THE POTENTIAL FOR SOIL CARBON SEQUESTRATION, BUT WITH A FULL GREENHOUSE GAS BUDGET

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This paper addresses the potential for soil carbon (C) content to be increased, i.e. C sequestered. However, it does so while making a realistic assessment of what will deliver a net increase above that resulting from current land management practices, and taking into account the effects of changed management on all the land-related greenhouse gases (GHGs): carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).

Soil C sequestration only makes a contribution to climate change mitigation if the change in land management causes a net transfer of C from atmospheric CO_2 to the soil, thus slowing the increase in atmospheric concentration of CO_2. Even then it must be born in mind that (1) the amount of C sequestered in any soil under any management practice is finite – the increase in soil organic C content ceases as a new equilibrium value is approached, (2) the process is reversible, (3) fluxes of other GHGs may be either increased or decreased by the change in practice. For example, evidence from the authors' and other research suggests that changing from conventional ploughing to no-till or min-till systems can reduce the loss of C via the mineralization of soil organic matter or even increase soil C content, but is likely to increase N_2O emissions. Because N_2O is such a powerful GHG, increases in its emission at least partially offsets any climate change benefits of sequestering some C.

Thus to assess whether or not particular land management practices that increase soil C genuinely mitigate climate change requires a full GHG budget to be made. We conclude that relatively few changes in land management will genuinely contribute to the mitigation of climate change. Indeed, the worldwide trend of clearing grassland and forest and draining wetlands is releasing C to the atmosphere and worsening climate change. Climate change mitigation would be best served by focusing on slowing these trends rather than attempting to quantify small and often questionable increases in soil C through changes in agricultural practice.

THE ENERGY BALANCE AND ECONOMIC OPPORTUNITIES FOR BIOCHAR IN AN EMISSIONS TRADING SCHEME

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Human induced carbon emissions are in the order 25 billion tons (gigatons-GT) carbon dioxide (CO_2) annually. Current atmospheric CO_2 levels are approximately 400 ppm or 3,200 GT CO_2 (1 ppm CO_2 equates to 8 GT CO_2 in the atmosphere) exceeding what are generally regarded as safe limits by 400 GT.

If we accept that levels of CO_2 in excess of 400 ppm in the atmosphere pose a threat to our environment, then the dual challenges that face us are i) to remove CO_2 from the atmosphere and stabilize it against re-release, and ii) to reduce the rate of release of CO_2 to the atmosphere. In both cases GT scale interventions are needed.

The potential contribution of biochar produced by the thermal conversion of biomass by pyrolysis, combined with the production of bioenergy products is both regionally and globally significant at the GT scale.

At current levels of vegetation growth globally the global hypothetical annual C stabilization potential, is more than 40 GT CO_2. Whilst this scale of C stabilization clearly is not a feasible, or sensible, target it does bound the scale of the opportunity. Lehmann (2007) demonstrated 0.6 Gigaton (GT) CO_2 could be sequestered as biochar annually in the US by any one of the following (1) utilization of 3.5 tons per hectare of residues or thinning from US forest land for timber production; (2) sustainable harvest of fast-growing vegetation on all idle cropland in the US; or (3) return of bio-char from 5.8 tons crop residues per hectare of all US cropland.

Key to delivering Gigaton scale annual removals of CO_2 from the atmosphere will be the establishment of robust, reproducible configurations of feedstock, pyrolysis technology energy and biochar products that can be tested and supported through the development of methodologies for emissions verification and certification that meet the requirements of both compliant and non-compliant markets for carbon emissions.

This presentation will examine such configurations and consider the opportunities for C trading in both compliant and non-compliant carbon markets.

INTERNATIONAL STANDARDS IN GHG FOOTPRINTING AND NZ' S RESPONSE

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Consumer and retailer demands in some of New Zealand's key markets are driving substantial changes in the value chains that New Zealand's primary industries participate in. There is an increasing expectation that products have sustainability credentials, and that these can be verified. In particular, there is increasing pressure for information on the greenhouse gas (GHG) intensity of products throughout the product life-cycle. This has led to growing interest in the development of standards for calculating and communicating GHG footprint information (also known as carbon footprinting).

Currently there are three main international processes that have either developed or are developing standards for GHG footprinting. These are the:

- DEFRA/British Standards/Carbon Trust standard (PAS 2050);
- International Standards Organisation (ISO) development of international standards for GHG footprint quantification and communication; and
- World Resources Institute/World Business Council for Sustainable Development (WRI) development of an international standard for product accounting of GHG emissions.

There are a number of tensions between all three processes. The ultimate objective for eventual 'users' of GHG footprinting, however, will be to ensure that these international processes are largely consistent with each other and can be practically and fairly applied in a scientifically robust manner across products, producers and countries. To ensure that this happens, New Zealand will need to maintain an active and constructive role in standard-making ensuring comprehensive input from industry, research and government. Example of areas where input will be needed is how land use change will be considered at product level and what allocation rules will be favoured in each international standard.

The New Zealand GHG Footprint Strategy for the Land-Based Primary Sector is one response that seeks to ensure that New Zealand can be influential in the development of fair and practical international standards for GHG footprinting, and in particular is seen as a leader and expert in applying these techniques to primary products.

QUANTIFYING THE IMPACT OF CARBON TRADING ON FARM BUSINESSES – HOW TO INTEGRATE CARBON MANAGEMENT WITH AGRICULTURAL PRODUCTION SYSTEMS

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Carbon Farming has become a buzz word in NZ forestry and agriculture with reports of both great opportunities and significant financial penalties likely. The truth is likely to be somewhere in between. The NZ Landcare Trust and NZ Farm Forestry Association are an integral part of the NZ rural community and have partnered with P.A. Handford and Associates and Greenco, under a MAF sustainable farming fund grant, to help farmers, agribusiness managers and farm foresters to understand carbon farming, and how it can be integrated with current agricultural production systems.

Understanding of the carbon cycle on pastoral farming enterprises, greenhouse gas emissions, carbon footprinting and the requirements of Kyoto protocol are improving. What is less clear is how these issues might impact or fit within the farm business and how government regulations and afforestation programs will affect profitability.

This paper will outline the basic concepts of the carbon cycle on-farm and show how, through case studies, credits and liabilities might be managed with the integration of two government afforestation programs, the Permanent Forest Sink Initiative (PFSI) and the Afforestation Grant Scheme (AGS) and their relationship to the current Emissions Trading Scheme.

ON-FARM BIOFILTERS OFFER REDUCED METHANE EMISSIONS TO PARTLY OFFSET THE ENVIRONMENTAL FOOTPRINT

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Methane (CH_4) represents 35% of New Zealand's total greenhouse gas emissions (MfE, 2007). It is mainly produced in the rumen of grazing animals, but effluent ponds and landfills are also important sources. Despite the large contribution from enteric fermentation, no viable mitigation options are currently available apart from reducing livestock numbers, which would have a large negative impact on the economy and global food production. One option could be to "treat" the CH_4 (i.e. oxidise it to carbon dioxide and water vapour) after it has been emitted by the animal, or from an effluent pond. The recent trend on some dairy farms to temporally house cows in herd homes or barns concentrates the CH_4 emissions from animals and their waste in the surrounding air, which makes treatment more feasible. Treating CH_4 emissions from animal waste systems (e.g., effluent ponds) is potentially easier because the CH_4 source is localised, concentrations are much higher and flow rates lower than in animal houses.

We aim to develop CH_4 biofilters containing soil methanotrophs to "filter" CH_4 emitted from housed ruminants and effluent storage areas. This is based on our recent research showing that forest and pasture soils differ in their capacity to oxidise atmospheric CH_4 due to different methanotroph populations. These populations are being tested in a unique system of automatically monitored chambers that can resolve extremely low fluxes of CH_4 and N_2O. In this paper we quantify CH_4 oxidation rates of forest and pasture soils in response to varying CH_4 concentrations. Results to date indicate that Type II methanotrophs (predominant in forest soils) become progressively saturated as CH_4 concentrations rise, and this is shown by a decrease in uptake efficiency as CH_4 concentration increased. In contrast, the increase in CH_4 oxidation was almost always proportional to the increase in CH_4 concentration for Type I methanotrophs that predominate in pasture soils. There was no evidence of substrate saturation, which was reflected in constant uptake efficiency over the range of CH_4 concentrations measured. The resilience of methanotrophs is also being tested using soil-perlite mixtures, as an on-farm biofilter will need to operate under aerobic conditions in all weathers and across a wide range of CH_4 concentrations with minimal maintenance. In our most recent experiment, we have found that soil sampled from above a landfill covered in 2000 is able to oxidise very high CH_4 concentrations (e.g., >3000 ppm), suggesting the methanotrophs in this soil could be useful in capturing the CH_4 emissions from an effluent pond.

SOURCES AND MANAGEMENT OPTIONS TO REDUCE NITROUS OXIDE EMISSIONS FROM DAIRY FARMS

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Animal excreta deposited onto soil during grazing is the single largest source of nitrous oxide (N_2O) in New Zealand, producing over 80% of the direct and indirect N_2O emissions from agriculture. N_2O gas is formed in soils during the microbiological processes of nitrification and denitrification. These processes are affected by many soil and climatic factors (e.g. soil moisture and nitrate concentration). N_2O emissions are generally highest in winter or spring when soil is wet. There is a range of possible management options that can reduce N_2O emissions from New Zealand dairy farms.

These mitigation options include:

- Using stand-off/feed pads or herd homes to keep animals off paddocks during wet winter conditions. Animal excreta is collected from stand-off pads or herd homes and applied evenly to pasture in summer or early autumn when conditions are likely to be less conducive to N_2O production.
- Using low-N feed supplements such as maize silage to lower the amount of N excreted in urine. Urine is the highest risk source of N loss from excreta.
- Using a nitrification inhibitor that inhibits conversion of soil ammonium to nitrate, which reduces nitrate accumulation in soil.
- Applying fertilizers and farm dairy effluent at an optimum N level and limiting the amount of N fertiliser and dairy farm effluent applied during late-autumn/winter when soil is wet.

Some of these options are in use, whilst others require further research and development. The effectiveness and cost of these options differ and the preferred option, or options, would vary between individual farms depending on economics and practicality. The use of multiple options may achieve larger reduction of N_2O emissions, but the individual effects of each option may not necessarily be cumulative. Most of these options also reduce N leaching, which is an indirect source of N_2O emissions. Care must also be taken to avoid "pollution swapping" as some of these N_2O mitigation systems can result in higher ammonia (NH_3) losses that need to be controlled. Quantifying and reducing N_2O emissions from whole farm systems is also required.

In this presentation we will discuss results from studies involving some of these options and evaluate their cost effectiveness. We will also discuss responses from the industry and farmers to those N_2O mitigation practices and technologies that have been developed.

PASTURE LEAVES EMIT N_2O: GHG MITIGATION OPPORTUNITY?

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Nitrous oxide (N_2O) is an important part of the N.Z. GHG inventory and significant reductions in emissions will require the development of new mitigation tools. Current N_2O mitigation technologies target soil microbial processes. Our preliminary experiments suggests that the leaves of pasture plants – or more correctly ammonia oxidising bacteria (AOB) associated with these leaves, particularly in high ammonia (NH_3) environments - are potentially a significant source of N_2O and thus provide an alternative target for mitigation.

