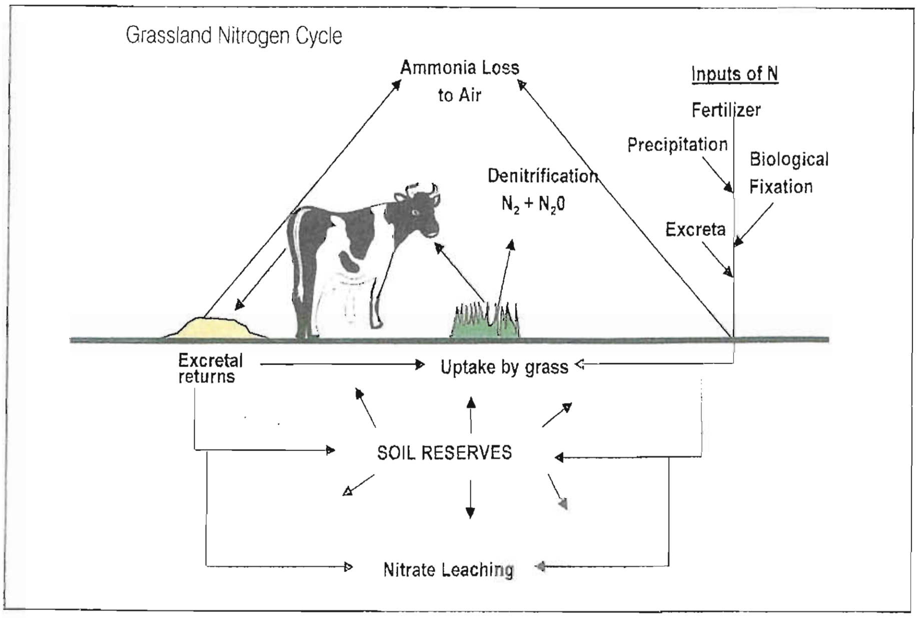
KELLOGG RURAL LEADERSHIP PROGRAMME 2006

NITROGEN IN NEW ZEALAND GRAZING SYSTEMS



CYCLING OUT OF CONTROL?

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2006

PRIMARY INDUSTRY COUNCIL & LINCOLN UNIVERSITY

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1. Executive Summary

Productivity increases by farms over the past twenty years have been large. Farmers are always looking for ways to increase output, especially in the last ten years in a period of high market returns for farm products. Productivity increases have been partly achieved through intensification. Intensification of farming systems over the last ten years has lead to an increase in the amount of inorganic fertiliser inputs of nitrogen (N), particularly on dairy grazing systems and more recently on less intensive sheep and beef farms. Nitrogen fertiliser inputs in New Zealand (NZ) have climbed from 50,000 tonnes to 400,000 tonnes of nitrogen during the 1990 to 2006 period.

Research trials both in New Zealand and overseas clearly show the benefits of additional inputs of N fertiliser on increasing annual and seasonal pasture production. N fixation by white clover provides the majority of N inputs in NZ farming systems. N fixation by white clover is estimated to range from about 25 to 250 kilograms of N per hectare per year on differing NZ grazing systems. Fertiliser nitrogen inputs are estimated at 120 kilograms of N per hectare per year on dairy farms in 2006 and are expected to increase to 170 kilograms per hectare by 2010.

Increased N inputs leads to more intensive farming systems supporting higher animal numbers. Most losses of N occur via the grazing of these systems by ruminant animals. Ruminants do not convert the N they ingest very efficiently. Conversion of N into products such as meat and milk is often less than 20 percent from high N input systems. The N that is left is at risk of being lost to the environment. This is the main impact of high N inputs supporting intensive grazing systems especially those grazed by cattle. Losses of N that are damaging to the environment are:

- Leaching of nitrates (NO_3^-) from drainage and ground water.
- Volatilization of ammonia (NH_4^+) to the atmosphere.
- Denitrification resulting in loss of nitrous oxide (N_2O) to the atmosphere.

Environmental losses will become important in the future as policies are put in place to reduce farming's impact on the environment. NZ has recently signed the Kyoto Protocol the aim of the protocol is to reduce greenhouse gas emissions to 1990 levels. NZ Farmers managed to block measures by the government to introduce a tax on livestock for methane gas emissions ('FART' Tax). As the world becomes more aware and concerned about global warming caused by greenhouse gas emissions it will become harder for farmers to block such policies. Farmers must become more accountable for their nutrient inputs and outputs by nutrient budgeting, because if they as an industry do not, policies will be put in place to make it happen. These policies like the Nitrate Directive in Europe and the Dairying and Clean Streams Accord in New Zealand will come at a cost to the agricultural industry as a whole.

Once farmers start to use nutrient budgeting programs such as OVERSEER™ via their fertiliser representatives, they will gain a better understanding of nutrient inputs and outputs. Farm fertiliser plans will become more precise at the farm level. Nutrient losses will be reduced making fertiliser use more efficient and sustainable. The majority of NZ farmers are environmentally considerate because they know that gives our industry an advantage on the world market. Recent reports of poor compliance rates for effluent discharges within the dairy industry are and will continue to put the industry under greater environmental scrutiny by national and regional authorities.

Current policies in the United Kingdom will make intensive farming using high inputs of N harder to justify in the future. There is pressure from the urban population to have greater access to the countryside and farms. The same can be said in NZ with the present government task force looking at public access to the high country and rivers. Other United Kingdom pastoral research areas are looking at returning some areas to semi-natural grassland. In the past these systems had a large diversity of grasses and other pasture species and supported a variety of wildlife.

