers are aware of the negative effects of 'sacrifice paddocks' on soil, pasture and surface water. 'Sacrifice paddocks' are where animals are allowed to graze or feed on supplied feed in selected paddocks for a longer duration. 'Sacrifice paddocks' are more susceptible to pasture and soil damage through compaction and excessive loading of animal excreta. 'Sacrifice paddocks' take a long time to return to their original state, in some cases the damage to soil is irreversible. Despite these facts, farmers continue to use 'sacrifice paddocks' to minimise damage to other parts of the farm, confining the damage to a small land area.

However, more recently, increasing numbers of dairy farms in the Waikato Region are using 'stand-off' or 'feedpads' as a substitute to 'sacrifice paddocks' to conserve feed and to minimise damage to soil and pasture during winter. Generally these pads are used during winter where the dairy herd is fed by supplementary feeding or on-farm feeds. Therefore it could be argued that the use of feeding pads is a good practice from the sustainable soil and pasture management viewpoint.

For a 200 cow herd it has been estimated that approximately 50 kg N/day could be deposited onto feeding pads (other assumptions: amount of dry matter consumed during winter = 7 kg/cow/day; % N in herbage = 4). If the cows are allowed to use the feedpads for 2 months (assuming that the herd is also given a month of grazing opportunities outside the feedpad area), the N loading on the feedpads will be about 3000 kg/winter season. This is three times greater

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than the amount of N discharged in the farm dairy for the entire milking season (assumptions: amount of N excreted in the farm dairy = 20 g/cow/day; length of milking season = 270 days; herd size = 200 cows). These estimates highlight that if feedpads are not managed properly the potential for ground and surface water contamination is very high.

Methods of minimising dairying impacts on water quality

A direct approach for avoiding or minimising contamination is to manage sources effectively.

Stock access to waterways

Fortunately a majority of the waterways in the Taupo catchment area are fenced off from stock access. Fencing of any remaining unfenced areas will minimise direct animal excreta input to the streams. Reticulated water supply must be provided to stock to discourage them from accessing waterways.

Grazing practices

Grazing can be performed on a rotational basis (rotational grazing) or permanent basis (set grazing). Research shows that set grazing causes more nitrate leaching than rotational grazing and hence rotational grazing is preferred.

Nitrate-N is produced more rapidly during warm, moist conditions. Nitrate accumulation exceeding plant N requirement is potentially available for leaching loss. Soon after the end of grazing period, plant uptake of N is very low due to damage to grass by grazing animals and the subsequent time required for grass recovery. To make the uptake system more efficient over grazing should therefore be avoided. This will allow plants to continuously absorb nitrate in soil rather than undergoing a lag period of nitrate absorption, and will also minimise the excretal return during grazing and allow an efficient excretal breakdown in soil.

The use of sacrifice paddocks should be avoided. If feedpads are used the feedpad area must be lined to prevent any effluent from leaking into soil and ground water. Various methods could be used to minimise contamination to water from feedpads. Some suggested methods are:

- Use of wood chips/bark material to absorb effluent for composting purposes
- Collect effluent and discharge into a holding system to discharge onto land

Fertiliser-N use

Use clover as the major N source

High use of fertiliser N leads indirectly to accumulation of N in soil and subsequent leaching. It is well known that provided soil moisture is not restricted, fertiliser N addition results in greater grass

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production. Typically in the Waikato dry matter production is around 13000 kg/ha which is equivalent to 520 kg N/ha. Such growth can be achieved without any fertiliser N use because of clover-N contribution (approximately 200 kg N/ha). When fertiliser N is used in excessive amounts (e.g. >200 kg N/ha), clover's ability to fix atmospheric N decreases. Moreover, clover population also decreases due to rye grass dominance. Where possible farmers should use clover as an N source rather than depending on fertiliser N.

N loading rate

Amount of N added should be decided not only on the basis of productivity, but also considering the potential for environmental pollution. High use of fertiliser should be discouraged. For example, for dairy farming an application rate of 100 kg N/ha/year appears to be environmentally and economically sustainable. Although high use of fertiliser N can increase farm profit, in the long-term the environmental impacts outweigh short-term benefits of increased profits.

Soil N test

Soil N tests are a vital tool to manage N. Fertiliser N should not be used when there is mineral-N accumulation in soil. Alternatively, a nitrogen budget could be used to determine N application rates (Selvarajah, 1996b).

Timing of fertiliser-N application

Farmers use high amounts of N fertiliser during autumn to boost grass growth during cold weather. This is because mineral-N production in soil is very low during cold conditions due to low microbial activity. On the other hand, plant N uptake is slow during cold conditions and most applied fertiliser N can accumulate in soil. As long as the applied N remains in ammonium form, leaching will be minimal. Fertiliser application should also consider forecast rainfalls. Fertiliser N applied just before a heavy storm is susceptible to leaching losses.