Our evidence for a canopy source of N_2O from AOB is 1) the presence of AOB on leaves determined by molecular detection of AOB genes from the DNA extracted from pasture leaves exposed to high NH_3 environments 2) direct measurement of N_2O emissions from leaves when exposed to a high NH_3 environment, and 3) inference from field chamber measurements.

Our inference from field chamber measurements has this logic: when urine is applied to a pasture, N_2O emissions are stimulated as a consequence of increased nitrification; this nitrification takes perhaps 4-7 days to occur; however, increased emissions of N_2O are frequently observed almost immediately urine is applied. No explanation has been found for this emission; we are proposing that the emission comes from AOB exposed to the high NH_3 environment created by the urine application. We have measured NH_3 induced N_2O emissions of 25 µg N_2O-N/ g leaf DM /day on detached leaves in the laboratory; if we assume these might occur in the high NH_3 environment created by a urine patch we can roughly scale this emission to give us an annual value of 1-2 kg N_2O-N/ha per year from a moderately fertile pasture. Estimates of annual emissions from pasture (currently assumed to be from the soil) are in the range 1-5 kg N_2O-N/ha per year, hence a large percentage of total pasture emissions could be from AOB on/in plant leaves.

We have measured different AOB infection rates and different rates of N_2O emission among pasture species raising the possibility that emissions might be manipulated through pasture species selection. This, together with targeting AOB on leaves directly; present two potential mitigation technologies which could be developed to help N.Z. meet its Kyoto Protocol obligations.

DOES THE ADDITION OF CHARCOAL AS A CARBON SEQUESTRATION STRATEGY COMPROMISE A SOIL'S BIOPHYSICAL FUNCTIONS?

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The sequestering of carbon through the addition of charcoal to agricultural and horticultural soils is a strategy that has recently gained interest as a way to mitigate climate change. To assess the practical feasibility of this strategy the impact of the addition of charcoal on soil biophysical properties needs to be understood. As yet, only limited field trials have been conducted to investigate this. The objective of this study is to measure the effects of the addition of charcoal to soil on a number of biophysical soil properties in an integrated research apple orchard in Havelock North.

Charcoal was added at a rate of 2 kg/m^2 (2 tonnes/ha), and mixed with the top 0.1 m of the soil. This was done at three sampling sites within a single tree row. Three separate sampling sites in the same tree row, but without the addition of charcoal served as the control. The 6 sites had the same soil type and climate, and had received the same orchard management. The charcoal was added on July 10, 2008 and samples to a depth of 0.1 m were taken on December 8, 2008.

We compared the microbial biomass, basal respiration and hot-water extractable carbon (HWC) of the soil with and without charcoal as a biological property. Using quantitative polymerase chain reaction (qPCR) we tested for the presence of microbial groups and genes associated with methane metabolism as indicators of any change in microbial diversity resulting from the addition of charcoal. As a soil physical property we analysed if the addition of charcoal had an affect on soil water repellency.

Our preliminary analysis showed that the addition of charcoal resulted in no significant change to microbial biomass, basal respiration or HWC. The qPCR analysis showed that there was also no significant change to biodiversity. The soil water repellency has not been measured yet. So far, the results of this experiment suggest that the addition of charcoal to the soil of an integrated apple orchard has no effect on generic biological properties.

Keywords: Basal respiration, microbial biomass, hot water carbon, qPCR, carbon sequestration.

DENITRIFICATION RATES ON AMENDED DAIRY PASTURE PLOTS: CAN INSITU DENITRIFICATION BE MANIPULATED TO CONTROL N LOSS?

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Denitrification is the only natural process by which applied N fertiliser can be converted back to inert atmospheric nitrogen (N_2). Efforts to decrease nitrate concentration in groundwater (e.g. denitrification walls) have shown promise. However, evidence that denitrification can be manipulated in soil (prior to nitrate leaching to groundwater) is lacking. Denitrification is a spatially variable process dependent on soil microsites that are anaerobic. We hypothesised that by increasing the number of microsites in the soil, denitrification potential would be enhanced on a paddock scale.

Topsoil of a well drained Allophanic (Horotiu) soil under typical dairy farming conditions was amended (five replicated plots, each 5 by 5 m) with two types of particulate organic carbon (sawdust and coarse woody mulch). Disturbed control (topsoil disturbed in a similar manner to amended plots, but no organic matter incorporated) and undisturbed pasture control treatments were also included in a randomized complete block design. Denitrification rate (via acetylene block technique), denitrifying enzyme activity (DEA), and soil nitrate and ammonium were measured monthly, beginning in February 2008. Soil biological properties (microbial biomass carbon and nitrogen, and N mineralisation rate) were also measured every 3 months.

Initial results indicate that DEA in the organic amended treatments was significantly greater than the unamended control treatments (1.5 –2.5 times on a gravimetric basis). The coarse woody mulch showed the greatest increase in DEA. Despite significant differences in DEA, no detectable differences in the cumulative denitrification rate were detected, in part because denitrification rate of amended treatments in some months was greatest whereas in other months unamended treatments had the greater denitrification rate. Soil chemical and biological properties differed both seasonally and by treatment. Microbial biomass was significantly higher in both amended treatments. Extractable soil nitrate-N and N mineralisation were generally significantly lower in the sawdust treatment (but not the coarse woody mulch), suggesting immobilisation of N by the sawdust amendment.

Although we did not detect a difference in total N denitrified in the amended Horotiu treatments, the DEA, soil nitrate, and temporal patterns in denitrification rate suggest that during periods of peak denitrifying activity – high soil water content and high N availability (when leaching of soil N is likely), denitrification rate may be able to be manipulated to reduce N leaching. Our focus in the next phase of the project will be to quantify denitrification rates during these peak periods of denitrification.

USE OF REFLECTANCE SENSORS TO OPTIMISE NUTRIENT MANAGEMENT

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There is considerable interest in using sensors which measure the light reflectance from crops in order to work out their fertiliser requirements and therefore optimise fertiliser use. These sensors operate in the (VIS) visible spectrum and the (NIR) near infrared. The reflectance properties give an indication of crop biomass which can be calibrated against tiller number or GAI in the case of cereals or simply biomass in maize.

This paper explains some of the physics behind these sensors and the types of vegetative indices used to describe the crop in order that fertiliser optimisation can be achieved.

PRACTICAL USES OF SMART TECHNOLOGIES

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There are a number of technologies available to farmers to aid crop management. These include, electromagnetic EM sampling of the soil, sampling for fertility, yield mapping and protein mapping. Of recent interest is a family of sensor used to measure the reflectance from the crop canopy. These sensors can be used to make decisions about crop fertiliser requirements and increase crop yield and maximise the utilization of fertiliser, with a particular focus on Nitrogen application.

To some extent the measurement process and producing information is the easier part of the process. What farmers sometimes have difficulty with is how to turn this data into management information that is of economic benefit to the farm business. Results from field scale practical on farm trials and general use indicate that these sensing technologies can be used to increase yield and profit while reducing nitrate leaching from winter cereals.

Methods used to calculate nitrogen requirements utilising this technology are presented.

CROP SENSORS
– TOOLS FOR BETTER NITROGEN MANAGEMENT?

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This paper is an updated version of that presented at the LandWise conference held in Gisborne in May 2008. The results presented are from a Grains Research Development Corporation (GRDC) funded project (SFS 00015) on disease and canopy management in cereals taking place in southern Australia and an agribusiness extension project on canopy management which took place in NSW. These are joint projects linking the Australian farmer groups with the New Zealand levy organisation Foundation for Arable Research (FAR) and in northern NSW Agvance Agriculture and the Eastern Farming Systems group.

This work has lead to an investment in crop sensor research in New Zealand which has just commenced, initial results of which are also presented in this paper.

- Crop sensors, measuring the reflectance from the cereal crop canopy, may offer a better opportunity of matching crop needs to nitrogen input, when combined with GPS technology.
- Early trials in Australian wheat crops have shown good correlations between crop structure scores, such as tillers and crop reflectance readings NDVI (normalised difference vegetative index) and nitrogen uptake when assessed at early stem elongation (GS30-31).
- At the same growth stage, initial work comparing the reflectance of nitrogen rich strips (plots receiving nitrogen at planting) with zero N control plots has revealed that these reference points could be a guide to the likelihood of a nitrogen response.
- Trial work has also demonstrated that crop sensors (GreenSeeker® in these trials) could have use as a research tool to quantify differences in green leaf retention during flowering and grain fill.
- In initial FAR work carried out in New Zealand, NDVI measurements taken with the GreenSeeker® at late booting (GS45-49) gave very good correlations to final yield taken three months later at harvest. In work in NSW (Australia), the correlations between NDVI readings at flowering and final yield have been better than dry matter assessment taken at the same time.
- There are a number of issues that need to be clarified if NDVI readings are to be used commercially as a basis for nitrogen application, for example the documented lack of correlation to canopy size above a Green Area Index (GAI) of three, the possible need for different NDVI algorithms for different varieties and the ground truthing to ensure that variations in canopy biomass are linked to nitrogen.
- However the use of crop sensor information such as NDVI, combined with GPS could be a powerful tool for applying variable rate nitrogen on the "visual" basis of crop need.

AMAIZEN - A YEILD AND N FERTILISER FORECASTING TOOL FOR MAIZE SILAGE AND GRAIN CROPS

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Maize is widely grown as both grain and silage for a range of livestock production (dairy, poultry, swine, cattle etc). Nitrogen (N) is the nutrient most required by maize thus optimising N management is important for getting best crop production and avoiding environmental impact.

AmaizeN uses a crop model based on radiation interception driven by sowing location, sowing time, hybrid and population. The crop model is coupled with a soil mineralisation and drainage model to predict N requirements and leaching losses. Deep soil N testing (to 60 cm) of mineral N after cultivation is required to run the soil model.

AmaizeN has been validated over three seasons in 16 commercial crops across a wide range of weather/soil conditions that received different N-fertiliser treatments. Predicted maize yield and the end-of-season soil mineral N content matched well with the actual measurements from experimental crops. In most cases, the recommended N-fertiliser strategy was more cost-effective than farmers' practice.

The user interface has been tested and designed by maize growers and industry consultants. The "Lite" version of AmaizeN was released in spring 2008 for industry use.

YIELD AND QUALITY RESPONSE OF WHEAT TO NITROGEN

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With the recent rapid increase in the price of nitrogen (N) fertiliser arable growers are asking whether the economic optimum N fertiliser rate has decreased. For milling wheat the premium paid for wheat with a higher protein content also needs to be considered.

The Foundation for Arable Research has conducted 6 N rate and timing trials on Autumn sown irrigated milling wheat over the past 4 seasons. Data from these trials has been reanalysed with current grain and N prices. The optimum N rate and timing for yield, protein and margin over N cost is calculated.

In 5 trials the N rate that optimised yield also gave the highest margin over N cost. Treatments with the highest proportion of N fertiliser at early stem extension gave a higher yield compared with treatments with a later split application at ear emergence. In contrast, the highest protein content was from the treatments with a later split N application.