Biodiversity losses are one feature of systems using high inputs of nitrogen. Fresh water bodies such as Lake Rotorua and Lough Neagh, along with saline water bodies like the Gulf of Mexico are examples of the effect that excess nitrogen form agricultural sources has on life in these ecosystems. Seventy five percent of nitrogen inputs into Lake Rotorua come from agricultural sources. Agriculture represents forty five percent of the land use area.

New Zealand is a small biological economy based on agriculture. Developing countries such as China, India and central and southern America have huge land masses when compared to New Zealand. As agricultural systems in these parts of the world continue to intensify like New Zealand greater pressure will be placed on local and global natural resources. These will range form local fresh water quality through to global effects from global warming from nitrous oxide emissions.

The NZ agricultural industry needs to start to look at putting standards in place regarding the use of nitrogen inputs. These standards need to have specific trigger points using actual figures. These figures need to possibly cover such areas as; stocking rates, nitrogen fertiliser inputs, effluent disposal areas and nitrogen leaching levels. The author would suggest that the impact of this would be less than will be the case if it is left to a group outside the industry to set these standards. Our country portraits itself on our clean and green image, the time has come to show that that image is being protected and enhanced through some global leadership on behave of all New Zealander's.

If not managed sustainability the impact on the environment of present day nitrogen inputs will be continually seen by future generations.

2. Introduction

Nitrogen is an important macro-nutrient for New Zealand (NZ) agricultures biological farming system. The same is true for everything that lives. Nitrogen (N) is not a new nutrient for NZ farming. As soon as land was cleared for agricultural farmland the process of nitrogen cycling began. What has changed though is the intensification of the farming systems; from fencing and fertilizer, grazing systems and pasture species to stocking rates and livestock species. These have all lead to increases or changes in nitrogen inputs, outputs and cycling.

The main input of nitrogen in NZ agriculture comes from pastoral legumes, mainly white clover. This is the basis to NZ agricultures competitive advantage. Phosphate fertilisers were increasingly applied mid way through the 20th century with the advances in topdressing using aero planes. This phosphate fertiliser increased white clover production which fixed atmospheric nitrogen via the *rhizobium* bacteria, making it available to grass species in the sward. At the start of the twentieth century two Germany scientists Fritz Haber and Carl Bosch developed a way to change non reactive atmospheric nitrogen to ammonia (Haber-Bosch process). Ammonia is the reactive compound that was then and still is now used to make Nitrogen fertilisers.

From 1990 the use of nitrogen fertiliser in NZ agriculture has started to increase at a fast annual rate, from about 50,000 to around 400,000 tonnes N annually in 2006 (*Lambert)*. Furthermore the majority is being used on more intensively grazed livestock systems. Both international and National research around this time and earlier is showing that nitrogen levels in both fresh and saline waters are increasing.

These factors are leading to widespread concern that nitrogen from agriculture is entering water systems in quantities that are affecting water quality for recreation use and eco system biodiversity. Five years ago the main agricultural media around the use of nitrogen inputs were about the agronomic benefits from applying additional N. Within the last five years this has changed to the environmental effects that intensive agriculture using higher levels of N fertiliser is having on the environment both within the farm gate and beyond.

3. Nitrogen Fertiliser in New Zealand Livestock Farming

3.1 The Haber Bosch Process

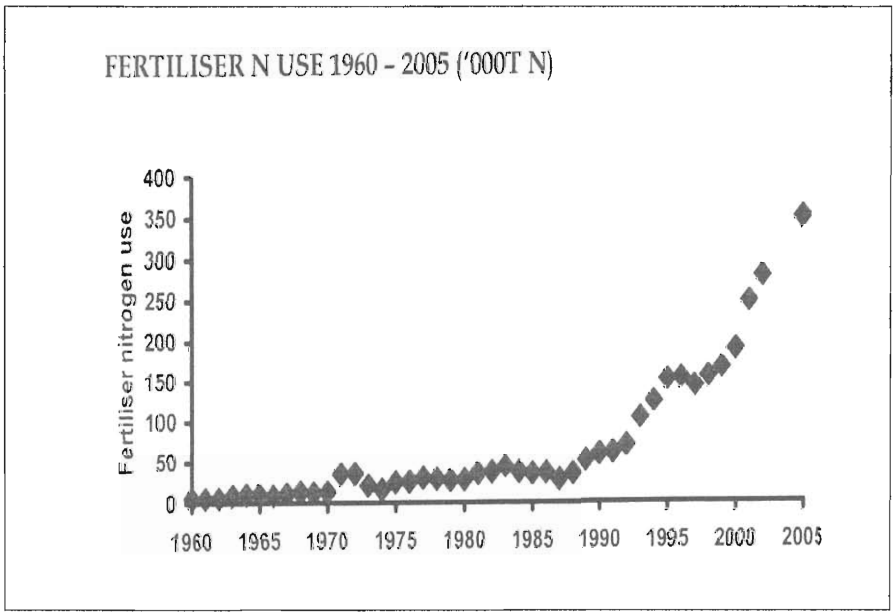
This process was developed prior to World War 1 by two Germany scientists and allowed for the economical mass production of ammonia form non reactive nitrogen and hydrogen. Although this process is not well known about it is one of the most important advances in the 20th century. It is estimated to feed around two billion people from the food grown with this fertiliser.

