Sustainability of Agricultural Systems regarding Nutrient Losses

A report to the New Zealand Nuffield Farming Scholarship Trust

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Executive Summary and Recommendations

There is little doubt that the environmental cost of food production is becoming a much greater concern to the general public. Since the change in land use of our own property here in coastal Southland from sheep and beef farming to dairying in 2002 there has been a highly effective campaign to highlight the negative consequences for lowland water ways resulting from this change in land use. This has had a significant impact on public opinion which will inevitably have an impact on the decisions of policy makers who regulate our farming practices.

The aim of my study was to look at the result of intensive agricultural land use in the countries I visited and from that see what can be applied to our situation here in New Zealand.

My conclusions are:

- New Zealand animal production systems are much less intensive than those that dominate food production in the northern hemisphere where the majority of animal production is in confined or housed systems. This means they are significantly more energy intensive and have far more animal manure to spread mechanically.

- Nutrient regulation seems to follow mechanical manure spreading, probably due to visibility and odour issues. Pressure for regulation increases with affluence and population density.

- Regulations are invariably the result of public outcry due to incidents of mismanagement. The response of publicly elected regulators does not necessarily follow good science and tends to be prescriptive and overly cautious.

- Prescriptive regulation rarely achieves positive outcomes for the environment as farmers then tend to farm the regulations and it becomes difficult for the game keeper to keep ahead of the poachers.

- Regulators tend to focus on limiting inputs and controlling systems (including stocking rate) when their objective is to reduce nutrient losses.

- Prescriptive regulation of farming systems effectively stops useful on farm innovation, and reduces the incentive for scientific research into mitigation or even efficiency strategies.

- Public opinion towards food production is no longer coloured by the potential for shortage as was the case 50 years ago. With there being no prospect of supermarket shelves going bare, the public are less susceptible to threats that local food producers are unviable.

- The majority of farmers see themselves as good custodians of the environment but have no way of proving it. They have little defense when regulators suggest that they are having a deleterious effect and tend to stoically accept the inevitable.

My recommendations are:

- We need to convince farmers that the cumulative effect of mismanagement of highly visible issues like dairy effluent is a serious risk to the viability of our farming systems.

- Understand that the opinions of the voters will determine the rules which our farming system will be subject to. We collectively and individually need to make an effort to convince those not involved in farming of the integrity of our systems.

- Have the best information available on the environmental output from farm systems. This will likely include some nutrient modeling but measuring of surface water quality will be invaluable to establishing environmental credentials.

- Make the best use of the available science around nutrient losses and ensure that future research is sufficiently funded.

- Lobby the regulating bodies (regional councils) against the pit falls of prescriptive regulation and encourage focus on outcomes.

- Look for innovative and inexpensive ways to establish environmental integrity to a doubting public.

Introduction

In response to the demand for cheap food from the growing urban population, agriculture moved to fully embrace mechanisation in the second half of the twentieth century. Farm systems came to increasingly rely on cheap fossil fuels and extensive use of artificial fertilizers to lower the cost of production.

An unintended outcome of the intensification of agriculture is the “leakage” of nutrients from:

- Fertilizer application.
- Direct losses from animal dung and urine.
- Mechanically applied animal effluent.

Excessive accumulation of these nutrients in surface waterways and ground water is now widely seen as an unacceptable outcome of farming systems, or to put it more simply, pollution.

In the course of my Scholarship I visited:

- The Netherlands
- United Kingdom
- France
- United States of America
- Canada

My intention was to see how these countries viewed their agricultural production systems and the environmental regulations imposed upon them.

This report discusses the public perception of agriculture both in the countries I visited and New Zealand, the science of nutrient losses from agriculture, and the regulatory response of various countries.
My aim is to draw some conclusions regarding what it will take for our agricultural systems in New Zealand to be environmentally, economically and politically sustainable into the future.

1. Public Perception

The public perception of food growing systems is the driving force for this study. It is apparent that the growth in global trade means the modern consumer is spoilt for choice and there is no profit in producing agricultural products that the consumer doesn't want to buy.
There has also been a rapid loss of political power from food producers to consumers as the number of people employed in food production has fallen and the population has grown around urban centers.

The last time there was a genuine food shortage in developed countries was after the Second World War. This resulted in agricultural production being scene as politically important if not essential. This is to a large extent no longer the case in Europe and the United States.

Modern consumers have never experienced a shortage of food at the supermarket and see no prospect of a shortage ever occurring.
The overwhelming trend is for food to be produced and traded globally with fresh fruit for example to be available all year round from a variety of source countries. The consumer does not generally see it as essential that this food be produced in their country or even essential that their countryside produces food.

There is however a small but growing contrary trend towards "local food" as sold in Farmers Markets. This is generally fresh food at premium prices, brought by middle class consumers who are prepared to pay more for food that they feel better about buying for a variety of poorly defined reasons generally described as "quality" which are nearly impossible to quantify.

In this atmosphere it is unsurprising that there is a growing clamor from the public for the regulation of deleterious effects of agricultural production.

1.1 The United Kingdom

The current political trend in the UK is towards it being far more important that the countryside is maintained in a "park-like" manner than any modification for efficiency of agricultural production.
This is in stark contrast to the period after WW2 of food rationing when agricultural production was seen as vital for the security and wellbeing of the nation and all manner of incentive and subsidy for agricultural production was seen as being in the national interest.

1.1.1 Food Safety.

Public concern has evolved from doubt that they will have enough to eat to concerns for food safety and food production systems.
The consumer has been bombarded by food safety scares including salmonella in eggs, campylobacter in poultry, BSE in beef, scrapie in sheep, and finally the sight of millions of animals being slaughtered and burnt to contain Foot and Mouth. It is hardly surprising that consumers are taking a hard look at farm practices.

The growing level of distrust with food production systems is more politically apparent than the actual level of alternative consumer purchase behavior. When it actually comes down to the purchase of groceries on a daily basis, to a large extent, price is still the most important factor for the vast majority. However, the force of public opinion regarding food safety and the integrity of the growing system is still rapidly changing the requirements for producers. This continues to express itself in a variety of ways:

- -Free range eggs.
- -Organic certification.
- -Retailer driven farm assurance programs.