EFFECTS OF PASTURE CULTIVATION ON SOIL PHOSPHORUS STRATIFICATION AND SUBSEQUENT FERTILISER REQUIREMENTS

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Conventional cultivation is commonly used on dairy farms for periodic pasture renewal, which may include growing a summer forage crop followed by autumn regrassing. Mouldboard ploughing inverts the soil and redistributes phosphorus (P) down the soil profile, decreasing surface soil P concentrations and perhaps reducing potential P runoff risk. However, a disadvantage of mouldboard ploughing to 15-20 cm depth is the potential for decreasing the pool of available P in the soil testing depth (0-7.5 cm) for pasture soil. A recent doubling in the cost of single superphosphate has highlighted the importance of quantifying the impact of cultivation on soil P status and subsequent pasture growth. The objective of this study was to assess the impact that pasture cultivation, growing a summer turnip forage crop and regrassing have on soil Olsen P stratification, potential P runoff risk and estimated fertiliser P requirements of the new pasture soil.

Long-term pasture (*LP*) treatment plots were compared to adjacent plots that were cultivated, used as a summer turnip forage crop for dairy cows and then regrassed (*CP*). The *CP* treatment received an additional 31 kg P/ha as single superphosphate during cultivation. After regrassing, both treatments were grazed by dairy cows as part of the farm's normal grazing round. Soil samples were collected at four depths (0-2.5, 2.5-7.5, 7.5-15 and 15-22.5 cm) 18 months after the *CP* treatment plots were sown into new grass.

Soil Olsen P values for the *CP* treatment were lower in 0-2.5 and 2.5-7.5 cm soil depths but higher in the two deeper sampling depths, compared to the *LP* treatment. At the shallowest depth (0-2.5 cm), the average Olsen P value for the *CP* treatment was 31 mg P/kg, which was 33% lower than the *LP* treatment average of 47 mg P/kg. This result demonstrates that cultivation substantially reduced the potential P runoff risk, as predicted from Olsen P, of the *CP* treatment soil.

Soil Olsen P in the 0-7.5 cm soil depth was 26 mg P/kg for the *CP* treatment, which was 11 mg P/kg lower than the *LP* treatment value. This difference equates to a capital fertiliser requirement of 55 kg P/ha (Overseer Nutrient Budgets 2008). This result demonstrates the need, particularly during a period of rapidly increasing fertiliser costs, to assess the potential advantages of using shallower cultivation methods to minimise future fertiliser P requirements.

EFFECTIVENESS OF SPACE-PLANTED TREES FOR CONTROLLING SOIL SLIPPAGE ON PASTORAL HILL COUNTRY

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Spaced trees, predominantly species of *Populus* (poplar) and *Salix* (willow), but also species of other genera (e.g. *Eucalyptus*), have been grown to stabilise erodible pastoral hillslopes in New Zealand for more than 40 years. *Populus* and *Salix* spp. are most suitable for relatively moist sites whereas *Eucalyptus* spp. are more tolerant of summer-dry sites. Despite the widespread use of these tree species, there is negligible quantification of the effectiveness of different densities and sizes of trees for reducing mass movement erosion, such as common and unsightly soil slippage, which can significantly alter sediment/nutrient distribution on slopes and reduce pasture productivity. This study determined in winter 2007 how much groups of 5-10 spaced trees reduced soil slippage at 65 sites in Manawatu (40 sites) and Wairarapa (25) following the most recent storms in February 2004 and July 2006, respectively. There were 53 sites with *Populus* trees and six sites each with *Salix* and *Eucalyptus* trees. Sites had a mean slope of 27^{o} (mostly 25-30^{o}) and soils were predominantly silt or sandy loams. Diameter at breast height (DBH) of all trees averaged 52 cm and ranged from 18 cm to 99 cm. Over all sites, trees (three genera) reduced the extent of slippage by an average of 95% (98% in Manawatu, 90% in Wairarapa) compared with slippage on nearby (< 1 km) pasture control sites of similar aspect and slope. On sites with trees, slippage (up to 11% of assessed area) occurred at 10 of the 65 sites, and the greatest extent of slippage occurred where trees had a DBH of < 30 cm. It is concluded that spaced trees dramatically reduced the incidence and severity of soil slippage on erodible slopes, and that they were even more effective when their average DBH exceeded 30 cm. Established plantings at 30-60 stems per hectare (13 m to 18 m spacing) were very effective in reducing soil slippage. Regional Councils recommend planting *Populus* and *Salix* poles at a spacing of 12 m or closer on erodible pastoral slopes, and if all poles survive to produce trees, the results suggest that tree thinning could be conducted later to increase understorey pasture production without compromising slope stability.

THE NITROGEN REQUIREMENTS, UPTAKE AND LOSSES IN PERENNIAL RYEGRASS (*Lolium perenne L.*) SEED CROPS

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Nitrogen (N) is an essential nutrient input for achieving high seed yields in perennial ryegrass. Nitrogen also provides the largest source of environmental concern in the form of leaching to ground water systems and green house gas loss to the atmosphere. Nitrogen has long been identified as a limiting factor in perennial ryegrass seed production and as such spring application is common practice. Recent field trials have established an optimum total N for seed yield (including soil mineral N) of 185 kg N/ha. This generally means an optimum application rate of 145 kg N/ha (*Rolston et al*. 2008). However what happens to applied N which is excess to optimising seed yield?

Work at Lincoln University in the late 1990's showed leaching rates of less than 1.5 kg N/ha during the following winter when application rates of up to 350 kg N/ha were applied in the spring to match plant demand. Labelled ^{15}N showed the applied N remaining after winter was held within humified organic matter (immobilised).

More recent work has shown that perennial ryegrass is a very good scavenger for spring applied nitrogen. At application rates as high as 300 kg N/ha, all applied nitrogen can be accounted for within the plant after harvest. For example, when 270 kg N/ha was applied in 2006 the plant contained 343 kg N above ground at seed harvest. Seed consists of approximately 2 % N, therefore a 2000 kg/ha crop contains only 40 kg N/ha. The ability to accumulate and hold nitrogen is a function of the stem. The straw N percentage is flexible depending on the soil supply. This data indicated that perennial ryegrass seed growers are extremely unlikely to apply N at rates which will result in contamination of water systems.

THE EFFECT OF SLOPE AND ASPECT ON PHOSPHATE RUNOFF IN HILL COUNTRY

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On the east coast of the North Island, steep (>26^0) north-facing hill slopes often produce significantly less pasture than small slopes (<26^0). One of the major factors underlying this variability is the soil moisture relationships of the different slopes and aspects. In early spring, higher inputs of solar radiation to steep north-facing slopes with shallow soils results in premature drying and the onset of hydrophobic surface soil conditions that reduce the infiltration of subsequent rain, thereby keeping these soils droughty for the summer and autumn months. Previous research has shown that the major runoff season for north-facing slopes is late spring, summer and autumn while the soils remain hydrophobic. We are concerned that the common regional practice of late summer-autumn fertiliser topdressing, leaves superphosphate granules on dry hydrophobic surfaces where the risk of surface runoff is extreme. The aims of this study were to collect and measure runoff water volumes and phosphate concentrations from different slopes and aspects.

A trial site was established (April 2006) at Pori Station (22 km SSE of Pahiatua). Runoff plots and climate stations have been installed on both a steep (30^0) and shallow (20^0) slope of a north-facing aspect; a steep and shallow slope of a south-facing aspect and two east-facing aspects (steep slopes). On 24th January 2008 the site was topdressed with 30% sulphur super at 250 kg/ha. Runoff was proportionally sampled to allow analysis for sediment and various phosphate (P) fractions.

As for the 2006/2007 year, soil on the north-facing aspects became hydrophobic in summer and autumn when a very significant portion of the rainfall was directed as runoff (sometimes up to 60% or more of incident rainfall). The first runoff event on the north-facing slopes was recorded in early March, whereas on the south-facing slopes runoff did not occur until mid April.

For the 16 runoff events collected for the less drought prone south-facing slopes, total dissolved P (TDP) concentrations ranged between 0.1 and 1.8 ppm; only two events had total dissolved P (TDP) concentrations greater than 1ppm. In comparison, TDP concentrations in runoff form the droughty north-facing slopes ranged from 0.3 to 7.6 ppm. The pattern of TDP concentrations in relation to aspect, slope, topdressing and animal camping behaviour is discussed.

USING BIOSOLIDS TO IMPROVE PINE FOREST PRODUCTION IN A LOW FERTILITY SOIL

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Biosolids from the Nelson regional wastewater treatment plant have been applied to a 1000-ha Pinus radiata plantation at Rabbit Island since 1996. An experimental research trial was established within the plantation in 1997 to investigate the effects of biosolids applications on tree growth, nutrition, and the ecosystem. Biosolids were applied to the trial site in 1997, 2000, 2003, and 2006 at three application rates: 0 (Control), 300 (Standard) and 600 kg N ha^{-1} (High). Three stocking density treatments, i.e., subplots of 300, 450 and 600 stems ha^{-1}, were included within each biosolids treatment main-plot. This study is to investigate the responses of tree growth, tree nutrition and wood properties to biosolids application.

Continuing significant increases in growth of P. radiata have been observed on the biosolids research trial site since the trial was established. In June 2008 at age 17 years, the mean basal area (BA) of trees in the High biosolids treatment was 37% greater than the Control, and that in the Standard treatment was 28% greater than the Control. Stem volume of the High treatment was 38% greater than the Control treatment, and that of the Standard treatment was 29% greater than the Control treatment. Although, the relative improvement of stem volume increment in biosolids treatments over the Control has been decreasing in recent years, this is due to the natural sigmoidal pattern of growth rather than evidence of a decline in response to treatment.

At higher stocking rates, competition has led to significantly smaller diameter trees. However, the higher stocked plots have significantly greater per hectare BA and volume than the lower stocked plots, irrespective of biosolids application. Tree stocking rates have had no significant effect on mean top height.

In general, biosolids application has been greatly beneficial to trees growing on this site. Effectively they have transformed it from a relative low productivity to a moderately high productivity forest site. However, the increased productivity has been accompanied by some negative influences on wood properties. The implications of the changes in growth rate and wood properties on economic return will be presented.

USING MAIZE SILAGE TO STRIP NUTRIENTS FROM HIGH FERTILITY SOILS

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Many dairy farmers apply effluent collected from the milking shed and surrounding platform back to their paddocks. Land application is considered a standard management practice, but repeated irrigation with nutrient-dense effluent can cause the soil to become overloaded with nitrogen (N), phosphorus (P) and potassium (K), especially when the area available for treatment is small or the farm system has intensified. Consequently, negative effects on animal health as well as on the environment are occurring. Improved management practices that reduce these risks and enhance nutrient use efficiency are required, especially for high-input farms if they are to meet the conditions for land application of effluent set by Regional Councils.

In spring 2007 we studied four sites in the Waikato region to determine whether maize silage could be used to strip nutrients from high fertility soils. All paddocks were coming out of permanent pasture and had been used as effluent application blocks for extended periods. Three treatments were compared, including each grower's standard fertiliser practice (GF, starter and side dress), a reduced fertiliser practice (RF, starter only) and a no fertiliser control (NF). The grower's standard practice ranged from 45 to 149 kg N/ha and 20 to 50 kg P/ha. No K fertiliser was applied at any site.

At three sites soil mineral N levels were higher at harvest than at sowing, even where no fertiliser had been applied. Residual soil N in the top 60 cm was very high (171 to 427 kg N/ha) where both starter and side dress fertiliser had been applied. All sites had little decline in soil Olsen P levels by harvest, reflecting both the small amount of P required by plants and the buffering capacity of the soil; several seasons of cropping may be required to significantly reduce P loading. In all instances soil K was lower at harvest than at sowing, primarily reflecting crop uptake. There was no effect of nutrient management practice on silage yield at any site at harvest. Across treatments, silage yield averaged 25.4 t DM/ha, good for that region. Total N, P and K concentrations in the silage were also unaffected by nutrient management practice. Nutrient removal in the harvested NF crop was equivalent to 290, 42 and 322 kg/ha of N, P and K respectively, all of which was supplied from the soil. These results broadly confirmed that maize silage can strip nutrients from paddocks that have had a history of permanent pasture and effluent application. NF gave no yield penalty and a saving in fertiliser costs of between $235 and $470/ha across all sites.