The process uses very high pressures (200 to 400 atmospheres) and high temperatures of (400 – 650 degrees Celsius). These factors mean that large amounts of energy are needed to complete the process. At present it is estimated that 500 million tons of fertiliser is produced using the process and uses around one percent of the worlds energy (*wisegeek)*.

3.2 Nitrogen Fertiliser Inputs in New Zealand Agriculture

New Zealand agricultural inputs of N come mainly from biological fixation via pastoral legumes and inputs of N Fertiliser. Inputs of nitrogen fertiliser have increased sharply since 1990. Even during the period 1996 – 2002 the use of Urea (46 percent nitrogen fertiliser) rose by 160 percent in New Zealand's livestock farming sector (*Williams)*. During the same period stocking rates and milksolid production increased 19 percent and 34 percent respectively.

Fig 1. Nitrogen fertiliser inputs in New Zealand (*Lambert)*



3.3 Dairy Farming

New Zealand dairy farming represents of 11 percent of the total land used in agriculture (1.76 million Hectares) *(Dairying)*. The average rate of nitrogen fertiliser input per hectare is 120 kg N / ha / year in 2006 *(Rennie)*. Therefore 210,000 tonnes or 54 percent of nitrogen fertiliser inputs are applied to 11 percent of New Zealand agricultures land area. Predictions by Dexcel show that to increase to 170kg N / ha / year by 2010. If this is multiplied over the present dairy farming area of 1.76 million hectares the total nitrogen fertiliser input for the dairy industry will increase to around 300,000 tonnes of N.

Fig 2. Inputs and outputs of N from an Average Waikato Dairy Farm *(Edmeades)*

	DAIRY FARM
N INPUTS (kg / ha / yr)	
Fertiliser	**122**
Clover	**101**
N OUTPUTS kg/ha/yr & (% of total N)	
Product	**69 (31)**
Atmosphere	**56 (25)**
Leaching	**37 (17)**
Immobilisation	**61 (27)**

The table shows the amount of nitrogen cycling that takes place in a dairy grazing system. Also highlighted is the inefficient transfer of nitrogen inputs going out in product leaving the farm. 42 percent of the annual nitrogen input is lost to the environment. United Kingdom research has shown nitrogen transfer into animal products is often less than 20 percent *(Watson)*. Leaching loses of nitrogen is mainly via the urine from the cows grazing pasture.

Urine patches from cattle often contain the equivalent of 1000 kg of N / ha, which is well in excess of the amount available to be utilised by pasture. It is this nitrogen in the form of ammonia that is readily converted to nitrate, which can be leached from the soil. During winter when soil moisture levels are high and pasture growth is low is a high risk period for leaching of nitrates from the root zone.

Dairy farming systems generally have a more intensive grazing management system. Most dairy farms in New Zealand are milked twice daily and are also likely to be grazed on a small area between these milking times. High cow numbers on a small area increases the grazing intensity. Large amounts of animal excreta and the high N inputs are the reason that higher losses are found in dairy systems.

The greatest pressure from nitrate leaching on fresh water ecosystems in New Zealand are found, at present, in the Waikato region. One third of New Zealand's 3.85 million dairy cows (2003/04) (*MAF*) are farmed in the Waikato. Increased monitoring and recording is being undertaken to measure the environmental impacts of the outputs of N from the dairy industry in the region.

Fig 2 shows that an average Waikato dairy farm loses of nitrogen to the atmosphere equates to 56 kilograms per hectare per year. These loses are in the form of ammonia gas which is associated with acid rain and nitrous oxide which is New Zealand's second most significant green house gas emission.

3.4 Sheep Farming

Sheep farming systems in New Zealand are run less intensively than dairy farming systems. Ewes mainly spend the spring period under set stocked grazing systems. Together with lower gross revenue per hectare contribute to lower fertiliser nitrogen inputs being applied. The main nitrogen inputs in a sheep farming system are from white clover. New Zealand lamb producers rely on this as their competitive advantage over other world lamb producers.

Compared with cattle, sheep have smaller bladders and urinate more often in smaller quantities. The amount of nitrogen in a sheep urine patch is often equivalent to 500 kilograms of N per ha, compared to cattle at 1000 kilograms. Along with lower stocking rates on sheep farms make these systems less "leaky" of nitrates from leaching. However due to the camping nature of sheep especially on hill country means that some areas have higher nitrogen loading from dung and urine than others. When sheep are rotationally grazed in intensive farming systems nitrates are often lost through surface runoff more than leaching through the soil profile.

Fig 3. Inputs and outputs of N from an average Waikato sheep and beef farm (*Edmeades*)

	SHEEP / BEEF FARM
N INPUTS (kg / ha / yr)	
Fertiliser	**10**
Clover	**65**
N OUTPUTS kg/ha/yr & (% of total N)	
Product	**11 (15)**
Atmosphere	**18 (24)**
Leaching	**10 (13)**
Immobilisation	**35 (46)**

New Zealand sheep and beef systems have lower nitrogen inputs. Along with differences in the grazing management systems mean that the losses are also lower than that of dairy farms. New Zealand sheep farms pastures respond very well to the addition of nitrogen fertiliser. They have a history of low inputs of nitrogen, so by adding more nitrogen to the soil speeds up biological activity. Dry matter responses to nitrogen fertiliser inputs is often in the range of 15 – 30 kilograms of dry matter per kilogram of nitrogen *(Lambert)* when applied in warm growing seasons. Lambert also showed that applying 400 kilograms per hectare per year of nitrogen to hill country pastures increased nitrate leaching from about 6kg N / ha / yr to 31kg N / ha / yr. These levels are still lower than the average Waikato dairy farm.