This trend definitely started in the top end supermarkets like Waitrose and Marks and Spenser which are a relatively small part of the retail food business, in Waitrose case, less than 5%.

Farm assurance schemes have rapidly been adopted by the supermarket giants, Asda and Tescos, fundamentally as marketing tools. Supplying a portion of organic milk is now a condition that has to be filled by companies tendering to supply these large retailers. Tescos now uses only biodegradable shopping bags and has announced their intention to display the food miles involved in the production of all items.

1.1.2 Wildlife and Environment.

Wildlife and heritage issues have been the dominant public concerns about food production and the countryside in general in the past. To a certain extent this has been addressed by the change from production subsidies to single farm payments and the mass of cross compliance issues around habitat protection and environmental protection. The combination of direct financial incentives and the reduced profitability of broad acre cropping at that time had certainly had a significant effect.

What I found fascinating if not entirely rational was the drive from urban environmental groups to see the countryside taken back a generation to a rose tinted view of the 1950’s. It appears they associate agricultural progress with destruction of wildlife habitats and other values that are important but difficult to define. I think that this is typified by the quasi government organization “Natural England” which is leading the reintroduction of sheep to the Yorkshire moors and cattle to the water meadows of Wiltshire, as they have recognized that the environment has developed in the presence of grazing and is not sustainable without it. The vision of Natural England is not without humans, as we might imagine, but English countryside in the 1950’s perhaps because they don’t know what the country looked like without humans.

1.1.3 Climate Change.

My impression was that consumers and the general public are more convinced that human activity is the cause global climate change in Europe and particularly the UK. This is understandable in England where 50 million people live on a land mass around the size of the South Island of New Zealand where we have around 1 million. Population density alone seems to add more urgency to the issue.

It seems that climate change will become a more significant issue around food purchase decisions and probably represents as much of an opportunity as a threat to our agricultural products.

1.1.4 Conclusion.

It is vital that both New Zealand farmers and our major food marketing companies understand these trends and adapt our systems to fit them. Like it or not we have little option but to accept that the demands of the supermarkets reflect views of their customers. The comment I often heard in the UK was the only thing worse than supplying supermarkets was not supplying them.

1.2 The Netherlands.

The Netherlands have been an economy based on international trade for many centuries. Trading is accepted as a key source of wealth creation. The Second World War caused deprivation and near starvation which drove the political agenda in the post war period leading to the European Common Market Agricultural Policy. This drive to secure peace and adequate food supply was shared across Western Europe but the trading background of the Dutch people seems to mean they are much more open to traded food than some other European countries.

1.2.1 Food Safety and the Environment.

Generally borders have much less significance on mainland Europe than in the UK so consumers are conscious about European food safety issues in general. This is particularly the case for the Netherlands where the population has a far more international outlook than in France for example. There is a general concern about environmental pollution but I think this is tempered by the acceptance that man has radically changed the environment, including the water ways. There is little else you can do when a large portion of the population lives below sea level.

This is a society that values quality very highly, from flowers to food sourced from all around the world. They take environmental pollution from agriculture very seriously and take a highly regulated, bureaucratic approach. This is generally accepted as a cost of living in the most densely populated country in Europe.

1.3 France.

Tradition and regional or local are the key words when thinking of the public attitude towards food in France. There is a far greater support for local farmers and food producers than seen elsewhere in Europe. There is a growing internationalization of the diet among the young and the large immigrant population but more than any other country I visited in France a large portion of the population consistently purchase locally produced food at premium prices.

The complexities of land inheritance provisions means a significant portion of the urban population have some financial interest in agricultural land which is usually operated by a relative. This connection with the land helps to cement the urban affinity with farmers in general.
The net effect of this is that the French farmers have strong support from their urban cousins and it is acknowledged that producing "fine food" is seen as an essential part of the French character.

In our discussions with some French farmers at Amiens we were taken by their insistence that they had no trouble controlling wolves that could be a threat to livestock where as this would not be publicly acceptable in the UK or US under similar circumstances. I think this public support will mean that French farmers will be least affected by environmental controls like the EU nitrates directive. The other side of the coin is that French consumers have not driven industrialized intensification of food production to the same extent as has occurred in the rest of Western Europe by their preference for locally produced food. The result is that effluent disposal problems are not as acute as elsewhere.

1.4 The United States.

Nowhere is the trend towards mass production of cheap food more apparent than in the United States. As a gross generalization, Americans meal portions are large, meat tends to be high in fat, processed food is high in fat, sugar and salt, and prices are generally low. The response of the US food producer is to increase scale and drive down costs through intensification and use of cheap labour, usually Mexican.

1.4.1 Food Safety.

For some reason the public in the US have a huge level of trust in their Food and Drug Administration. Once the USDA pronounced that beef was safe the outbreak of BSE in US and Canadian cattle had no effect on consumption. This is in stark contrast to the UK where beef consumption has still not recovered to pre BSE levels. I honestly can’t say whether this faith is well founded but it was again born out by the recent bird flu scare where consumption was largely unaffected.

1.4.2 Environment.

Environmental protection has become a significant driver of agricultural policy making in America. The last US Farm Bill saw a significant shift in agricultural support payments from production subsidies towards more environmental payments. This reflects a move in public sentiment that appears to be less acute than the mood in Europe.

The exception to this is the state of California where there is intense concern about the vast food production from the Central San Joaquin valley area. Public concern is centered around spray residues from the vast area of irrigated intensive horticulture and vegetable cropping. Public pressure has resulted in a prescriptive system of bureaucratic regulation of pesticide application.

Beef finishing and milk production are almost exclusively from feedlot systems in low rainfall areas. There are controls on nutrient loading from feedlots over a certain size but this doesn’t appear to be a major public concern, certainly not compared to pesticide residues. The American public have a high level of acceptance of these feeding system to produce food, particularly marbled beef.

1.4.3 Homeland Security.

The threat of terrorist tampering with food supplies is sometimes quoted by agricultural producers and industry representatives in the US, and this is the reason given for restricting access to large scale production and processing sites. While security is definitely still an important issue in the public mind I don’t believe that this is a significant factor driving food consumption trends.