MATRIX BASED FERTILIZERS CONTROL ENTERIC BACTERIA AND NUTRIENT LEACHING AFTER DAIRY WASTE APPLICATION

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*Presenter

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We tested the efficacy of matrix based fertilizers (MBFs) to reduce *Escherichia coli* and *Enterococcus* spp., NH_4, NO_3, dissolved reactive phosphorus (DRP), and total phosphorus (TP) in leachate and soil after dairy manure application in greenhouse column studies. The MBFs are comprised of inorganic N and P in compounds that are relatively loosely bound (MBF1) to more tightly bound (MBF3) mixtures using combinations of starch, cellulose, lignin, $Al(SO_4)_3$ H_2O and/or $Fe_2(SO_4)_3$ to create a matrix that slowly releases the nutrients. One day after the first dairy manure application, *E. coli* numbers were greater in leachate from control columns than in leachate from columns receiving MBFs. After three dairy manure applications, *E. coli* and *Enterococcus* spp. numbers in leachates were not consistently different between controls and columns receiving MBFs. When MBF1 was applied to the soil, the total amount of DRP, TP NH_4, and NO_3 in leachate was lower than in the control columns. Bermuda grass receiving MBFs had greater shoot, root and total biomass than grass growing in the control columns. Grass shoot, root and total biomass did not differ among columns receiving MBFs. N and P bound to the $Al(SO_4)_3$ H_2O or $Fe_2(SO_4)_3$ - lignin - cellulose matrix, become gradually available to plants over the growing season. The MBF1 and MBF3 formulations do not depend on organic or inorganic coatings to reduce N and P leaching and have the potential with further testing and development to provide an effective method to reduce N and P leaching from soils treated with animal waste.

ON-FARM EFFLUENT MANAGEMENT
- HOW EFFLUENT SAMPLING CAN CONTRIBUTE TO IMPROVED NUTRIENT MANAGEMENT

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Effluent land application is recommended practice for dairy farming and it is a Permitted Activity in the Waikato Regional Plan subject to conditions (Rule 3.5.5.1.). One of the conditions is that the total effluent loading can not exceed 150kgN per ha and year for grazed pasture. Furthermore farmers are required to have a Nutrient Management Plan (NMP) if they are applying any fertiliser to land that has received effluent in the preceding 12 months.

The 2003 Clean Streams Accord target is for dairy effluent to be appropriately treated on every dairy farm immediately. Environment Waikato promotes the concept of effluent land application to utilise the nutrients and acknowledges the ongoing improvement of suitable application equipment by the effluent industry.

The nutrient content of dairy effluent varies greatly depending on the farm system's intensity, management practices, the infrastructure in place and of course weather conditions. Effluent testing for nutrient content will enable farmers to manage effluent nutrients more effectively to avoid negative effects on animal health as well as on the environment. Enhanced nutrient efficiency will contribute positively to on-farm economic performance reducing costs.

Environment Waikato initiated an effluent sampling campaign in 2007/08 promoting the concept of nutrient testing to dairy farmers. In conjunction with Hill Laboratories Ltd. sampling kits and a user-friendly reporting system were developed. Farmer feedback is very encouraging. Anonymous data have been screened since to develop a better understanding about the variability of effluent on-farm. Opportunities exist to provide additional service to farmers taking effluent nutrient management to the next level.

EFFECTIVENESS OF DICYANDIAMIDE IN REDUCING NITROGEN LEACHING LOSSES FROM TWO CONTRASTING SOIL TYPES UNDER TWO RAINFALL REGIMES – A LYSIMETER STUDY

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The use of the nitrification inhibitor dicyandiamide (DCD) has gained increasing attention in New Zealand pastoral systems as a technology to reduce urinary nitrogen (N) leaching losses. Given the potential for widespread use of DCD, there is need to examine the effect of contrasting soil and climatic conditions on the effectiveness of DCD to inhibit leaching of urinary N.

A four year field lysimeter study is currently underway to investigate the effectiveness of DCD on urinary N leaching losses from contrasting soil types under different rainfall regimes. Treatments include two soils (Horotiu silt loam and Waikare clay), contrasting in structure and drainage class, under two rainfall regimes (1100 and 2200 mm year^{-1}) with +/- DCD in a factorial design. Urine was applied to all lysimeters in a single application (equivalent to 1000 kg N ha^{-1}) in autumn (May). DCD was applied (10 kg DCD ha^{-1}) in May and July as a fine particle suspension.

Results for the first winter period (May-August) showed that soil type and rainfall regime influenced timing and form of N leached, and efficacy of DCD. More nitrate-N was leached from the free draining Horotiu silt loam compared to the impeded drainage of the Waikare clay soil (averaging 427 vs. 270 kg N ha^{-1}, respectively). When DCD was applied, nitrate-N leaching was reduced by 42% and 36% for the Horotiu silt loam and Waikare clay soil respectively, compared to the urine controls. Macropore flow processes occurred in the Waikare clay soil, resulting in large (30 kg N ha^{-1}) urea-N leaching losses. Subsequently, this process may affect the efficacy of DCD on total N leaching in this soil.

Leachate will continue to be monitored through the year.

WINTER GRAZING OF A FORAGE CROP; EFFECTS ON NITRATE LEACHING

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Grazing winter forage crops *in situ* is an approach increasingly adopted by dairy farmers to address winter feed shortages. The aims of this study were to quantify nitrate losses after winter grazing a brassica crop and to investigate the use of the nitrification inhibitor dicyandiamide (DCD) for decreasing this nitrate leaching.

Twenty large (324 m^2) plots were established in a paddock of kale/turnip on a freely draining pumice soil during winter 2008 on the property of Wairarapa Moana Incorporation, Pouakani (central North Island). The paddock was grazed in late June with cattle alternating between the brassica (18 hours per day) and an adjacent pasture (6 hours per day).

DCD was applied to half the plots within 2 days of grazing being completed (12 kg/ha a.i.), and re-applied 6 weeks later. Porous cups (60 cm deep) measured nitrate leaching May-October. They were removed for soil cultivation in August and were replaced after triticale was drilled.

There was 798 mm drainage between May and October. Nitrate-N losses were large from the grazed forage crop, and were decreased by DCD application. Nitrate-N losses between grazing and soil cultivation were 56 and 44 kg N/ha without and with DCD, respectively (significant at $P<0.05$). Losses between cultivation and the end of drainage in October were 59 and 43 kg N/ha without and with DCD, respectively (significant at $P<0.05$). Thus, total nitrate-N losses following grazing were 114 and 87 kg N/ha without and with DCD, respectively (significant at $P<0.05$).

Nitrate leaching was also measured in an area of the crop fenced to exclude animals and harvested by hand. Nitrate-N loss over the winter from this ungrazed patch was 60 kg N/ha. Thus, *c*. 52% of the winter leaching was attributable to growing a forage crop and then leaving the soil bare over winter after its removal; by difference, therefore, about 48% of the N loss could be attributed to excreta/urine deposition.

These preliminary results indicate a high risk of nitrate leaching from winter grazing forage crops *in situ*, but also some benefit from use of a nitrification inhibitor in this situation.

DEVELOPING BEST SOIL MANAGEMENT PRACTICES FOR INTENSIVE VEGETABLE PRODUCTION

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New Zealand's vegetable industry relies heavily on the surface 15 cm of soil. However, there are increasing concerns about the sustainability of current intensive production practices which can reduce the resilience of soils, leaving them less productive and more prone to wind and water erosion. Regional councils need management solutions to help minimise environmental impacts, and growers need new options to reduce production losses.

To help address this challenge, in 2008 the vegetable industry and several regional councils initiated a new 3-year program ('Holding it Together') to identify and implement improved best management practices (BMPs) for sustainable soil surfaces that address existing challenges in Horowhenua, Ohakune, Hawke's Bay and Pukekohe. In its first year, the project is addressing issues related to soil resilience, a key factor influencing a soil's ability to cope with the impacts of intensive management. In particular, demonstration sites are being established to highlight the effect of soil compaction, loss of structural condition, cultivation intensity, surface flooding and green cropping on economic and environmental indicators. In subsequent years the focus will be on mitigating impacts by drawing on innovative techniques as well as the best established practices.

Information from this project will be used to adapt and enhance existing grower guides for sustainable land management.

REDUCING SOIL N MINERALISATION WITH STRIP TILLAGE DURING THE CONVERSION OF PERMANENT PASTURE TO MAIZE SILAGE

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Mineralisation of nitrogen (N) from paddocks that have been in permanent pasture can be very high following conventional cultivation practices. In many instances this N release can far exceed plant N demand from crops like maize silage, resulting in poor nutrient use efficiency and a high N leaching risk. Two sites were studied in central Hawke's Bay in 2007–08 to determine whether strip tillage could be used as an alternative approach to establish maize silage crops and reduce soil N mineralisation. In each paddock, replicated plots were set up to compare the grower's conventional tillage (CT) practice with strip tillage (ST). Soil mineral N (MinN) was measured separately in the plant-row and mid-row, both preplant and at harvest, at the two sites; additional measurements were collected at Site 1 at 2 and 6 weeks after sowing and at silking. At harvest, crop yield was measured at both sites.

At Site 1 soil MinN levels increased rapidly in the top 30 cm following cultivation. Soil MinN was lower under ST than CT early in the season, primarily due to the lower levels in the mid-row of ST plots compared to the mid-row of CT plots. This was consistent with the reduced tillage in those areas. Soil MinN levels declined rapidly between 6 weeks and silking, reflecting a period of high plant biomass accumulation and N demand. At both sites there was more MinN in the top 30 cm of CT plots than ST plots at harvest. Crop performance was not significantly affected by tillage practice; across sites, DM yields averaged 22.6 and 21.9 t/ha for the CT and ST practices, respectively. Plant populations were slightly lower with ST, reflecting some establishment difficulties. There was no effect of tillage on plant N uptake. Across sites, uptake averaged 212 and 207 kg N/ha for the CT and ST practices, respectively.

These findings confirm that ST can be used to successfully establish maize silage and delay soil N mineralisation. Additionally, reduced tillage options are likely to result in significant energy and labour savings, and minimise the risk of wind erosion. Ongoing trials will enable better prediction of the rate of N mineralisation under different cropping histories, an important step in forecasting soil N supply.

NITROGEN FERTILISER TRIAL DATABASE: A VALUABLE RESOURCE. CLIMATIC FACTORS AND FIRST CUT RESPONSE TO NITROGEN APPLICATION

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Data from 1,272 nitrogen (N) fertiliser trials from around New Zealand over the last 80 years were collated onto an electronic database. Data collected included nitrogen (N) fertiliser forms, N application rates, plant dry matter (DM) yields, botanical composition, soil types and weather conditions. These data were sourced mostly from original, unpublished trial records and reports. In this paper, a summary of the information gathered from the database and relationships between the first cut N response and climatic factors are presented.