A small dressing of Fertiliser nitrogen is becoming more popular in hill country sheep farms during the late winter early spring period. Increased numbers of multiple bearing ewes have increased animal feed demands at a time when pasture production and feed supply is low. From an animal production and farm management perspective these applications can be very beneficial. From an environmental aspect they are being applied at a high risk time. During this period there is low pasture growth, low soil temperatures and high levels of soil moisture. This means that the chances of loses of nitrogen through leaching and surface runoff are more likely.

4. Environmental Policies in Agriculture

As agriculture becomes more intensive they encounter greater scrutiny from both regional and national authorities. This section is an insight into two examples of policy based around nutrients that has been implemented in agriculture. One is a New Zealand policy and the other is from the United Kingdom.

4.1 New Zealand Dairying and Clean Streams Accord (May 2003)

Wellington Region Action Plan (July 2004) *(Dairying)*

Dairying is a significant land use in NZ. Dairying represents 11 % (1.76 million hectares) of the total land area used in agriculture. Dairy cow numbers stand at 3.9 million head (cows in milk in the 2002/03 season). Increasingly concerns about the effects of this intensive land use on the quality of water within streams, rivers, lakes and wetlands have been raised.

The goal of the Accord reflects an agreement that:

> Fonterra Co-operative Group, regional councils and authorities, the Ministry for the Environment and the Ministry of Agriculture and Forestry will together work to achieve clean healthy water, including streams, rivers, lakes, ground water and wetlands, in dairying areas.

The goal is to have water that is suitable for:

- Fish
- Drinking by stock
- Swimming (in areas defined by regional councils)

Five priorities for action are identified in the Accord to reduce the impact of dairying on these waters.

- Cattle access to water bodies
- Dairy herd stream crossings
- Management of dairy shed effluent
- Nutrient management
- Significant or important wetlands

The Accord establishes national performance targets with respect to each of these priorities.

- 50 % of dairy cattle excluded from streams, rivers and lakes by 2007, 90 % by 2012.
- 50 % of regular crossing points have bridges or culverts by 2007, 90 % by 2012.
- 100 % of farm dairy effluent discharges to comply with resource consents and regional plans immediately
- 100 % of dairy farms to have in place systems to manage nutrient inputs and outputs by 2007.
- 50 % of regionally significant wetlands to be fenced by 2005, 90 % by 2007.

This Accord is not legally binding on the parties or on Fonterra's shareholders.

The performance targets for 2007 are now only months away. On the television program One News (6.00pm) on the 26th of October 2006, it was reported that fifty percent of the 540 dairy farms in the Canterbury region do not discharge of dairy effluent properly. Environment Canterbury (ECAN) also stated that one in five farms is seriously non compliant. Canterbury region represents five percent of all New Zealand dairy farms *(Fonterra)*.

4.2 European Community Nitrate Directive

Nitrates Directive. Second Consultation Paper. Proposal for Northern Ireland (April 2004).
Rural Northern Ireland Environment
Department of Agriculture and Rural Development Northern Ireland (DARDNI)

The Nitrates Directive was first introduced in 1991 and is designed to protect water against pollution caused by nitrates from agricultural sources. The primary emphasis is on the management of manures and other fertilisers. Nitrate polluted water is defined as water sources with a nitrate concentration greater than 50mg / l. Natural waterways both fresh and saline that are eutrophic, or at risk of becoming eutrophic are the other water pollution areas that the directive is aiming to reduce.

Eutrophication is the process whereby excess nutrients in the water, in particular nitrogen and phosphorus (P), result in an over-abundant growth of algae and plants, which affects the balance of organisms, and water quality. Eutrophication in fresh water arises mainly from excess inputs of P from sources such as farming, industry and sewage. Excess inputs of nitrates also contribute to eutrophication especially in saline waters i.e. estuaries, coastal and marine waters. Algal blooms can be associated with eutrophication. P is normally in short supply in fresh water sometimes referred to as the 'limiting nutrient' and the same applies to N in salt water. However studies have shown that both nutrients either together or in turn can be the limiting nutrient in both types of water.

<u>The Nitrates Directive's main requirements are for member states to:</u>

- Monitor waters and identify polluted waters.
- Develop and implement action programs to reduce and prevent pollution of waters.
- Monitor the effectiveness of action programs.
- Report to the EU Commission on progress in reducing pollution.

The member states must either:
1: Apply action programs throughout their whole territory or;
2: Apply action program measures within discrete Nitrate Vulnerable Zones (NVZs)

<u>Measures included in action programmes are:</u>

- Periods when fertiliser application is prohibited.
- Storage capacity for 5 months of livestock manure (from housing over the winter period).
- Limitation of the amount of fertiliser applied to land.
- For each farm, the amount of livestock manure applied per year, including that deposited directly from livestock themselves, shall not exceed 170kg N / ha / yr.
- Keeping of records on fertiliser use and the establishment of a fertiliser plan on a farm-by-farm basis.

<u>Implications of this - Northern Ireland</u>

Seven NVZs have been designated to date, accounting for less than 0.1 percent of the land area. This low level is because nitrate concentrations in surface fresh water throughout Northern Ireland are below the directive's 50mg nitrate / l standard (equivalent to 11.3mg nitrate-N / l). However a scientific report identified eutrophication as a major environmental problem in lakes and rivers throughout Northern Ireland. Lough Neagh (biggest lake in the UK) and Lough Erne in Northern Ireland have been described as being hypertrophic and eutrophic respectively.