While we were in Washington we attended the opening of a conference titled “25 by 25” which aimed to plot a path for the US to reduce its reliance on imported oil by moving to 25% use of renewable energy by 2025. The key point of interest was that this movement was not being organised by members of the green movement, but key members of the Republican party. It is hardly a coincidence that shortly afterwards US president George Bush announces subsides for a massive program of ethanol production from biofuels. This has radically changed the demand for grain, particularly corn, which has doubled in price. This significantly lifted the cost of production for livestock causing a lift in world prices.
It is difficult to decide whether this shift in policy is a result of public opinion, political lobbying or geo-political machinations.

1.4.4 Consumer Trends

The US consumers are starting to demonstrate a similar trend to the UK where a small but growing portion of consumers are making food purchase decisions for reasons other than price, convenience or measurable food quality standards. This can be seen by the growth of the “Whole Foods” chain of retailers. They have a high proportion of Organic food, free range, and other “healthy” type brands. Their consumers are prepared to pay premium price for food they feel better about eating. While this part of the market is tiny it is growing and tends to increase as affluence increases. These consumers are likely to be attracted to the idea of eating “local food”.

The bulge in the population demographics we call the “baby boomers” will continue to drive consumer spending patterns by their number and wealth and their growing desire to eat “healthy” food. This is both a threat and an opportunity for New Zealand food producers.

1.4.5 Conclusion

Environmental pollution due to nutrient and sediment losses from agricultural production is less of a public concern in the United States than in Europe at this point.
We should watch carefully the form of the US Farm Bill currently being negotiated as this is the key driver of agricultural subsidies. While the trend from production subsidies to environmental subsidies can be expected to continue, the decision to pursue energy self-sufficiency could be more important to New Zealand producers at least in the short to medium term.

1.5 Canada

Environmental pollution from agricultural production is not a large issue in the public mind in Canada. Public opinion is not driving regulation of agricultural practices to a large extent. Many of the farming systems are essentially a replication of the American plains and mid-west, with a shorter growing season. i.e. extensive broadacre grain production for both human consumption and intensive livestock finishing and milk production.

Canada has had the same food safety issues as the US with BSE and bird flu, but again has followed the US lead and this hasn't had a major effect on public opinion and consumption trends.

1.5.1 Environment

While there are controls on nutrient loading of soils by effluent application they are not onerous or limiting to production and don't add unnecessary cost. This tends to reinforce the theory that population density is a key driver of public concern about agricultural production systems.

1.5.2 Regulation

The key agricultural regulations in Canada are not environmental but numerical. They have a vast system of quota limitations on numerous agricultural products, basically supply management to protect the prices received by growers of those products. These quotas are even enforced between provinces.

Quotas do not cover export products like grain or pork where Canadian production is highly competitive with world prices.

1.5.3 Conclusion

Artificial control of production volumes in Canada has reduced pressure to intensify agricultural production which along with the vast distances involved does not appear to make nutrient pollution a pressing issue. The possible exception is likely to be the highly efficient pork industry, but again population density means this is not seen as a pressing issue.

I think we can assume that environmental regulation will not be particularly onerous in the near future.

2. The Science of Nutrient Losses

The science of agricultural pollution through nutrient losses is relatively straight forward if commonly poorly understood. The loss of a portion of available nutrient to waterways when growing food from the soil is an inevitable and natural process. This occurs when food is grown directly for human consumption or indirectly when plants are grown to feed animals. Increasing the potential for plant growth by enhancing soil nutrient availability will also increase the potential for nutrient losses. This in itself is not pollution. Pollution would only be said to have occurred when these losses accumulate, usually in surface or ground water to an unacceptable level as defined by public opinion or other political decision making processes.

Nutrient losses occur by:
1. Leaching. Nutrients are carried with water moving down the soil profile into subsurface drainage.
2. Overland flow. Nutrients are carried via direct overland flow, usually during periods of heavy rain to surface water ways, often along with soil particles, animal dung and urine or applied fertilizer particles.
3. Gaseous losses. Soils and the essential living organisms they contain respire continuously and cycle nutrients. These losses are beyond the scope of this report.

2.1 Economic Drivers

Nutrient losses are a cost to agricultural production as nutrients have to be replaced to maintain future production. It could be assumed that there would be no need to regulate nutrient loading of soils as it is a financial cost to the grower to waste nutrients. Many agricultural crops, particularly vegetables, are gross nutrient feeders and show economic yield response to comparatively high nutrient loading. This combination of the high value of the crop, the growth habit of the plant, and the cost of supplying nutrients, mean that it is often economic to provide growing conditions of luxury nutrient uptake. While it may be currently profitable to grow crops by this system it should be recognized that if technology or systems were devised to maximize use of the nutrients, therefore minimizing losses, then more profit again would be available to the grower.

There is definitely the opportunity for some producers to benefit economically from loading excess nutrients into the environment which can accumulate, usually down stream or in ground water, which can be determined to be pollution. This is the most logical reason for regulation of farming practices.

2.2 Factors affecting potential nutrient loss.

Table 1. Potential for Nutrient Losses

Low	High
low soil moisture	high soil moisture
low rainfall	high rainfall
low nutrient status	high nutrient status
high Cation Exchange capacity	low CEC
flat aspect	sloping aspect
high soil temperature	low soil temperature
actively growing crop	dormant or absent crop

2.2.1 Soil Factors.

The Cation Exchange Capacity (CEC) is a measure of the soils ability to hold key soil nutrients required for crop growth. The CEC of a soil is determined by the volume or depth of the soil and the clay and organic matter content. This can be thought of as the number of sites available to hold key plant nutrients like Calcium, Potassium, and Magnesium.

As a generalization a soil with a high CEC will be able to hold more applied nutrients in a plant available form until crop growth stage requires them. A soil with a lower CEC may require more frequent applications of nutrients to meet crop growth requirements. Applied nutrients above the capacity of the soil particles to hold them are readily leached by movement of water through the soil profile. This is likely to be an issue affecting leaching of nutrient on many free draining soils.