Nitrogen response was calculated as the daily kg of plant DM produced per kg of N applied. Data were restricted only to first cut response for this study.

Most of the trials either used Nitrolime or Urea. A comparison of N responses between these two fertiliser products showed no significant overall difference.

Late spring gave the greatest and most reliable responses to N application. In general, only weak relationships between climatic factors and response to N were established. The strongest relationship was found to be between response and average daily temperature for each soil, but under near-ideal conditions (average daily rainfall $\geq$ 1 mm and soil deficit $\leq$ 20 mm) and where basal fertiliser had been applied. The relationship between N response and rainfall was weaker than the relationship between N response and temperature.
An estimate of minimum temperature for an N response in spring was established as 5^0C and is consistent with overseas studies.

However, from the data to date, no single relationship has explained pasture response to applied N fertiliser application (perhaps not surprisingly). Some of the factors confirmed as important are temperature, soil type and basal fertility. Therefore, a fertiliser decision support system needs to take into account at least these factors. The database represents a useful resource, going forward.

IMPLEMENTING ON-FARM P MITIGATIONS IN REREWHAAKITU CATCHMENT

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Lake Rerewhakaaitu is a shallow lake, unique amongst the Rotorua Lakes, for having a catchment comprising mostly dairy farms. In 2001, EBOP reported that water quality was satisfactory but noted increasing nutrient levels in streams flowing into the Lake. Farmers within the catchment were concerned about: 1) future condition of Lake and 2) possible imposition of constraints on their farming operations. A two-phase SFF project was set up to address the water quality issues by identifying ways that pastoral management in the catchment could be changed to minimise the environmental impact on the Lake, while still allowing sustainable dairy farming to continue.

Phase 1 focused on nitrogen (N) management. A farmer survey was conducted and OVERSEER® nutrient budgets were complied for the 33 farms. Phase 2 focused on phosphorus (P) management. OVERSEER® findings were that farm soil Olsen P averaged 65, exceeding the optimum for pumice soils (35-45). The farmers' recognised the need to reduce soil Olsen P to optimum levels to reduce P loss as pumice soils are amongst the highest risk soils for P losses. As P loss does not occur from whole catchment but rather from "critical source areas", the research focused on identifying the main pollutant form of P so that appropriate on-farm P-mitigations could be installed. Five sites were selected for installing P-mitigations and collecting surface runoff measurements to evaluate efficiency of P removal. The P-mitigations investigated have included filter strips (both grass and artificial), sediment traps, P-socks filled with steel/iron slag or a combination of these mitigations.

The success of the project has been the close interaction between the farmers and the science providers through frank discussions, regular newsletters and farmer meetings.

IMPROVING EFFICIENCY OF PHOSPHORUS AND MICRONUTRIENT FERTILISERS IN CEREAL CROPPING SOILS - THE ROLE OF SPECTROSCOPIC AND ISOTOPIC RESEARCH TOOLS

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Examining reactions of fertiliser elements in soil, and understanding fundamental processes affecting plant acquisition of soil nutrients, has been significantly advanced over the last two decades through the use of isotopic tracing techniques, coupled with advanced spectroscopic and chromatographic ion separation techniques. We will demonstrate the application of these methods to examination of the efficiency of P and trace element fertilisers for dryland grain production on alkaline soils.

Their use has been pivotal in explaining the mechanisms responsible for the high agronomic efficiency of soil-injected fluid phosphorus and trace element fertilisers in calcareous soils, and for understanding nutrient reactions in and around fertiliser granules that reduce fertiliser efficiency in the same environments. They have also been central to the development of new trace element formulations. Micro-scale reactions in the soil can have a marked effect on crop nutrient acquisition, and some of the newer spectroscopic methods provide not only micro-scale soil analytical data, but also new information on the chemistry and reactions of fertiliser nutrients.

Recent advances in isotopic tracing techniques provide us with the ability to measure ever smaller differences in elemental and isotopic composition, yet these precise measurements are changing our understanding of the soil-to-plant transfer of some nutrient elements. These techniques do not replace traditional agronomic experimentation, but when used in tandem with field experimental data, they can provide important insights into the fundamental soil and plant processes responsible for differential crop responses to fertilisers observed in field trials.

DIGTIAL IMAGING FOR SPREADER TESTING

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This paper describes a system being developed that will use digital imagery to calibrate the spread pattern from spreaders. The digital image analysis allows the spread distribution to be quantified and particle size distribution analysed from a single view. This helps to eliminate human error, speed up the testing process and provide more information to the user of the actual performance of the spreader.

The system has been developed under a Sustainable Farming Fund grant with the assistance of the Fertiliser Quality Council and FertResearch.

MINIMISING N LOSSES FROM INTENSIVELY GRAZED PASTURE SYSTEMS AS AFFECTED BY A COMBINATION OF UREASE AND NITRIFICATION INHIBITORS APPLIED AT DIFFERENT TIMINGS

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Nitrogen (N) losses from urine patches in New Zealand grazed pastures are one of the major contributors to our clean environment and sustainability. The uses of N inhibitors (urease and nitrification inhibitors) have been proposed to mitigate such N losses. A lysimeter experiment near Lincoln, Canterbury, New Zealand on a permanent pastoral site is currently underway to quantify N losses via gaseous emissions of ammonia (NH_3) and nitrous oxide (N_2O) into the atmosphere along with nitrate (NO_3^-) leaching and pasture dry matter yield. The 4 treatments: cow urine applied at 600 kg N/ha only, urine with nitrification inhibitor dicyandiamide (DCD) applied at 10 kg/ha), urine with the combination of 1 litre/ha of urease inhibitor N-(n-butyl) thiophosphoric triamide "Agrotain" and 7 kg/ha of DCD (double inhibitor) and the control (no urine) were applied to undisturbed lysimeters in autumn and spring. The inhibitor treatments were applied at 4 different timings of urine application (i.e. 10 days and 5 days prior to urine applications, the same day of urine application and 5 days after urine application). Gaseous emissions of NH_3 and N_2O, NO_3^- leaching and pasture production were monitored following the application of treatments during each season. Nitrogen losses varied with the timing and type of the applied inhibitors during the 2 seasons. Detailed results will be presented after availability of analyses results.

Keywords: Agrotain; DCD; inhibitors; mitigation; NH_3; N_2O; NO_3^-, pasture, urine;

GIBBERELLIN APPLICATION TO PASTURES: A 50-YEAR OVERVIEW OF RESEARCH AND PRACTICE

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Gibberellins (GA) are plant hormones that reactivate dormant enzyme systems. Applied to pasture, they can stimulate growth through reserve mobilisation, or acceleration of leaf and stem elongation, depending on season. In some herbaceous species GA can induce premature flowering.

Historical experiments evaluating pasture responses to GA typically used rates exceeding 100 g/ha active ingredient (a.i.). Responses were found to be uneconomic, and there were often negative side effects including a decrease in tillering, decreased root mass, and a yield depression subsequent to the initial response. Currently, cheaper sources of GA and use of application rates as low as 5 – 10 g a.i./ha has led to GA-induced pasture responses costing as little 10c /kg DM in some situations, though little formal experimental data on such responses is available to farmers. Also, in a typical scenario of a 250 kg DM/ha response to 10 g a.i./ha GA, it is difficult to measure DM with sufficient precision to confirm statistical significance of the response.

A small trial of a commercially available GA product at Massey University in 2008 indicated that GA and N-fertiliser responses are additive, and suggested that even at 10 g a.i./ha GA, historically reported side effects still occur, but appear to be reduced when GA is applied together with N-fertiliser. In our trial, GA-induced increase in pasture height reduced the multiplier coefficient of a rising plate meter (RPM) calibration equation by approximately 10 kg DM per RPM unit.

SPREADING BLENDED FERTILISERS

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A project was completed to investigate spreading blended fertilisers from a spinner spreader. Two loads of a 70% to 30% mix of superphosphate and potassium chloride were used. Their spread distribution on the ground was measured using 850 collection trays for each load.

The trial was to investigate two aspects of performance. Firstly; what degree of mixing is required within the load to allow an even distribution of fertiliser throughout the spreading process, and secondly; what level of segregation of material took place at the spinners as the material was being spread.

The first load was formed using a loader to layer measured buckets of each material in the spreader, the second was thoroughly mixed using a chain and flight mixer. The experiment showed that the thoroughly mixed load had less variability in the distribution of nutrients spread throughout the load. It also showed that there was significant segregation of material from the spinner with the KCl tending to be thrown further than the Super.

A full analysis of particle size distribution of spread is given.

OBSTACLES TO ACHIEVING GREATER EFFICIENCY, COST-EFFECTIVENESS AND ENVIRONMENTAL PROTECTION WITH FERTILISER NITROGEN

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Obstacles to achieving much greater on-farm efficiency, cost-effectiveness and environmental protection with fertiliser nitrogen (N) are considerable, but are not principally agronomic in nature.

The effectiveness of urea fertiliser, by far the most widely used N fertiliser in New Zealand (and the rest of the world) has been proven beyond reasonable doubt, in a number of field trials on pasture in New Zealand and Australia, to be able to be improved 2 to 3 times by a combination of applying it in fine, wetted form (ie, as a thick fluid), and incorporating the urease inhibitor NBPT (trade name Agrotain).

Scientific research currently being undertaken at Canterbury University and elsewhere will provide more detailed explanations for this improved efficiency, but the major reasons are reduced ammonia volatilisation, increased efficiency of conversion to plant protein of urea taken up directly through the leaves, and reduced nitrate leaching losses.

Equipment for on-truck processing and application of the fluidised product has been developed and the first trucks are in part-demonstration, part-commercial use in New Zealand and Australia. Patents have been applied for, and already awarded in Australia.

The significant obstacles to the uptake of this technology on a large scale are (a) financing trucks at $300,000 each, in today's difficult credit market, (b) gaining acceptance of focussing on the improved bottom-line for both spreading contractors and farmers, rather than the necessarily higher application cost, (c) convincing farm consultants that this is new technology, not Maxicrop, and needs to be looked at with an open mind, and (d) concern in the fertiliser supply industry regarding the adoption of technology that has the potential to literally halve current fertiliser N requirements.

CAN FINE PARTICLE APPLICATION OF FERTILISERS IMPROVE N USE EFFICIENCY IN GRAZED PASTURES?

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Improving fertiliser-N efficiency is critical for sustainability and to minimise its rising cost. Three field experiments, comparing the agronomic efficiency of various N fertilisers applied in fine particle suspension and granular forms, were conducted on permanent grazed pastures under spray and border dyke irrigation systems in Lincoln and Ashburton, Canterbury, New Zealand during 2006 and 2007. In Ashburton-spray-irrigation experiment, 4 replicates of 3 fertiliser treatments: urea, urea + the urease inhibitor NBPT (Agrotain), and urea + Agrotain + elemental sulphur (S) each applied at 30 kg N ha^{-1}, were applied in November 2006. In Ashburton-border dyke-experiment, 4 replicates of 5 treatments: urea, urea + Agrotain, urea + Agrotain + elemental sulphur (S), sulphate of ammonium (SOA) and di-ammonium phosphate (DAP) each applied at 25 or 50 kg N ha^{-1}, were applied in March 2007. In Lincoln–spray-irrigation experiment, urea + Agrotain was applied at 25 kg N ha^{-1} to 2 pasture heights (5 cm and 10 cm) and 10 cm pasture height with 10 mm of spray irrigation after 1 day of fertiliser application in March 2007. Control treatment (no N) was also included in each experiment. After fertilizer application, pastures from each experiment were harvested twice to determine pasture dry matter yield, N response and response efficiency. Except DAP, fertilisers applied in FPA form at lower rate (25 kg N ha^{-1}) performed better by producing significantly more pasture dry matter and exhibiting higher N response and response efficiency compared to their corresponding treatments applied in granular form. Applying FPA to high pasture cover and applying light irrigation after 1 day of fertiliser application further improved N response in those treatments. In all three experiments, urea applied with Agrotain in FPA form exhibited higher N response and efficiency than urea alone or other form of chemical fertilisers. These results suggest that applying urea with Agrotain in FPA form may have the most potential to improve pasture production in intensively grazed systems.