Other N inputs

Every farm should have a N budget showing input and output of N. Supplementary feed brought into farms as silage, hay or concentrates should also be accounted for since these sources can add a substantial amount of N to the system. Addition of whey or other wastewater onto pasture should be carefully planned using appropriate N and hydraulic loading rates. Avoid fertiliser N use where effluent is irrigated.

Use of nitrification inhibitor

Nitrification inhibitors such as dicyandiamide can be used to inhibit *Nitrosomonas spp* which are responsible for oxidising ammonium into nitrite. This way the entire nitrification process is arrested in soil and leaching potential is reduced. These inhibitors have been tested rigorously for their persistency and toxicity and approved world wide for using on grazed pastures.

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Phosphorus application

Smaller doses of P application can minimise the potential for P runoff. Farmers also could use partially acidulated P fertilisers to minimise surface runoff of dissolved-P. Regular liming is important to minimise soil acidity. Acidic soils require high P loading.

Farm dairy effluent management

Effluent irrigation should match the land use. For example effluent loading to a 'cut and carry' pasture system could be up to 600 kg N/ha/year whilst the loading onto grazed pasture should be restricted below 150 kg N/ha/year. It is advisable to construct effluent holding ponds lined with synthetic material in pumice area.

Cultivation

Avoid cultivation

Cultivation should be avoided as much as possible because cultivation causes aerobic conditions and rapid breakdown of organic-N in soil (approximately 6000 kg N/ha in a plough layer of 0-15 cm depth) resulting in very high accumulation of mineral-N. Cultivation also increases infiltration rates which accentuate leaching problems.

Unlike arable farming, cultivation of dairy pasture can be completely avoided. For grass reestablishment, oversowing has been found to be equally effective to sowing after cultivation. Cultivation can cause more leaching in a dairy pasture system because of the greater amount of N accumulation in pasture soils than arable land (e.g. pasture soil may contain up to 0.9% total-N whilst arable soil may contain up to 0.3% total-N).

Timing

Recent research in New Zealand and overseas demonstrates that if cultivation is required it should be performed during cold seasons to avoid microbial breakdown of organic-N.

Straw incorporation

Straw or stubble can be incorporated with soil during cultivation which can 'lock-up' the mineral-N released in soil as microbial biomass.

Pasture irrigation

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If possible avoid pasture irrigation. Soils kept at field capacity are susceptible to nitrate leaching during rainfall. Soil pore volume should be considered when planning the amount of irrigation. Sandy soils should be irrigated less than heavier soils (e.g. clay soils).

If performed, pasture irrigation should be conducted according to the following conditions:

- a) The water shall not be applied to exceed the water holding capacity of the soil within the root zone (rhizosphere).
- b) The rate of irrigation shall not exceed the infiltration rate of soil. To this end there shall be no run-off of irrigated water or ponding.
- c) There shall be no significant ground water contamination as a result of irrigation. To this end, significant ground water contamination is considered as more than a 10% increase in annual peak background nitrate-nitrogen in ground water.

Regulation

Use of two ponds or barrier ditch systems to discharge treated effluent in the lake catchment should be prohibited. The fertiliser industries and regional councils must monitor fertiliser-N use. If used excessively advice must be available on sustainable use of fertiliser-N. If the N use increases, despite these efforts, the regional councils in the lake catchments should regulate fertiliser-N use.

Research

Environmental research should be undertaken based on sound risk assessments. In New Zealand the ground water nitrate problem is not clearly understood. Since nitrate levels in shallow aquifers change temporally and spatially any ground water sampling programme requires careful planning to ensure optimum sampling frequency and selection of appropriate sampling sites.

Soil research is required on the appropriate rate of N application for different soil types with different climatic conditions and land uses.

Grass research is necessary on deep-rooted grass species or grass rhizospheres that can inhibit nitrification activity in soil. Animal and plant research is required on increasing N absorption and metabolic efficiency in ruminants to reduce N loading as urea in urine. Duplication of research should be avoided and collaborative work should be encouraged between research organisations and regional councils.

Technological transfer

Research organisations should communicate frequently with dairy farmers to provide information about efficient soil N management. Regional Councils could do the following:

1. Inform farmers about the state of the lake environment on a regular basis. Such information should include a sound interpretation of research and should provide farmers with advice aimed at minimising nutrient runoff.

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2. Encourage the farmers to monitor the surface water quality of the streams/rivers on their farms.
3. Facilitate land care groups to increase awareness about lake water quality management.
4. Assist farmers to fence waterways and to reticulate stock water supply.

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