The other side of the coin is that free draining soils usually have high infiltration rates of either applied water or rainfall. This means that the likelihood of overland flow of nutrients and sediments is reduced. Soils with high clay content tend to have low infiltration rates when the soil moisture status is high making overland flow a high risk. This is a major concern when applying animal effluent. Sloping sites are particularly vulnerable to this combination of factors as the soil does not have time to absorb available nutrients before gravity takes hold.

2.2.2 Moisture.

This must be seen as a combination of the amount of:

1. The moisture a soil can physically hold, again mainly a factor of soil volume, clay and organic matter content.
2. How much of that potential water holding capacity is filled at a particular point in time.
3. The quantity of rainfall.
4. The intensity of rainfall events.

The soil can be thought of as a sponge, once saturated then more applied moisture simply flows overtop and straight through. This is very likely to remove nutrients that are weakly held by the soil.

Very intense rainfall is likely to have some level of surface runoff as the infiltration rate of the soil is exceeded. This can carry both recently applied fertilizer particles, animal dung and urine and soil particles which will also carry nutrients with them. All of these factors can contribute to agricultural pollution of surface waterways but this is really dependant on where these elements accumulate. In many high rainfall situations the material is simply flushed out to sea and it is highly unlikely that this would be seen as pollution. Indeed this is the natural way many of the agricultural flood plains were formed. The situation can be significantly different when either rainfall intensity events are localized and there is insufficient flow to flush the material or the surface water flows into an intermediate water body where a much slower flow gives time for the material to accumulate. This situation contributes to algal blooms and Nutrification of lakes and estuarys.

2.2.3 Stage of Plant Growth.

Plant demand for nutrients peak when plant growth is at its maximum. This is usually when soil temperatures are rising in late spring and the plant is initiating its reproductive phase. Most agriculturally useful plants are particularly good at mopping up available plant nutrients at this stage of growth. This means that nutrient leaching losses are less likely at this stage of plant growth. Alternatively when soil temperature is low plant growth slows to a greater or lesser extent the potential for losses is greater. If the plant is harvested and there is no plant growth to utilize nutrients over winter the potential for leaching losses is greatest.

3 Nutrient Application

Nutrients are continually cycled in the soil pool but losses occur from the system as described previously and through harvest of the crop, either mechanically or by animals. All production leaving the property removes plant available nutrients and these nutrients need to be replaced to maintain soil fertility levels and future production from those soil. Timing of nutrient application to suit plant growth requirements will achieve maximum utilization of applied nutrients, maximize profits and minimize nutrients losses.

3.1 Chemical Fertilizers

The relative ease of applying expensive chemical fertilizers usually makes it economic to time their application to the appropriate stage of plant growth. The exception to this is when plant growth is slow but marginal production at that time of the year is particularly valuable. (2.1)
To a large extent, following agronomic best practice will manage nutrient losses to an acceptable level.

3.2 Animal Manures

These are applied to soils, both directly by the animals and by mechanical means from confined animals. This are essentially the same material containing the same quantity of nutrients but the timing of application and the uniformity of spreading creates different nutrient loss issues.
Urine contains the bulk of plant available mineral Nitrogen (N) and Potassium (K) while dung has more slowly available organic N, K as well as phosphate. (P)

3.2.1 Grazing animals

In general grazing animals tend to be a natural and effective way of spreading surplus nutrients. The fact that ruminants have evolved to browse pastures and other forages and the sheer bulk of material they need to ingest means they need to cover a large area to meet their daily needs, frequently defecating and urinating. The nutrient cycling tends to be relatively effective with some notable exceptions:

- Humans have modified the system by breeding both animals and plants to produce more and by adding fertilizer nutrients.
- Animals continue to add nutrients to the soil when soil temperatures are low and plant growth is slow.
- Urine patches from large ruminants have very high nitrate concentrations.

These factors increase the potential for nutrient losses particularly in combination.

Plant and animal breeding programs have tended to move forward in tandem so that higher producing forages are effective scavengers of available nutrients that intensive livestock grazing produce. Amazingly it appears that for the large part of the growing season that soils and plant can make use of the 1000kg of N applied per hectare to a cow urine patch.

Studies of Nitrate leaching to ground water show that it is mainly when soil temperatures drop and plant growth slows dramatically in late autumn/early winter that leaching peaks. This reflects the combination of high soil moisture levels and low plant nutrient requirement.

3.3 Mechanically Applied Animal Manure

The vast majority of animal protein produced world wide is not by grazing animals but by contained feeding systems where the animal is usually but not necessarily housed and all feed and water is brought to the animal. Pork and poultry are produced almost exclusively by this system based on grain feeding. This requires the removal of animal manure and usually the application of this manure back to land. If the manure is not applied back to the land from which the grain was produced then even greater levels of artificial fertilizer will need to be applied to grow future crops. Intensive beef finishing and dairy production in the northern hemisphere is also heavily dependant on grain feeding and animal confinement.

Mechanical application of manure has the advantage that if storage facilities are adequate then timing of manure application can be timed to suit crop growing requirements and the issue of very high N application rates in urine patches can be avoided by effective mixing and spreading systems. The downside is the high energy requirement and expense of carting all the feed to the animals and then carting all the manure away.

There is also a greater risk of poor application system, user error, or adverse climatic events causing associated nutrient pollution. This is a major factor shaping public opinion both in the countries I visited and in New Zealand, more recently along with concern about global warming and methane emissions from ruminants.

The variation between northern hemisphere production systems and those in New Zealand is most pronounced in dairying and to a certain extent beef production.

Table 2. Variation in Mechanical Manure Spreading

	Typical % of manure applied mechanically
North America	100
Europe	75
United Kingdom	60
Southern Ireland	40
New Zealand	6

This simply reflects the time animals are confined and not grazing.
While these figures are reasonable averages and there can be wide variation within systems in each country this does put the issue into perspective.
The fully contained systems based on grain and maize silage "cut and carry" that dominate North American dairying require all of the animals manure to be mechanically collected, stored and applied to land.