Keywords: fine particle, granular, urea, urease inhibitor (NBPT, pasture dry matter

COMPARING UREA AND SUSTAIN AS A BROADCAST FERTILISER FOR MAIZE PRODUCTION

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Urea is the most common N fertiliser applied to maize crops at side-dressing. Sustain, a slightly more expensive N fertiliser, contains a urease inhibitor designed to reduce volatilisation losses. If losses are less, lower rates of Sustain may improve the profitability of its use in broadcast applications.

A total of 13 trials over three seasons compared Urea and Sustain applied at various rates 8 weeks after sowing. Soil mineral N, grain yield and grain moisture content were measured. The trials were located in commercial maize crops and were managed with standard grower practice.

In the first year, the N fertilisers were ‘knifed’ into the soil using a side-dresser. This practice minimises volatilisation and hence there was no effect of fertiliser type on yield. The fertiliser N treatments were broadcast in year two however the wet season meant there was no effect of fertiliser type. Dry conditions in year three resulted in yield effects at two of the three trial sites.

Where good crop yields were achieved at two of the three trial sites in year three, the overriding treatment effect on both soil N and crop yield was N fertiliser rate, with the Sustain plots tending to have greater yields and/or higher soil mineral N at harvest, particularly at full application rates. A severe drought severely limited crop yields at site three, with yields less than half the average. Thus we found no response to fertiliser N. Soil mineral N at harvest was substantial, and reflected fertiliser N application rates.

We conclude that in some specific conditions there may be either a yield or soil N retention benefit to using Sustain rather than Urea, which in some cases may also produce an economic advantage. However only two sites in the past three years has shown such a response and any advantage of increased soil N at harvest will only be realised if a winter crop is sown to take up that N.

THEORY UNDERPINNING THE ISOTOPIC INDICATORS OF LAND-TO-WATER NITROGEN TRANSFERS FRST PROGRAMME

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GNS Science's National Isotope Centre and has obtained FRST funding of $1.05 million over three years to lead the Isotopic Indicators of Land-to-Water Nitrogen (N) Transfers programme, and coordinate a range of collaborations. The programme focuses on developing stable isotope ratios ($^{15}N/^{14}N$ and $^{18}O/^{16}O$) as indicators of nitrogen from pastoral agricultural land to surface water. In this poster, the theory underpinning the programme and its application to stable isotopes in New Zealand will be presented. The underpinning theory has been developed based on overseas research and limited New Zealand data, and our three-year programme will verify the theoretical basis for the programme, providing the understanding needed to develop robust indicators. The programme centers on the science of developing isotopic indicators, with long-term delivery occurring through large ongoing programmes focused on land use and water quality within AgResearch, Landcare Research and the Sustainable Land Use Research Initiative (SLURI).

Our proposed indicators are intended to:

- Classify the vulnerability of farm units to ongoing losses of N
- Identify the proportion of river nitrate (NO_3) loads from differing farm types
- Quantify the proportion of NO_3 lost during transport

These indicators recognise that multiple isotopes of N and oxygen (O) exist naturally, and the relative abundance of these isotopes records the sources of N and O, as well as the effects of biochemical processes occurring in soil and water. We believe NZ pastures represent an ideal opportunity to define N and O isotope systematics for agricultural systems in the absence of the pollution that obscures relationships in the Northern Hemisphere. We plan a primary focus on the Upper Manawatu Catchment, to support the development of water quality policies within Horizons Regional Council's One Plan.

NITROGEN STATUS VARIABILITY WITHIN THE PASTORAL SYSTEM

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Export of nitrogen (N) to water bodies is one of the primary environmental concerns facing the pastoral industry. Nitrogen is the most used nutrient in intensive agriculture. To optimise the use of N fertiliser on a farm, applications need to be adjusted to take account of other sources of N supply to the pasture or crop. This includes soil N supply through mineralisation of soil organic matter. Mineralisation of N can potentially vary greatly with location (organic matter content) and environmental effects. An accurate assessment of mineralisable-N across a farm would allow better targeting of N fertiliser applications. However, how variable is soil N status between and across pasture farms?

In order to determine this variation across New Zealand pasture farms, 93 sites were chosen over a range of fertility levels. Soils were collected from individual paddocks on dairy and sheep/beef farms to a depth of 7.5 cm. The sites were located between Northland and Southland to provide a good geographical spread and to cover all the major soil types.

To determine the N status variability within a farm, every paddock was tested on two farms located near Rotorua and Tokanui. Also, within two paddocks at the Tokanui farm, detailed soil sampling was undertaken to examine within paddock variability, which could then be compared to the paddock and farm variability.

Measurements of inorganic-N, mineralisable-N (hot water extractable N) and total soil N (TN) were made on all soil samples collected.

Soil total N status varied greatly across New Zealand farms (0.2–1.5% for mineral soils). The TN status could also vary greatly within a farm; the range for the Rotorua and Tokanui farms were 0.4-0.8% and 0.4-1.4%, respectively.

For the samples tested, the majority of N in soil (99.5 %) was present as organic-N, with the remaining 0.5 % usually in a form directly available to plants i.e. inorganic-N (nitrate-N and ammonium-N ions). Approximately 5-10% of the organic-N was in an easily mineralisable-N form.

These results suggest that there may be benefit for N fertiliser management from better understanding of variability in TN status between and within farms, provided that TN is shown to be a useful guide to soil N supply.

NITROGEN MANAGEMENT FOR ENVIRONMENTAL ACCOUNTABILITY – TOOLS TO ASSIST SMART DECISION MAKING

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Industry and Regional Councils have identified the need for tools to assist in smart decision making in relation to the use of nitrogen fertilisers in the production of horticultural (winegrapes, fruit and vegetables) and arable crops. Efficient and effective use of nitrogen fertiliser is vital to ensure sound economic and environmental bottom lines.

Nitrogen Management for Environmental Accountability (NMEA) is a 3 year project nearing completion that has been funded by the horticulture, arable and fertiliser industries, local regional authorities and the Ministry for Agriculture and Sustainable Farming Fund (MAF SFF). The objective of the project was to develop a tool that could accurately calculate nitrogen leaching across a range of industries, including multiple cropping scenarios taking consideration of local weather conditions and soil type as well as mitigation factors (e.g. timing of fertiliser application).

Researchers at Plant and Food Research were able to utilise existing mechanistic models (the LUCI framework model and SPASMO) to produce data on the effects of key environmental and management factors on nitrogen balances. This enabled development of mechanisms and parameters to predict nitrogen losses (leaching and denitrification), nitrogen additions (mineralisation) and nitrogen removal (crop nitrogen uptake determined from user specified yield expectations). In particular, a detailed statistical analysis of this data resulted in a generic relationship to calculate nitrogen leaching ($= 10^a \times \text{Drainage}^b \times \text{Soil mineral N}$).

AgResearch staff have incorporated these functional relationships into an upgrade of the OVERSEER® Nutrient Budgets model that is currently widely used by the pastoral industries for assessing the environmental impact and sustainability of agricultural management practices. OVERSEER® was selected as the preferred delivery mechanism because of well established and supportive ownership structure (MAF, AgResearch and FertResearch) and it is already recognised by national and regional government. The incorporation of these functional relationships will significantly improve the existing horticulture and arable models in OVERSEER® and substantially increase the number of crops listed.

Outputs from the upgraded horticulture and arable OVERSEER® models are currently being back validated to outputs from the parent tools and validation against actual field data is anticipated.

SUSTAINABLE MANAGEMENT OF PHOSPHORUS ON THE FARM

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The transfer of phosphorus (P) in runoff from agricultural land contributing to eutrophication in both flowing and standing waters has become an important environmental, social and economic problem in many regions of the world. Correct identification of the major sources contributing P is critical for the development of cost-effective measures to combat eutrophication. Research over the last 15 years suggests that these measures must address both the mobilization and delivery of P from multiple source areas on the farm and within the wider catchment area.

Sustainable approaches to P management on the farm must therefore take account of the need to:

(a) appreciate the severity of eutrophication problems in the area and proximity of the farm to receiving waters

(b) balance P inputs according to agronomic need but without causing increased leakage from the soil

(c) reduce the rapid P loss that occurs soon after application of P amendments but without adversely affecting their longer-term P use efficiency

(d) reduce runoff risk and associated dispersion and entrainment of soil particles through careful soil and crop management

(e) identify high-risk sources and source areas for priority management including those associated with impervious surfaces on the farm and the functioning of rural communities

Sustainable solutions to these issues are challenging due to the inefficiencies of P use, especially in livestock systems where P surpluses are commonplace, and the recognized difficulties of linking eutrophication impacts back to specific and often interactive sources on the farm. Targets for achieving good ecological status in surface waters are also very low and unlikely to be achieved by best management practice alone in intensively farmed areas. Recent evidence from the UK has highlighted the importance of understanding the ecological relevance of different sources in terms of their potency, form and timing of delivery to the watercourse as a guide to priority management. The rising demand for food, concerns over the long-term availability and pricing of rock phosphate and the increasing need to recycle a wider range of bioresources to land also suggests a need to explore innovative strategies for improving P use efficiency on the farm.

CONTROLLING NITROGEN AND PHOSPHORUS LOSS FROM DAIRY FARMS USING RESTRICTED GRAZING PRACTICES

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Restricted grazing practices, in conjunction with increased use of cow housing or feedpad facilities, are used in New Zealand to reduce treading damage to pastures during wet periods. Removing cows from pasture also reduces the excreta load returned to pasture. Simulation models suggest that if the excreta captured on the standoff facility during restricted grazing is stored and uniformly re-applied to paddocks, then this can lead to subsequent reductions in N leaching.

A large grazing trial has been established on the Massey University No.4 dairy farm to investigate the effect of restricted grazing on the quantities of nitrogen (N), phosphorus (P) and faecal microbes lost in drainage and runoff from grazed pasture. The experimental facility has 14 drainage plots (each plot ~850 m^2), which provide continuous monitoring of mole and tile drainage water flow rates. Seven plots are managed under restricted grazing (RG; 4 hr day or night graze) and another seven plots under 'normal' grazing (NG; 6 hr day graze, 12 hr night graze). Plots are grazed alternatively between morning and night grazings.

There have been a total of five grazings since trial initiation (3 day grazings and 2 night grazings), with the fifth grazing occurring mid-December 2008. Over this period, grazing duration was 45% lower on RG plots compared to NG plots, on average. Total dung deposition, estimated from pat counts, was 54% lower on RG plots compared with NG plots.