In relation to nitrate loading in both Lough's lowland agriculture is identified as the major source, accounting for 75 percent of the nitrate in Lough Neagh and 92 percent in Lough Erne. P concentrations in Lough Neagh are 15 $_{u}$g P / l of which 62 percent is from agriculture. Lough Erne P concentrations are 60 $_{u}$g P / l of which agriculture accounts for 73 percent. 35$_{u}$g P / l are the recommended limit.

The European Court of Justice (ECJ) has argued the NVZs must be declared for eutrophic freshwaters where a significant proportion (>20 percent) of the nitrate comes from agriculture. Therefore it is likely that Northern Ireland will have to take a total territory approach to implement the Nitrate Directive. The Republic of Ireland has done this in May 2003. Seven member states including the UK have designated less than 50 percent of their land as NVZs. The European Commission is currently taking legal proceedings against all seven, for insufficient designation.

Therefore: *For each farm the amount of livestock manure applied per year, including that deposited directly from livestock themselves, and that brought onto the farm shall not exceed 170kg N / ha / yr.* Note, this level relates only to nitrogen produced by livestock; it does not include nitrogen from inorganic fertiliser.

Nitrogen Produced by Livestock on the Farm (Sheep and Cattle)

Type of Livestock	Total N produced / yr / unit (kg N / yr)
Cattle	
Dairy Cow (550 kg)	**96**
Dairy Cow (450 kg)	**76**
Cattle 12-24 months (400 kg)	**58**
Bull Beef 6-12 months	**23**
Sheep	
Sheep	**9**
Finishing Lamb (6-12 months)	**3.2**
Finishing Lamb (0-6 months)	**1.2**

This table indicates that a dairy farm under the Nitrate Directive could carry about 1.7 cows (550kg) per hectare. A sheep farm running ewes and lambing at 150 percent could run about 15.5 ewes / hectare. 60 percent of dairy farms in Northern Ireland have a stocking rate above this level. Options for these farms would be to; reduce stocking rate to meet the required level; buy more land so that their Organic Nitrogen Loading (ONL) is at or below 170kg N / ha / yr; or to export some of their farm manure to a property with a ONL below the 170kg N / ha / yr. The major implication of the Nitrate Directive if implemented over the whole of Northern Ireland is a reduction in total livestock numbers.

4.3 Farm Subsides

Farm subsides in the European Union have started to be phased into Single Farm Payments (SFP) from the old Common Agricultural Policy 1958 (CAP) subsides. The CAP subsides were a farm payment based on the production output of the farming system. The new SFP subsides are a single payment that will cut the link between production and subsides. This new system will reward environmentally friendly practices so reductions in stock numbers are likely. There is a clear drive in the United Kingdom to reduce the environmental impact caused by agricultural production. Currently a lot of pastoral research is being done to encourage lower input pastoral systems. These projects are given priority funding over production research according to the head scientist at the Institute of Grassland and Environmental Research (IGER), Doctor David Hatch.

5. Nutrient Budgeting

Nutrient management will become a mandatory requirement for fertiliser users in New Zealand. The Dairying and Clean Streams Accord has a performance target in place of 100 percent of dairy farms to have systems in place to manage nutrient inputs and outputs by 2007. Nutrient budgeting is now available to New Zealand farmers through the leading fertiliser company's. Using nutrient budgets is gaining popularity with farmers especially within the dairy industry. Farmers will find these budgets a good guide to understand the cycling of nutrients in the farming system and to identify the imbalances between nutrient inputs and outputs at the farm level.

The Fertiliser Code of Practice suggests that annual applications of more than 200kg N / ha / yr may lead to unacceptably high levels of nitrate leaching. A number of intensive farms in New Zealand are now using more N than this on their pastoral systems. The majority of these farms would be dairy milking platforms. On these farms it is not uncommon for feeds like grass and maize silage and some grains to be imported from other properties. These imports contain nutrients including N. Total N inputs are therefore even higher than that of just the inorganic fertiliser input and are not being managed. The total N loading and the intensive grazing systems with dairy cows on these operations are not environmentally sustainable. Systems like these are the reason that policies will be put in place to monitor and govern the industry as a whole.

The computer programme 'OVERSEER' has been developed as a nutrient budgeting model to measure inputs and outputs of nutrients from a farm. This program is available for free download from the Agresearch website (www.agresearch.co.nz). The leading fertiliser company sales representatives have OVERSEER available to their clients and should be encouraging its use on high fertiliser input systems. Dairy farmers will become familiar with this program over the next few years as the Dairy and Clean Streams Accord comes under pressure to achieve its performance targets.

By entering parameters such as farm type, stocking rate, topography, location, rainfall and fertiliser inputs, OVERSEER calculates nutrient inputs and outputs from the farm. N inputs for example come from N fertiliser, legume / atmospheric additions and from feed imported to the farm. Outputs of N are from atmospheric, leaching / runoff and animal products.

New Zealand's Resource Management Act (RMA) how has requirements for nutrient management. The recent application for water consent from the South Canterbury Irrigation Trust (SCIR) along with Meridian Energy has a 100 page section that covers nutrient management of nitrogen and phosphate. Users applying for water consents must demonstrate that the water they are taking is being used in a responsible and sustainable system.

Nutrient budgeting is one management tool that can be used to significantly reduce nutrient losses from agricultural land. Financial budgeting and feed budgeting are common in farming businesses; nutrient budgeting will be no different.