3.3.1 Mechanical Effluent Application in New Zealand

On a New Zealand pasture grazing system the dung and urine is only collected during the milking/holding yard part of the day which averages around 1 hour per milking, 2 hours per day, for the 9 month milking season. Reflecting this, our effluent handling systems have traditionally been rudimentary and relatively inefficient "disposal systems" first and foremost. The issue of making best use of the nutrients available has not been a high priority. Traditionally manure is not collected at all during the winter when the majority of our cows are dry prior to calving. Cows are grazing 24 hours a day. This is both a blessing and curse in that manure does not need to be collected and stored over this period but the cows are spreading manure at a time when leaching of nutrients is most likely to occur.

As a consequence of the low volume and winter dry period New Zealand effluent storage systems typically have had very low storage capacity which combined with the rudimentary spreading systems has lead to significant inefficiency and cases of nutrient accumulation or pollution, particularly early in a wet Spring. Resource Consents for effluent application typically specify only 2 days of effluent storage. In practice this means that effluent will inevitably need to be applied to soils at field capacity which in combination with low soil temperatures and low nutrient uptake by plants that the potential for nutrient leaching is increased.

The form of nutrient pollution that is most readily apparent is by either overland flow or by collection of surplus moisture in subsurface "tile or mole" drains, prior to discharge into open waterways. At that time of year there is often little or no soil moisture deficit so extra applied moisture is rapidly lost from the soil system taking soil nutrients with it.
The simple and relatively inexpensive option of increased effluent storage capacity will allow effluent to be stored until there is sufficient soil moisture deficit for nutrient uptake.

Unfortunately more than 90% of the animals dung and urine is still being applied to cold and waterlogged pastures by the animal itself.

3.3.2 Manure/Slurry Application Overseas

North American producers are generally much better at recognizing the value of animal manures as they have much larger quantities of what is usually a dry manure to handle and spread. This is a factor of their relatively dry climate and confined feeding systems. Most manure is manually scraped into storage areas rather than hosed with water as is common in New Zealand. If water is used it is usually in a flood wash system using recycled water after manual solid separation. Electrically driven screw press solid separators produce a relatively low volume of dry fibrous material. This material is often dry enough to be directly applied by manure spreaders.

In Europe and the UK animals are traditionally housed for 6 months and effluent is collected by scraping or under slats. (animals standing on concrete grating over concrete storage) The resulting slurry is higher in dry matter and consequently has higher nutrient concentration than typical NZ effluent, but is generally not as dry as the collected manure in the US.
This slurry needs to be applied in a semi-liquid form. This has traditionally been via a slurry tanker fitted with splash plates which tend to give poor uniformity of spread and a fairly random application rate depending on driver discretion. Couple this with the time required to spread 6 months worth of effluent and the relatively low cost of artificial fertilizers and often the task is probably more one of disposal rather than aiming to make the best use of available nutrients.
Slurry tankers are now being replaced by contractors with umbilical pumping systems to tractor powered dribble bar application. These can achieve reliable application rates, consistent spread pattern and allow great flexibility of coverage area.

Umbilical systems have the advantage of efficient slurry spreading and they allow a large volume of effluent to be applied in a short period of time. However, we need to foresee the end of a long, 6 month winter when rationally all slurry storage capacity will be full and farmers need to empty their tanks. (slurry is still being produced and needs to go somewhere) Naturally the majority of the farmers in a catchment will take advantage of the first dry period to get the contractor in to apply slurry. The potential quantity of nutrient applied to the catchment is vast. If heavy rain follows, as it often can with changeable spring weather, then the potential for massive runoff of applied slurry is significant risk if not a probability.

Table 3. Comparison of UK and NZ effluent volume for a 300 cow farm.

	UK	NZ
Effluent collected Over winter only	60 l/cow * 180 days 3 240 000 l	 0
Effluent collected Over milking season		20 l/cow * 270 days 1 620 000 l

The UK dairy farmer has twice the effluent on hand at the end of winter that a NZ dairy farmer spreads for the whole year. However this does not tell the full story as due to the fact we wash our yards compared to the scraped slurry in the UK, our diluted effluent has typically only 1/3 the nutrient concentration of UK slurry. This means the UK dairy farmer has 6 times nutrient on hand at the end of winter than the NZ farmer spreads for the whole year.

While the sheer volume of slurry creates the potential for disaster with housed animals they do have the distinct advantage of removing animal applied dung and urine from vulnerable soils over winter when plant nutrient uptake is low. This needs to be balanced against the expense of housing the animals, harvesting and carting all their food, storing and applying their waste. This also requires a large quantity of fossil fuel.

4. Regulation of Agricultural Nutrient Application

The aim of nutrient application regulation is to limit/control agricultural pollution or surplus nutrient accumulation, to date usually in open waterways. The issue of diffuse leaching into ground water and its contamination are generally a lesser focus at this stage as these underground water bodies are more difficult to monitor and even more difficult to attribute direct cause and effect. Regulations are virtually always the result of public demand rather than scientific evaluation of the issue of nutrient movement, so it not surprising that regulation is focused on visible nutrient accumulation. In other words, out of sight, out of mind.

The other key question is why regulate the input when your interest is nutrient losses? The answer is this is the easiest option. Measuring nutrient losses is difficult, inaccurate and probably expensive at this stage.

The downside of nutrient application control is that there is little incentive for nutrient loss mitigation strategies or innovative approaches to reduce losses. There also appears to be little incentive for scientific research into techniques to increase production while controlling nutrient losses.

4.1 European Nutrient Regulation

The key policy affecting livestock farming in Europe is the EU Nitrates Directive. This basically outlines concerns with Nutrification of open water ways and tasks each European country with achieving significant improvements in water quality. i.e. reducing levels of bacteria, nitrate and phosphate.

Enthusiasm for taking up the challenge has been mixed among EU members. The wealthy countries where the problem was bad have understandably been more aggressive in advancing the directive, namely Denmark, Belgium and The Netherlands.

4.1.1 The Netherlands

My experience was in The Netherlands where they have directly regulated both the amount of organic manure that can be applied to land to 250 cubic meters per hectare, and the number of livestock that can be carried. This effectively works out to be 1.7 dairy cows/ha. This is a severe limitation to the profitability of dairy farming in The Netherlands.