The drainage season (late-June 2008 to early-November) produced ~450 mm of cumulative drainage. During the first ~200 mm of drainage, nitrate-N concentrations progressively decreased from an average peak value of 9.3 ppm N, at the start of the drainage season, to <0.25 ppm N. The first three grazing treatments occurred during the last ~120 mm of the drainage for the season. During this period, nitrate-N concentrations remained below 1.6 ppm N and on average there appeared to be no clear difference between treatments. In 2008 the results show that nitrate-N accumulating in the soil prior to the start of the winter drainage season had greater influence on the quantity of nitrate-N leached than the three spring grazings that occurred during the drainage season. RG treatment will be practiced over the entire milking season in an attempt to reduce nitrate-N accumulation prior to the 2009 winter drainage season.

IMPLEMENTING NUTRIENT MANAGEMENT IN A RAPIDLY CHANGING WORLD

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Globally, agriculture is facing a rapidly changing world for reasons which include; a substantial increase in world population, rapid development of emerging economies, increasing international competition and intensification of agricultural systems. This is coupled with an increase in public concern about the environmental impacts of modern society, but also rapid advances in technology. Throughout history the application of nutrients and management of nutrient cycles has been an essential part of agricultural systems. Now, due to the effects of intensification and because agriculture is a significant contributor to the New Zealand's economic well being, the conflicting demands of economically viable production and environmental protection are possibly higher than they have ever been.

The fertiliser industry promotes and supports sustainable development through environmentally and commercially responsible nutrient management. To address these issues in a rapidly changing world the fertiliser industry has implemented approaches to nutrient management solutions which are; output based, science based, site specific / catchment specific, permit flexibility and innovation, encourage 'Best Management Practices', encourage a collaborative, consensus approach, and pursue continual improvement.

In very practical terms, the fertiliser industry has over many years consistently and methodically implemented programs and systems for continual improvement in nutrient management and farming practices by means of developing and investing in ;

- scientific research
- science based nutrient management tools
- industry codes of practice and information documents
- quality assurance procedures
- training and education programs
- accreditation procedures
- monitoring and evaluation procedures
- collaboratively programs with government, industry and interest groups
- innovation with new products and applications

These approaches and initiatives have delivered tangible outcomes in the form of nutrient budgets and nutrient management plans. This will enable farmers to use nutrients more efficiently, thereby achieving economic and environmental benefits.

This paper discusses the development and implementation of the required infrastructure and support base to achieve efficiency, flexibility and continual improvement in agricultural production systems.

ENVIRONMENTAL PLANS IN A FARM SYSTEMS CONTEXT

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The Dairy Industry Strategy for Sustainable Environmental Management recognises significant concerns about the impacts of dairying on surface and groundwater quality, regional issues with water availability for dairying and national concerns over climate change and greenhouse gas emissions. Given the major contribution that the Industry makes to New Zealand, both economically and socially, it is important that dairy farmers and the industry as a whole respond proactively to these environmental concerns to ensure that an appropriate balance between social, economic and environmental goals can be achieved and sustained.

A number of options exist for an industry-wide response to environmental concerns, growing community aspirations, as well as potential market drivers. These include allowing farming activity to be controlled through external regulation, with the industry supporting farmers to achieve compliance, and industry self-management, whereby environmental management systems are put in place to ensure farmers adopt practices that will achieve realistic environmental outcomes. The industry considers that self-management systems provide an appropriate means of improving management of dairying's environmental effects. With this in mind, the industry is developing a farm-scale Environmental Management System that provides individual farmers with an action plan to implement industry best management practices that meet environmental, social and economic objectives of the farm business.

We consider that successful adoption of an Environmental Management System by farmers will be influenced by a range of factors, including presence of suitable drivers (e.g. positive and negative incentives for change), ease of use, integration with farm business and clear links between changes to farm practice and environmental benefits.

Current work by DairyNZ is focused on developing systems for the integration of environmental actions plans into the farm business. Factors for farmers and their advisors to consider in this process will include financial and nutrient budgeting, an awareness of the impacts of nutrient losses and increasing background knowledge about nutrient, effluent, soil and water management. When developing environmental plans, farmers also need to consider the effects of proposed actions on the full spectrum of influences e.g. profitability, feed and animal production, management complexity, requirements for plant and equipment, staff requirements and training, public perception and compliance with council regulations. Some changes will require a carefully planned systems approach, use of rural professionals, or case study information. Individual farmer approaches will depend on how much time they are prepared to invest in gathering information and making decisions vs making use of professional assistance.

THE ROLE OF NEW ZEALAND FARM ENVIRONMENT AWARD TRUST IN PROMOTING SUSTAINABLE FARMING SYSTEMS

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New Zealand Farm Environment Award Trust, Hamilton

Mission Statement:

To be the leading independent advocate for sustainable management of land and other natural resources on New Zealand Farms

The New Zealand Farm Environment Award Trust is an independent non-profit organisation which seeks to advance sustainable environmental management of land and other resources on farms. The Trust owns and operates the Ballance Farm Environment Awards and manages several extension projects.

The principal objective of the Trust is the advancement, education, assistance and promotion of sustainable environmental management of land and other natural resources on farms within New Zealand.

It is the Trust's intention to continue the multi-pronged approach to achieving its objects by developing and expanding the regional Ballance Farm Environment Awards throughout New Zealand.

The core business areas identified for the Trust are:

- **BFEA Awards and Judging Process**
  The number 1 activity for the Trust is to run an effective and successful awards process. This involves a well planned, supported and executed judging process. Key areas of focus are:
    - Strong sponsorship support
    - Credible entries in good numbers
    - Judging process that has integrity and is robust
    - Promotion of best environmental practice
    - Strengthening capacity in the regions
    - High exposure of events and winners
- **Communications and Promotions**
  The number 2 activity for the Trust is to undertake effective communication and promotion of Trust activities and key sustainability messages. Key areas of focus are:
    - Increasing exposure of Trust activities and role models
    - Optimum use of tools and opportunities for messages
    - Better communications within the Trust (National to Regions), rewarding and recognizing all those involved

THE BMP TOOLBOX - SELECTING THE RIGHT BEST MANAGEMENT PRACTICE FOR MITIGATING FARMING IMPACTS ON WATER QUALITY

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Implementing mitigation measures to decrease the environmental footprint of pastoral farms is complex due to the variety of potential impacts, the varied potential sources of pollutants on farm, and the range of management options that could mitigate these sources. Given that farms are operational businesses with a finite budget available for environmental measures, it is important that policy and farmer decision-making is guided to ensure the best return on investment. Research by social scientists has informed us that (i) the provision of economic information is equally important as knowledge about how effective mitigation strategies are, and (ii) farmers have shown a strong preference for selecting from a range of mitigation options available to them, as opposed to more prescriptive approaches. Accordingly, the BMP Toolbox (BMP = Best Management Practices) has been developed to help identify the mitigation measures that are most relevant and cost-effective for an individual farm. The Toolbox provides a list of mitigation practices relevant to the issue that the user identifies when entering information about a farm's physical attributes (resource risk) and its management (management risk). The Toolbox estimates the effectiveness, cost and cost-effectiveness of each mitigation option, the latter metric helping to identify which management practice will provide most benefit for least cost i.e. the "biggest bang for buck". In this paper we outline the range of mitigation measures currently contained within the BMP Toolbox and some of the cost and effectiveness assumptions used for each option. A case study example based upon a typical dairy farm within the Bog Burn catchment (Southland) is presented to demonstrate how this tool has been used to guide farm planning initiatives within this catchment.

OVERSEER SCENARIOS – "WHAT IF" ANALYSES

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The OVERSEER nutrient budget model is currently largely used as a tool for reporting farm nutrient budgets and nutrient indices such as N leaching. However, the model has the capacity to be used as a tool to undertake scenario analyses of changes on the farm or block that may affect the corresponding nutrient budgets and nutrient indices. This role is likely to increase, given the increasing pressure on farmers to meet regional council policy initiatives to limit the loss of nutrients to the environment.

Although the model can be used for scenario analysis, the modelling approaches adopted within OVERSEER and the farm systems being modelled should be considered to ensure a valid analysis for a given farm.

This paper focuses on nitrogen and outlines how the model has been constructed to estimate N leaching. It also considers the implications of this construction when undertaking scenario analysis.

For example, some scenario changes may already be included because OVERSEER assumes that best management practices (BMPs) are already being followed. The implication of this assumption on scenario analysis is discussed. It is also important to consider how changes to one part of the farm system impact on other parts; OVERSEER does not automatically 'balance' the system. For example, adding N fertiliser results in increased pasture production and hence animal production, an important model driver. Examples of more complex downstream changes that should be considered are presented.

The paper describes some of the pre-defined scenarios that have been added to the scenario analysis part of the model, and the basis behind their development.

PRACTICAL AND REGULATORY FACTORS IN NUTRIENT BENCHMARKING WITH OVERSEER – A ROTORUA LAKES PERSPECTIVE

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The 12 Rotorua lakes are beautiful, diverse and threatened by actual or potential declines in water quality caused primarily by nutrient enrichment from land-based nitrogen and phosphorus inputs. As part of a programme to protect and restore lake water quality and other lake values, Environment Bay of Plenty proposed a set of water quality objectives and a supporting mix of regulatory and non-regulatory methods.

For five of the lakes, a nutrient cap regulation known as "Rule 11" was introduced via the Regional Water and Land Plan. Rule 11 seeks to prevent further increases in diffuse nutrient discharges within the respective catchments by limiting properties to the levels of N and P loss during the benchmark period of 2001-2004. The practical implementation of Rule 11 requires measurement at the property scale with one to one landowner engagement, whilst maintaining transparency and regulatory rigour. This paper discusses how Overseer came to be adopted for Rule 11 nutrient benchmarking and the various implementation challenges faced.

In parallel with the nutrient cap imposed by Rule 11, it is necessary to actually reduce lake nutrient inputs to meet the desired water quality objectives. The reduction targets, potential reduction mechanisms and timeframes (especially due to groundwater lags) vary hugely between the different lakes. For example, the proposed land-based nutrient reductions sought for Lake Rotorua are 170 tonnes N/year and 6 tonnes P/year, to be achieved over 10 years. The practical implementation of nutrient reductions will need to be assessed cumulatively across a large number of benchmarked properties.

The linkages between benchmarking and "what-if" mitigation scenarios via Overseer are addressed. Examples are given to illustrate some of the technical and resourcing challenges faced – these include consideration of the quality/completeness of Overseer input data, land tenure changes and the longevity of mitigation options. Finally, some points are raised about nutrient benchmarking given ongoing evolution of the Overseer model and the regulatory framework.

IDENTIFYING THE DECISION MAKING PROCESSES FOR APPLICATION OF N FERTILISER TO AN INDIVIDUAL PADDOCK

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The combination of factors influencing pasture's response to nitrogen (N) fertiliser is so large that there is insufficient experimental evidence alone to develop a N Decision Support System (DSS) (Parker et al. 1994); one approach should be to use expert opinion to supplement the response data when developing a DSS.

Therefore, a web-based questionnaire was used to seek the opinions of experts from the fertiliser industry and independent consultants to identify the main decision processes when planning a fertiliser application to a paddock. There were 83 responses to the first questionnaire.