6. Nitrogen Fertiliser Pastoral Research

Research into the addition of nitrogen fertiliser on pastoral agriculture has been carried out both in New Zealand and overseas. This section looks at two NZ trials on hill country and some pastoral work with nitrogen fertiliser in the United Kingdom.

6.1 Redefining the Production of Hill Pastures using Fertiliser Nitrogen (NZ)
(*M.G Lambert, A.D MacKay, B.P Devantier, D.B McDougall, D.J Barker and Z.A Park-ng*)

This trial was conducted from June 1996 to May 1998 on summer safe hill country at Agresearch Ballantrae research station. Prior to this research the trial area was a long-term grazing trial, investigating pasture and animal responses to P fertiliser regimes.
The trial used three different P fertility sites. The "Low" P site had not been fertilised since 1980, a "Med" P site had received 125kg (11.25kg P) super phosphate / ha / yr since 1974 and finally a "High" P site had received 625kg (56.25kg P) yr / ha / yr between 1975 – 1979 then 375kg (33.75kg P) super phosphate annually thereafter. In 1996 the Olsen P status was 6, 8 and 23mg / kg soil for low, med and high respectively.

The fertiliser treatments above were continued for each of the "fertility blocks". Two paddocks within each block acted as the control while the other two received a "Fertiliser treatment" comprising additional annual inputs of 70kg P, 50kg S and 400kg N per ha. The N was applied as urea in 8 dressings per year. Application dates were 1 June, 24 August, 16 October, 17 November, 12 December, 5 January, 1 February and 14 March for both 1996-97 and 1997-1998. The paddocks were set-stocked with breeding ewes at a rate proportional to pasture production.

Results:
N fertiliser increased pasture production across all fertility blocks. On the "Low" block the dry matter (dm) response to N fertiliser increased pasture production by 8909kgdm / ha / yr to a total annual production of 15542kgdm / ha. This represents a 22.3kgdm response / kg of N applied. On the "High" block the response to N fertiliser was 7296kgdm / ha / yr with total pasture production of 19425kgdm / ha / yr. This represents an 18.2kgdm response / kg N applied. These results are within the range found in the UK nitrogen research trials reported on.

There were also effects on pasture composition. In year two there was an increase in high-fertility-responsive grasses and a decrease in low-fertility-tolerant grasses. Fertiliser treatment did reduce legume content in both year one and two. N leaching also increased from about 6kg N / ha / yr on the control to 31kg N / ha / yr on the fertiliser treatments.

This increased dry matter production to nitrogen cost 7 cents per kgdm. This trial shows that nitrogen fertiliser greatly increases pasture production on hill country. The trial was run to stretch the boundaries of present practices. Caution is suggested regarding on and of-site impacts, including effects on nitrate and greenhouse gas emissions and nutrient cycling on long-term sustainability.

6.2 Pasture Responses to phosphorus and nitrogen fertilisers on Dry hill Country

(*A.G Gillingham, M.H Gray and D.R Smith*)

This trial was established in on dry hill country near Waipawa in the Southern Hawkes Bay. The field trial was designed to evaluate the responsiveness of summer dry hill country to P and N fertiliser treatments. The trial consisted of both north and south facing aspects containing both easy (15-20 ^{0}) and steep (25-30 ^{0}) slopes. The area had only been lightly grazed previously and was dominated by browntop with negligible legume content. The annual rainfall was only 800mm with the possibility of low rainfall over summer and autumn.

The trial area was 48ha divided into 4 farmlets of 12 one ha paddocks each, receiving contrasting P and N fertiliser treatments. Farmlets were balanced to contain similar slope and aspect. Two farmlets receive low P fertiliser rates (Low P farmlets) as super phosphate to maintain an Olsen P status of 9. The other two farmlets received an initial capital fertiliser dressing and were then maintained at an Olsen P level of 28 (High P farmlet) by applying super phosphate at the same rate as the Low P farmlets plus additional triple super fertiliser. In addition one each of the Low P and High P farmlets received 30kg N fertiliser/ha as urea in winter.
Each farmlet was self-contained with a stocking ratio of 65:35 sheep (5yr old Romney's) and cattle (18mth Angus / Friesian). The stocking rate was designed to fully utilise pasture growth from each farmlet.

Results:
Total pasture production increased in all seasons on the Low P farmlets as a result of added N fertiliser by producing an annual increase of 719kgdm / ha from the 30kg / ha of N fertiliser. This represents a response of 24kgdm / kg N applied, this is also within the range reported earlier. This N response ranged from 440kgdm (easy slopes) to almost 1300kgdm (steep north slopes) / 30kg N fertiliser applied. Therefore the best response occurred on steep north facing slopes with a low P status. These responses represent a 43kgdm / kg N. This trial highlighted the fact that pasture production on hill country varies due to aspect and slope. A steep north facing aspect that is dry does not support good white clover production and therefore N is the limiting nutrient.