In practice I observed their waterways were predominantly unfenced, effluent was spread to within 2 meters, and silage pits were also directly adjacent to them. While nutrient losses are theoretically controlled by limiting inputs, they hadn’t taken practical steps to limit point source pollution.

It needs to be taken into account that these are not natural water courses as this was all on reclaimed land below sea level, this water is pumped into the rivers before discharging into the sea.

4.1.2 United Kingdom

In the UK the response to the Nitrates directive has been slower but is now also starting to become a severe limitation to farm practice. The response of regulators has been to declare Nitrate Vulnerable Zones (NVZ’s) in areas assessed to be the highest risk. Initially these were centered around areas with a concentration of intensive pork and poultry production. These housed systems have a large quantity of manure which needs to be spread. The imposition of NVZ’s was an attempt to control organic manure application in these areas and therefore enhance water quality in the catchment.

Farmers were limited to 50 m^3 of 6% DM slurry application/ha, and 250 kg N/ha on pasture, or 210 kg N/ha on arable or forage crops. Cows are calculated to produce 119kg of N in their dung and urine and total production is limited to the 250 kg/ha effectively limiting stocking rate to 2.1 cows/ha. At that time it was widely expected that this N limitation was soon to be reduced from 250kg/ha to 200kg/ha to come into line with other parts of Europe at 1.7 cows/ha.

The time of year that slurry can be applied to land is also to be restricted. The proposal being that all farms must have 6 months slurry storage capacity as calculated by their stock numbers so that no slurry is applied at vulnerable times of the year, late autumn through to early spring. There have been significant subsidies for building slurry storage tanks but this now appears to be finishing. It is now proposed that all stored slurry should be covered to limit gaseous losses into the atmosphere which are a contributor to climate change.

The areas covered by NVZ’s have been expanded to the point where they now cover the majority of the agriculturally productive land in England and all of Ireland. While agricultural production subsidies are no longer a factor in decision making, countryside payments and cross compliance are a powerful incentive to make complying with NVZ regulations essential.

The regulations, while comprehensive, are not always rational. There was no limitation to how much fertilizer N could be applied to pasture while organic manure was strictly controlled. No serious attempt was made to actually measure nutrient losses from farms, the whole system is based on theory. All the incentives were for the farmers to “farm the regulations” rather than actually addressing issues that practically could reduce nutrient losses. There appeared to be little research into reducing nutrient losses and new techniques like the use of Nitrification inhibitors. In effect there is no financial incentive for nutrient loss mitigation.

4.2 Nutrient Regulation in the US and Canada

The essence of nutrient regulation in both the US and Canada is that you have to demonstrate that all nutrients applied, either artificial fertilizer or animal manure, has to be applied according to crop growth requirements as defined by a registered agronomist. This is an eminently sensible principle and appears to work in practice. The overwhelming bulk of animal production is based on grain feeding in confined animal systems.

The sheer bulk of manure produced and reliance on grain means that in many cases the majority of nutrient application to crops is from animal manure. This has lead to a culture where farmers understand the value of animal manure and have the equipment to effectively apply the manure to their crops.

The downside is that this system requires a huge amount of fossil fuel to cart all the feed to the cows, and then cart the manure out to the paddocks. We are now in an era of expensive fuel and now expensive grain due to the demand for biofuel production. This has significantly lifted the cost of production from these systems as compared to grass based animal production. This cost now reflects the large energy requirement of housed animal systems compared to grazing based systems.

In practice we saw efforts to stop agricultural degradation of water ways in the states surrounding Chesapeake Bay. The sheer size of the Bay meant that sediments and nutrient loadings draining from surrounding states accumulate in the bay. This has lead to a considerable dead zone with a reduction in marine life and loss of fishing resources. The focus was on removing stock access to water ways feeding into the catchment and changing cropping systems to reduce overland flow of sediments and nutrients during heavy rainfall.

In Virginia there was no regulatory means to compel farmers to fence water ways so the emphasis was on subsidizing fencing and tree planting riparian strips. This program was administered by our hosts, the Natural Resources Conservation Service. The farmer we spoke to was directly paid to fence his stream and plant trees. He was subsequently paid $73 US/acre/year for the loss of the land from production. This compared very favorably with the $45 US/acre he paid to rent the land in the first place.

The results from the NRCS program was some what piecemeal in that while one farm had taken advantage of the program the farmer directly downstream had not. His cattle had access to the unfenced waterway and were significantly degrading the water quality with both sediment and manure. In this state there was no means to compel the landowner to fence off stock access to waterways. The farmers comment to me was “I have never taken a dime from the government and I never will”, so he was unlikely to fall for the subsidized planting program.

Animal housing and handling systems in Canada very much reflect those in the US but with even more emphasis on housing due to longer colder winters. On the 600 cow dairy farm we visited in Manitoba the cows were fed 30 ton of feed/day. The ration was based on maize silage with added grains and straw. The 600 cows produce 45 ton of manure which had to be shifted and stored each day. This is an energy and labour intensive task.

Manure was applied to land being cropped for maize silage in the late spring. As in the US, the manure must be applied according to crop nutrient requirements as defined by a registered agronomist. The extensive nature of farming on the great plains and low population density mean that nutrient accumulation pollution is not a large problem.

5.0 Conclusions - Implications for New Zealand Agriculture

The purpose of the study was to look at farming systems and agricultural pollution issues around the world and how each country regulates nutrient losses. There is no doubt that New Zealand agricultural systems tend to follow overseas trends to some extent, but our low population base and temperate climate have seen a far greater reliance on low cost, grazed pasture, animal production systems than in the northern hemisphere. Grazing systems tend to have a lot lower energy requirement and consequently lower cost of production than confined animal feeding systems.

While it might appear that New Zealand grazing systems are becoming more intensive and productive they are still much less energy intensive than confined animal production systems that dominate production in the rest of the world and there is only a fraction of the resulting animal manure mechanically applied to land.