The wide range of answers presented suggests that:

(a) Not surprisingly, economics is a key driver in the decision making process
(b) There is no consistent method employed on-farm for developing a nitrogen fertiliser recommendation
(c) Decisions on-farm can be season and year specific and tend to be influenced by a wide range of considerations
(d) Factors taken into account differed markedly between some experts.
(e) There was a feeling that there is a need to develop better supporting information to guide N fertiliser applications

Analysis of these responses allowed a flow chart describing the decision process to be tested in a second round of the web-based questionnaire. In summary, the key decisions appeared to follow this pattern:

1. 'Is feed required? This was the most common decision point, and shows that this is usually THE main driver when deciding whether to apply N, not surprisingly.
2. 'Will the grass respond?' Again, it is encouraging that this is asked. How this is decided seemed to rely on a wide number of indicators, ranging from soil moisture and temperature through to a visual assessment of whether the pasture looked short of N.
3. 'How much N? Some evidence from some respondents that there was variation in application rate, based on a range of factors. There seemed contradiction between some responses to the survey – indicating the need for better advice, preferably quantitative advice.
4. Economics. Again, not surprisingly, as this underpinned many of the decisions; return on investment in N fertiliser.
5. Environment. Some recognition and concern over potential environmental effects, particularly on nitrate leaching.

COMPARISON OF SOIL QUALITY AND NUTRIENT BUDGETS BETWEEN ORGANIC AND CONVENTIONAL KIWIFRUIT ORCHARDS

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Land Research Services Ltd, Lincoln

Three long-term (> 10 years) systems of kiwifruit production were compared at 36 sites with respect to simple input/output nutrient budgets, extractable soil nutrient levels, soil organic matter status, the size and activity of the soil microbial biomass, earthworm numbers and key soil physical properties. These systems were (i) conventional production of the green-fleshed variety ‘Hayward’ (Green), (ii) organic production of ‘Hayward’ (Organic) and (iii) conventional production of the yellow/gold-fleshed variety ‘Hort 16A’ (Gold). Crop yields and nutrient removals were least for Organic and greatest for Gold, with Green being intermediate. The major nutrients removed in the harvested crop were K and N. Simple input/output nutrient budgets showed that inputs greatly exceeded removals in the harvested crop for all nutrients considered (i.e. N, P, S, K, Mg, Ca) in all three systems, suggesting nutrient inputs could be reduced. However, the nutrients added in the Organic system were generally made up of composts, liquid fish waste and RPR may not be equally available as more soluble chemical inputs. Soil organic C and total N content were greater under Organic and Gold than Green whilst extractable P was least under Organic. Soluble C, basal respiration and metabolic quotient were unaffected by production system while microbial biomass C and N were greatest under Organic. Within systems, organic C, total N, microbial biomass C and N and mineralisable N were greater between plant rows than below the vine canopies whilst the reverse was the case for metabolic quotient and extractable P. Soil bulk density was least and water content at field capacity and earthworm numbers greatest under the organic systems. It was concluded that long-term soil fertility can be maintained adequately under organic management and added benefits are increased organic matter content, a larger microbial biomass and improved soil physical condition. Although Organic orchards generally produce less fruit than their Green counterparts, mainly due to the absence of synthetic plant growth regulators and nutritional and varietal differences, comparatively good returns and surpluses can still be achieved.

WATER FOOTPRINTING, VIRTUAL WATER AND ECO-EFFICIENCY

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The *Guardian Weekly* noted in 2002 that “water is this century’s most urgent environmental issue”. There is increasing urgency to manage sustainably the irrigation of our lands so that the gold mine of our ground and surface waters, both their quantity and quality, are protected and enhanced.

In the soil-plant-atmosphere system, the prime element of natural capital is water. Yet measuring water quantities and fluxes directly, especially by sap flow within the plant, and by drainage flux meters in the soil, still remains a challenge. Soil is both the bufferer and filterer of water, as well as providing care and provisioning for the plant. The exigencies posed by climate change means we must act now to manage our soils and waters even better, just so as to overcome the additional pressures arising from global change. Water is the key, and we need to protect its stocks and its quality.

We discuss how smart technologies linked to plant-based measurements of sap flow, soil based measurements of drainage fluxes, and integrated modelling schemes are providing new knowledge and improved tools for better quantifying the water needs of our agricultural and horticultural crops. Increasingly these tools are being used in scientist-regulator partnerships to develop resource policies to protect and sustain our soils and waters, without compromising production. This will ensure sustainable and eco-verifiable production from our agricultural and horticultural crops.

The challenges for sustainability are great, yet the prospects are bright.

A STRATEGIC APPROACH TO SUSTAINABLE AGRICULTURE

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Agriculture is worth approximately $5 billion a year to the Waikato economy, provides employment to over 25,000 people, manages 55% of our landscape and forms an essential part of our regional identity. But as it is currently practiced in the Waikato region agriculture is unsustainable.

The paradigm of continuous intensification has reached a point where natural resource limits have been, or will soon be met or exceeded and this is beginning to impinge on resource use options for the wider community (including farmers). Examples include full allocation of surface water in many of our catchments, accumulation of contaminants in soils, groundwater nitrate levels exceeding WHO guidelines, and an increase in nuisance growths in surface waters arising from increased nutrient loads.

As a result, the options and choices remaining for other resource users and for future generations are becoming limited. Farmers' irrigation choices are reduced, some soils may become unsuitable for certain crops or for urban subdivision, some recreational uses of water are restricted and some groundwater is no longer suitable for drinking. So agriculture is failing to meet the social/cultural and environmental dimensions of sustainability. Continuing intensification will lead to these effects increasing if nothing else changes and clearly that is something that cannot continue indefinitely.

Environment Waikato and its predecessors the Catchment Boards have been working to manage these effects for decades and more recently industry stakeholders and partners have become more pro-active. This has led to significant achievements in terms of stream fencing, effluent management and nutrient budgeting. What this tells us is that despite all our efforts in terms of subsidies, advice, education and regulation, we are losing the battle to contain the effects of agricultural intensification. So EW is reviewing the effectiveness of its currently permissive Regional Plan, trialling Integrated Catchment Management including whole farm planning and developing new partnership approaches to find ways to stop or reverse the negative trends and maintain the benefits of agriculture. We are currently carrying out catchment modelling, social analysis, economic modelling and policy analysis to work out what is most likely to work, and to assess the economic, social and environmental consequences of a range of policy options.

Coming out of this work will be a Sustainable Agriculture Strategy that will guide our review of the Waikato Regional Policy Statement over the next two years. It's expected that this will set new objectives and targets and will in turn direct the review of the Waikato Regional Plan. The key message is that farming as we know it in the Waikato Region is unsustainable and change is coming. The Sustainable Agriculture Strategy will ensure that EW plays its part in ensuring that the economic contribution that agriculture makes to our region can continue in a healthy and stable environment.

INTEGRATED CATCHMENT MANAGEMENT AND NUTRIENT EFFICIENCY IN THE UPPER WAIKATO CATCHMENT

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Environment Waikato is now in the third year of a pilot integrated catchment management (ICM) project looking to define nutrient efficiency in the Upper Waikato catchment. The project has looked at multiple catchment issues such as flood hydrology, biodiversity and sediment and erosion control. However, the core focus has become on-farm nutrient management as we seek to lessen agriculture's impact on water quality.

The project began after the Waikato Regional Plan was challenged legally on the basis that the council's permitted activity rules for agriculture were inadequate to prevent diffuse nutrient loss. This, it was argued, was significantly degrading water quality and therefore more stringent regulation was needed. While this challenge was unsuccessful it did highlight the need to know more about current agricultural systems, where nutrient losses were occurring, and how to counter these.

The pilot project has worked with farmers in the Little Waipa and Waipapa catchments in South Waikato. EW staff carry out farm planning individually with farmers and, as a starting point, use industry-created nutrient budgets to determine the farm's current nutrient position and look at other issues such as effluent management. From there, a full field review is carried out using DairyNZ's farm walk and other issues are identified. This project has highlighted that much detailed information was missed in the fertiliser industry's understandable rush to create nutrient budgets for all dairy farms by 2007 to meet Fonterra's Clean Streams Accord targets.

So the ICM process has critiqued the current nutrient budget, with the farmer and fertiliser rep present, and any updates or corrections are made prior to scenario modelling. Following initial farm planning work under ICM, it was clear that expert nutrient management advice was needed. This work was contracted to AgResearch Ruakura and nutrient management and farm systems advice was given. Financial analysis of nutrient scenarios was carried out to assess how changes may affect farm business. In a combined report AgResearch and EW have shown that farmers can typically lower nitrate leaching from an average of 40kgN/ha to 30kgN/ha without large losses in profitability/production.

Such a drop is still some way off an indicative target of 26kgN/ha if we are to help dairying to prevent further declines in water quality, but it is a substantial start and provides some reassurance that solutions can be found that will meet the needs of farmers and the environment.

UNDERSTANDING THE VARIATION IN LIMITING NUTRIENT STATUS OF RIVERS IN THE HORIZONS REGION

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Nitrogen (N) and phosphorus (P) enrichment of waterways can have adverse effects on ecological, aesthetic and recreational values. In the past, phosphorus was commonly thought to be 'the limiting nutrient' for periphyton growth in many of the Region's Rivers. Management of the Manawatu River in particular has in the past relied on reducing phosphorus inputs to avoid nuisance periphyton growth.

Long-term State of the Environment N & P data were analysed against river flow for a number of sites in several of the Region's river catchments. Variation in the limiting nutrient status was found at a number of sites, particularly at low flows. Low flow investigations of water quality in two catchments found large spatial variation in limiting nutrient status on the same day, within the same sub-catchment. Anecdotal observations of periphyton communities at these sites noted change from filamentous green algae to potentially toxic cyanobacteria dominated mats, depending on the limiting nutrient status. Further work to determine the response of periphyton communities to nutrient limitation is needed.

More analysis of the variation in limiting nutrient status with flow, geology, land use and periphyton community composition is planned so the complex relationship between these variables is better understood. However, developing a regulatory framework for nutrient management, based on such highly complex interactions would be fraught with management issues and scientific uncertainties.

The One Plan proposes management of both nitrogen and phosphorus at all flows less than floods. As we learn more about the interactions between nutrient concentration, flow and periphyton in impacted river catchments, it becomes clear that the best approach is a catchment-specific framework, based on the combined management of N and P.

GROWING RESILIENCE: FIVE YEARS AFTER THE FRANKLIN SUSTAINABILITY PROJECT

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The market garden areas of the Franklin District are intensively managed ecological areas that are vital to the continued stability of social systems in the Franklin District and New Zealand at large. Environmental problems associated with common market garden management practices utilised in the District include soil erosion, soil quality degradation, and groundwater contamination. The Franklin Sustainability Project (FSP), a groundbreaking resource management approach initiated in 1997 and completed in 2004, utilised collaborative adaptive management techniques to address these complex environmental concerns. Five years after the termination of the FSP, despite many major improvements, the Franklin District market garden areas are still struggling to deal with numerous environmental problems. Figures from studies conducted in 2002 and 2004 reveal an overall decline in best management practice implementation and maintenance over the two year period, and preliminary results from a study conducted in January 2009 suggest that best management practice implementation and maintenance remains low. A cooperative and coordinated approach to policy, research and monitoring, land management and compliance work is currently being undertaken by the Auckland Regional Council to confront ongoing problems in the Franklin District market garden areas. Additionally, research is being conducted regarding the ability of different resource management approaches to generate long-lasting resilience in the region. Increasing the resilience of social-ecological systems may be an efficient way for resource management decision makers to improve the long-term stability of intensively managed and vulnerable ecosystems such as those found in the Franklin District market garden areas.