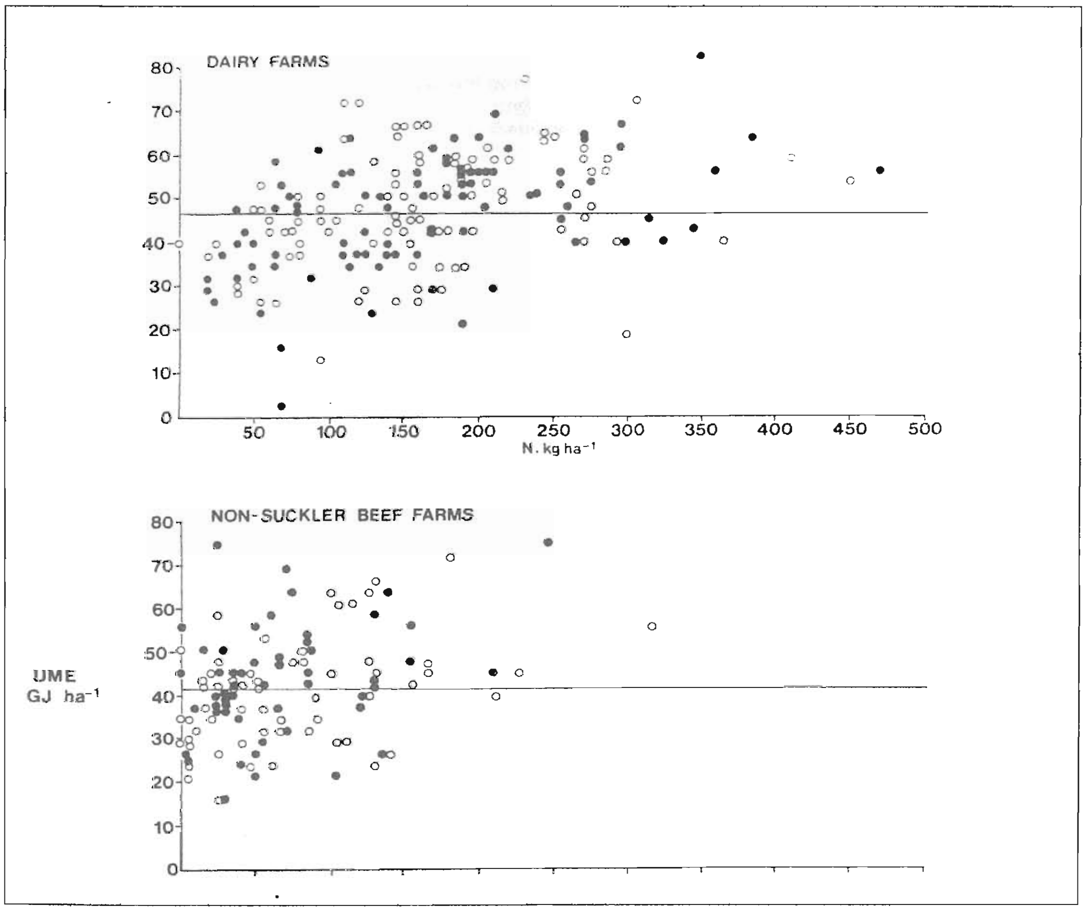
6.3 United Kingdom Nitrogen fertiliser Pastoral Research

Many research papers have been published from both field and farm trials on the addition of N fertiliser to grassland in the UK. N Fertiliser accounts for the largest fertiliser input on grassland farms. The majority of soil P levels on farm remain adequate to excessive, for pasture production. In 1940 75 percent of Northern Ireland soils were deficient or low in P. With increased use of P fertiliser during the 1960s – 1980s, 80 percent of soils are now classified as adequate to excessive in P status for grassland farming (*DARDNI*). Nitrogen fertiliser is now applied to 85 percent of grassland in England and Wales at a mean annual rate of 160kg N / ha / year. Dairy farmers use, on average, more than twice that of sheep and beef farmers.

Research trials have shown maximum response to nitrogen fertiliser on sown grassland occurs between 450 (*A. Hopkins, J. Gilbey*) and 700kg N / ha / yr (*Morrison*), although at the top end of these levels the response may be small i.e. 2.5kgdm / kg N between 450 – 700kg N / ha / yr. Total average response to N ranges from 15 – 30kgdm / kg N up to 450kg N / ha / yr. These levels of dry matter response to N fertiliser are within the range of research work in NZ done by *Lambert* and *Gillingham.* Changes in botanical composition occur rapidly (within two years) in response to increasing the rate of N. This change is shown as an increase in the amount of ryegrass and a decrease in less competitive grasses and legumes. Due to this change in composition there is often little advantage in response to N from re-seeded pastures, compared with existing pasture after the second year, as the existing pastures have an increased amount of ryegrass. Results confirm advantages of re-seeded perennial ryegrass over permanent swards at high levels of N (450kg N / ha / yr), though at 0 and 150kg N / ha / yr there was no advantage to the perennial ryegrass re-seed after its first year (*Hopkins and Gilbey*). In another publication (*A Guide to Sward Improvement)* it is suggested that re-grassed pastures require at least 200kg N / ha / yr to gain additional dry matter yields over permanent pastures receiving the same amount of fertiliser N over a five-year period.

On many commercial farms moderate to high levels of output are achieved from old grassland with little reliance on N. A study (*Forbes*) of productivity, using a sample of 450 permanent grassland farms, reported that many farms using little or no N, achieved a level of utilized output from grassland similar to the average for farms in the sample.