The down side of this is that dairy farms have had rudimentary equipment for applying effluent to land and very low storage capacity. The most commonly used application system is a traveling irrigator. They have an uneven spread pattern and a very high instantaneous application rate. They are prone to mechanical breakdown and require regular attention and maintenance to operate. Coupled with operator error this has lead to variable performance and has seen a relatively small amount of poorly handled effluent become a large issue in the collective public mind. I have no doubt that public pressure will force more timely and effective application of dairy effluent in particular.

The logical question is why is the 6% of dairy effluent we apply mechanically such a big issue compared to the other 94% applied by the cows? The answer I have come to is that regulations are virtually always the result of public pressure as opposed to logical scientific analysis. Mechanically applied effluent is more visible and to some extent relatively poorly handled to date.

5.1 Dairy Effluent Application

Public pressure will force much more effective and efficient handling of dairy effluent. Unfortunately I did not discover a magic, new, cheap and efficient system on my study tour that is ideally suited to our environment and production systems. In the short term at least the most promising advances are being trialed and developed here in New Zealand.

A variety of low application rate effluent systems have been scientifically evaluated and commercially installed on both new and existing dairy farms. The principle being to match effluent application rate and depth to the ability of the soil to absorb the applied nutrient load. In conjunction with this there is growing acceptance of the need to have significant effluent storage capacity so that effluent does not need to be applied to soils when they are at or near field capacity. (water-logged)

To an extent we are following the lead of unregulated food production overseas where they fully recognize the nutrient value of animal manures to enhancing crop performance. Applying manures to maximize nutrient value to the growing crop also tends to minimize nutrient losses or pollution.

It was noticeable that traditionally regulated farming systems like dairying in the UK were much slower to embrace more efficient nutrient application than unregulated industries like pork and poultry. The highly prescriptive nature of effluent application regulation as a cross compliance factor for the single farm payment has meant farmers are simply focused on following the rules rather than trying to be innovative and more efficient. The telling point is that they still see effluent as a disposal issue.

I believe this is the crucial decision that regulators in New Zealand have to make. We all want to see more effective effluent application, but what is the best means to achieve this? It is very simple to follow the prescriptive lead of the Europeans but this tends to be a way of limiting the damage rather than making a significant improvement in water quality.

In New Zealand the new low application rate systems have been developed by a combination of farmer trial, industry and state funded research and commercial entrepreneurs. This system of delivering innovative tools to our agricultural production system works because the requirement for the new technology is identified on farm, not by the regulator. This only happens because the farm operates in environment where the farmer has wide discretion over the way he chooses to manage the issue at hand. If there was a long list of rules over how that particular product must be handled then the farmers attention is focused just on following the rules, particularly if there is a financial penalty for non-compliance.

Regulatory agencies have a natural tendency for caution, and when in doubt drafting a new rule to cover the unexpected event. There is no doubt that most rules are drafted to cover the small minority within any population that do a bad job, and I certainly wouldn't argue that they should get off without punishment. My concern is that the simple answer is to stipulate that the consent holder should follow steps a, b and c. The problem is that we have now placed conditions on all consent holders, not just the miscreant minority. Not only does this remove the incentive for innovation but it limits the ability of the farmer to manage his resources to best effect. For example - make allowances for climatic variability. It also has the effect of reinforcing the disposal mentality.

If our shared goal is more effective effluent application, and we recognise the need to maintain an innovative attitude to achieving our goal, we need to regulate for environmental outcomes not behavior. It is currently difficult to accurately measure those outcomes from individual farms but this needs to be the focus of our attention. We can now do far more regular monitoring of surface water bodies both above and below individual farms. This should identify nutrient losses via either overland flow or subsurface tile and mole drains due to ineffective effluent application.

Monitoring of leaching into ground water is more difficult. The nature of nutrient movement beneath the plant rooting zone is a matter of estimation rather than measurement to a large extent. Nutrient and bacteria levels of subsurface aquifers can be routinely monitored but it is difficult to accurately say where the nutrients came from. We don't know enough about the movement of underground water to attribute nutrient loadings to specific properties let alone events.

5.2 Options to limit nutrient losses under grazed pasture

While public concern about nutrient losses under normal pasture grazing is not currently as great as that for dairy effluent, it is reasonable to expect that this is likely to be a greater focus in the future. Mechanically applied dairy effluent is less than 10% of the animals yearly dung and urine production under a traditional grazed pasture system. (This will increase if feed pads or housing are added to the system) The 90% plus of dung and urine applied by the cows themselves has the potential to be a greater source of nutrient loss. As discussed (section 3.2) research has shown that most leaching of nutrients into ground water occurs in late autumn and early winter when soil temperatures are dropping, plant growth slows, and so does nutrient uptake. Under our grazing systems stock are still depositing dung and urine on to pastures.

5.2.1 Livestock housing

The alternative is to follow the European system and house livestock over the period of the year, store the effluent and apply to soils in the spring when soil temperatures are rising. As discussed there is a risk of applying such a lot of nutrient at one time, and also a large financial cost of building and maintaining the shed. There is also the cost of carting, storing and feeding out to the housed animals and then shifting, storing and applying the effluent. From an environmental point of view this can be seen as replacing potential for nutrient leaching by using considerably more fossil fuel.

5.2.2 Nitrification inhibitors

A more promising strategy is the use of Nitrification inhibitors to slow the soil process which transforms Ammonia into Nitrate. Ammonia is held much more strongly in the soil than Nitrate. While there is still some debate about the level of response on different soils and in different climates this does show significant promise both at reducing nutrient leaching, improving spring grass growth, and reducing green-house gas emissions from pastures/soils.

It is significant that this technology has been commercialized here in New Zealand. Nitrification inhibitors were developed in the northern hemisphere but I found them to be unused under animal grazing. Perhaps this is because the response of their regulators to Nutrification of ground water was simply to limit stocking rate.

5.2.3 Riparian management

The aim of riparian management is to limit the movement of nutrient and sediments from the paddock to open water ways. The most significant benefit arises from livestock fencing to remove direct stock access from water ways. Significant sediment is deposited into streams from bank erosion where stock have access to open water ways. This will also reduce the nutrients carried by the sediments as well as direct animal deposition into the water way.