Fig 4. Utilised metabolisable energy and nitrogen fertiliser input (Forbes)



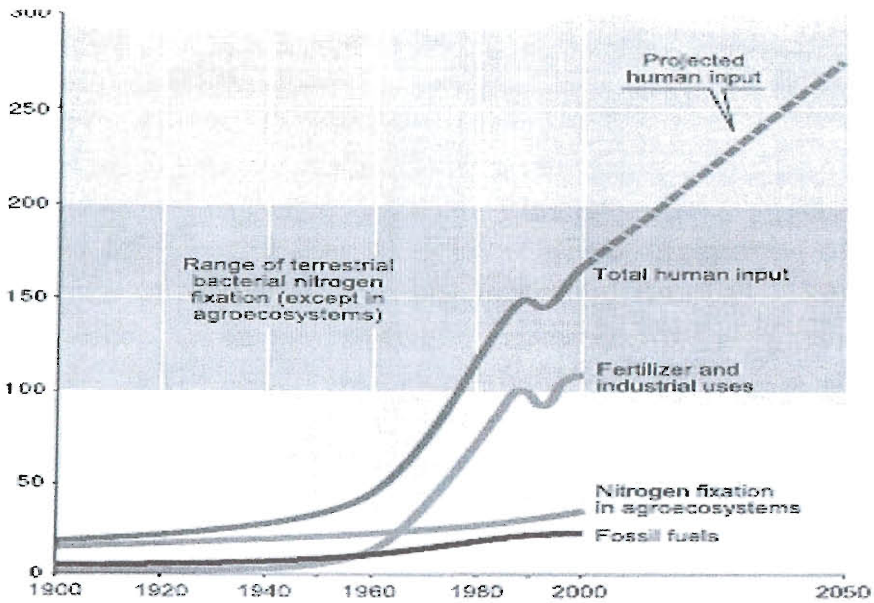
7. Nitrogen Losses to the Environment

Reactive nitrogen enters the cycling pool from two main sources; nitrogen fixing bacteria and inputs of nitrogen fertiliser. Only about 10-20 percent of this reactive nitrogen used for food is actually consumed and 95 percent is lost to the environment (Williams). Nitrogen is lost to the environment by three processes. These processes are; leaching of nitrate in drainage water or to ground water, volatilization of ammonia to the atmosphere and denitrification resulting in loss of nitrous oxide to the atmosphere.

7.1 Increased Inputs

The demand for food globally is increasing with world population and development. This is leading to increased inputs of reactive nitrogen. More nitrogen is being converted into reactive forms. This is adding to the nitrogen cycling poll globally.

Teragrams of nitrogen per year (Williams)



7.2 Leaching of Nitrates

Leaching losses are mainly in the form of Nitrate (NO_3^-), which is the result of a number of different soil processes. N Fertiliser and grazing animals influence these process rates rapidly. Risk of N leaching is greatest in the winter months. This is due to low plant growth rates to uptake the N inputs and, high drainage water from the soil. Winter N applications of greater than 50kg N / ha greatly increase the risk of direct N loss from fertiliser inputs. To limit this loss, N fertiliser would be better applied in autumn and the increase pasture growth could be carried in to the winter period where there is budgeted to be a feed deficit. The loss of nitrates through leaching is receiving the greatest awareness because water is a very important resource.

Nitrogen is the limiting nutrient in salt water ecosystems so any increase of nitrogen to these waters can have a severe effect on biodiversity. A World Bank draft report says excess nitrogen from fertiliser has already caused "dead zones" around the world, notably in the Gulf of Mexico, fed by nitrogen rich water from the Mississippi River (Sunday Star Times **October 10, 2004**). This dead zone has been estimated at 15,000 square kilometers.

Nitrogen inflows into Lake Rotorua have been estimated to be 450 tonnes nitrogen per year (*McIntosh*). Dr Morgan Williams presented research from the Institute of Geological and Nuclear Sciences (IGNS) that showed the nitrogen inputs into Lake Rotorua were 763 tonnes per year (2004). 75 percent of that nitrogen is from pastoral land use which makes up 45 percent of the land cover.

Lough Neagh (biggest lake in the UK) and Lough Erne in Northern Ireland have been described as being hypertrophic and eutrophic respectively. In relation to nitrate loading in both Lough's lowland agriculture is identified as the major source, accounting for 75 percent of the nitrate in Lough Neagh and 92 percent in Lough Erne (Nitrate Directive).

7.3 Volatization of Ammonia

Volatilization is the process by which ammonia is lost to the atmosphere from soils and organic manure. Ammonia from livestock waste is estimated to account for over 80 % of the ammonia emissions in Europe, mainly from cattle. This gas contributes to acidity of rain.

7.4 Denitrification

The Denitrification process produces the greenhouse gas nitrous oxide (N_2O). Although 1000 times less abundant than CO_2 in the atmosphere N_2O has a relatively long lifetime (100-200 years) and accounts for 10 percent of the greenhouse effect. N_20 is 200 times more effective than CO_2 at absorbing long-wave radiation, which makes it a contributory factor to global warming (*Watson*). N_2O levels in the NZ atmosphere have increased 25 percent in the past 10 years. This was reported by TV One News during October 2004 and is now second behind methane in terms of greenhouse gas emissions from NZ agriculture.

7.5 Recent Industry Comment

Federated Farmers (STUFF) has called on farmers to reduce the nutrient leaching from their farms by 10 percent in the next 10 years. This was launched at the federation's national council meeting under the "10 in 10" campaign.

Dairy Environment Leadership Group reported (Dairying Today) that the fertiliser industry has set a date to have nutrient budgets in place for all dairy farming clients. That date is June 2007. This announcement helps the dairy industry deliver on the Dairying and Clean Streams Accord.

These are positive steps that show the agriculture industry is looking to improve on environmental sustainability. Until nutrient budgeting is common practice in the agricultural industry there is no way that the "10 in 10" campaign can be achieved. If nutrient outputs are not being measured at present there is no way of knowing what reduction in nutrient leaching is being achieved.

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