The case for excluding animals, particularly cattle and deer from lowland water ways is overwhelming. For intensive dairying and in particular, stream bank damage can be acute, and the cost of fencing is very low. This situation is reversed in the catchment head waters where the combination of low intensity grazing pressure and less vulnerable stream banks would see little gain from the massive cost of fencing numerous small tributaries. Regulation to compel riparian fencing needs to take this into account.

The case for compulsory stream margin size and planting trees, shrubs or grasses is less clear. Once stock are excluded from the water way then it is assumed the purpose of the vegetation is to filter nutrients and sediments from overland flow into the water way. On a sloping site on soils with low infiltration rates this seems a soundly based assumption. My concern is that once these nutrients are filtered then logically they will encourage growth in the riparian zone, either long grass, or tree biomass. In the case of grass this will grow and eventually die releasing the nutrients back into the riparian zone and logically eventually the waterway. This is probably also the case with tree leaves and small branches. Over time the riparian zone slows the passage of nutrients into the water way rather than stopping the process. Removal of biomass from the riparian zone is the logical response. This could be achieved by either removing wood, mechanical harvesting of grass or even well managed grazing if deposition of nutrients can be limited.

There are other environmental benefits from riparian planting of trees and shrub. The shading of the stream will reduce aquatic weed growth which reduces the need for mechanical cleaning. Shading can also reduce the water temperature in summer which can provide a better environment for fish and insects, as well as general habitat enhancement for bird life.

5.3 Future Nutrient Regulation in New Zealand

Observing the trends in regulation of agriculture in the northern hemisphere left me with the distinct impression that regulations did not come about after careful scientific analysis of the outcomes of farming systems. They are almost invariably the result of a “knee jerk” reaction by an elected politician to a public outcry. There doesn’t seem to be any need to prove that the regulation is entirely justified. Once the public perception is strong enough then the argument seems to be “you can never be too safe” with either food safety or the environment.

My assumption leaving New Zealand was that pressure from our overseas customers would force environmental compliance on us, like the “clean streams accord”. I am now firmly of the belief that internal public pressure is far more likely to force unwelcome change on us. I am not confident that reasoned argument alone will suffice to win the debate. The public now perceive intensive dairying to be a land use that results in a bad outcome for the environment and will likely favour regulation as “better safe than sorry”.

5.3.1 Shaping the public debate

As a permitted land use, farming to date has not needed to monitor its environmental outcome. Indeed our industry has seen itself as “carrying the country”. I think we are now seeing a distinct movement in public attitude towards farming, focused on dairying at the present. Public pressure over water resources in Canterbury, Nutrification of lakes in the central north island and water way pollution in Southland are shaping the formation of future nutrient regulation. Publicly elected regional councilors will inevitably reflect public concerns.

Until recently we have been able to manage our farming systems until the regulating body has shown that our practices are having an adverse outcome. This is unlikely to continue. The burden of truth will go back on to the farmer who will have to prove that his farming system has a good environmental outcome.

5.3.2 Environmental Monitoring

Our best defense against irrational regulation will be detailed monitoring of environmental outputs from our farming system. Who ever has the best information has the best chance of winning the argument. This needs to be us. Considering the value of the investment in our businesses it would seem prudent to have the best information to evaluate the potential risk to our farming system. While we may see this as just another cost to our farming system I would suggest that in the case of dairying we are already paying for all the environmental testing carried out by the regional council specific to our property.

The level of testing should be to a level so that we have better information than anyone else as to the output from our system. To be seen as meaningful this information needs to be unbiased and made available to the regulating body. This may require the testing to be independent or audited in some form. I am confidant this would not need to be any more expensive than what we are currently charged.

There would be other important benefits to farmer initiated environmental monitoring. If a farmer was aware of significant nutrient loss he will be more likely to look for ways to change the management system to avoid the losses as they are a financial cost to him. He will also be more likely to take a proactive approach to environmental output than the current system imposes. This would encourage the spirit of innovation that has served agriculture so well to date, to encompass the environment as well as production.

5.3.3 Nutrient Modeling

The movement of nutrients through a farming system has been modeled by the AgResearch computer program Overseer. This is used to predict nutrient requirements and help provide fertilizer recommendations to farmers. It also predicts nutrient losses from the system.

The measurement of nutrient losses through the soil profile by Soil Lysometers at Lincoln University has shown that nutrient leaching losses are broadly in line with that predicted by Overseer. The extensive use of this type of nutrient movement modeling as an accurate predictor of actual on farm losses will need to be backed up by research and measurement to have public credibility.

5.3.4 Enhancement of biodiversity and habitat.

My logic for seeing enhancement of biodiversity and habitat as a good future path for New Zealand agriculture is more subjective than objective. While it is important that we have good quantitative information about our environmental impact there is more to winning the argument. Some members of the public may even be reluctant to accept the best scientific information available when considering their concerns about agriculture and pollution.

I found two farms in the UK with fairly detailed information on the wildlife on their property, mostly birds. This consisted of visual appraisal and the occasional notes while farm staff were carrying out their normal tasks. What interested me was the change in attitude of the staff and management. They took a genuine interest and seemed to get considerable satisfaction from the process. By studying the habits of birdlife they found ways to modify their farming system which enhanced their habitat:

- Not planting the corners of grain crops provided nest sites for skylarks
- Leaving difficult corners of paddocks uncultivated as general cover.
- Planting small areas of maize and leaving unharvested for pheasants

While the desire to provide suitable birds for hunting purposes was no doubt part of the purpose there were definitely good outcomes for many other species. I found it fascinating the level of understanding of how their farming practices affected various species of wildlife. Crucially they were able to monitor and achieve outcomes at next to no financial cost or lost production. In fact farm management and staff seemed to find their jobs more satisfying.

I think we have considerable opportunity to enhance wildlife habitats in marginal areas of our farms without significantly compromising production. This may entail both specific plantings and pest control.

It would be a relatively simple process to keep informal notes of where and when wildlife are present on the farm. This could build up a numerical record of our success at habitat enhancement over time which would be useful for trialing new systems and possibly convincing doubters of the integrity of our farming system.

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