DESIGNING SUSTAINABLE FARMS

Critical aspects of soil and water management

ABSTRACTS

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THE IMPACTS OF ENVIRONMENTAL BEST MANAGEMENT PRACTICES ON LANDCORP FARMING

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An outline of Landcorp Farming and its obligations and responsibilities (including environmental obligations) to its shareholders will be presented.

A number of strategic initiatives will be outlined along with a discussion of some of the more significant developments the Company has undertaken over the last five years and the reasons for them.

There will be an outline of a series of specific environmental initiatives Landcorp Farming have undertaken on farm and discussion about the general effects of these.

NEW NITROGEN MITIGATION TECHNOLOGIES FOR EVALUATION IN THE LAKE TAUPO CATCHMENT

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Planned implementation of a nitrogen (N) "cap" on land in the Lake Taupo catchment has led to the need for a range of options for pastoral farmers to increase profitability while farming within the N cap. A multi-disciplinary research programme has focused on the potential of targeting different parts of the N cycle to increase N efficiency and reduce N leaching losses. A range of research areas have been examined which focus on soil amendments, improved pasture plants, animal manipulation and farm system options. Results from this research will be presented.

The "best bets" of practical options from this research have been assessed and the final four N mitigation treatments have been selected for evaluation in a new farm grazing system trial within the Lake Taupo catchment. The trial development, details about its implementation, and the role of local farmers through the Taupo Lake Care group will be discussed.

FARM MANAGEMENT PLANS AND MITIGATION OPTIONS RELEVANT TO FARMS IN FOUR CATCHMENTS USED FOR INTENSIVE DAIRY FARMING

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On-going monitoring of streams and farms within the Toenepi (Waikato), Waiokura (Taranaki), Waikakahi (Canterbury) and Bog Burn (Southland) catchments shows that some improvement in farm environmental performances would generally be desirable, with stream concentrations of nutrients (N and P), sediment and faecal bacteria regularly exceeding guidelines recommended for surface waters. As part of this project, a catchment management planning process has been followed to strategically direct science activities and extension efforts targeting farmer adoption of key land management practices. Within each catchment this planning process has, in sequential order, (i) made an assessment of water quality status, (ii) identified the key linkages between land management activities and water quality, (iii) defined the key values associated with each catchment, which in turn defined a set of catchment-specific water quality targets, (iv) determined the most appropriate land management guidelines required to deliver to these targets, and (v) developed and implemented farm plans of varying complexity that address the key environmental performance indicators identified. This planning process has identified a number of lessons pertinent to the success of extension/adoption initiatives in the catchments. Farmers have identified that they prefer to consider a suite of mitigation options so that they can match individual practices to their farm context, rather than have prescriptive practices imposed upon them. This recognises that factors such as soils, topography, existing farm infrastructure and lifestyle combine to influence farmer decision-making. Accordingly, a range of BMPs have been incorporated into a Toolbox of practices which documents their effectiveness, cost-effectiveness and relevance. This Toolbox has increasingly been used to guide the Farm Planning initiatives underway within the catchments. Field-day presentations followed by one-on-one interactions via Farm Planning initiatives show some success in improved farm environmental performance, as evidenced by changes in fertiliser and effluent management practices. However, the adoption of other more costly management practices has occurred at a much slower pace.

THE NEXT CHAPTER IN REGIONAL POLICY DEVELOPMENT TO MANAGE ADVERSE EFFECTS OF LAND USE INTENSIFICATION

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The aim of this paper is to discuss how regional policy is being developed to manage the adverse effects of land use intensification. The paper discusses the historical changes in the dairy industry, which in the past decade has seen a significant growth in cow numbers on Waikato farms. As cow numbers have increased, there has been a corresponding increase in the use of nitrogen fertiliser. Effluent excretion by larger numbers of dairy cows, combined with increased leaching of nitrogen has begun to have a major impact on water quality.

This deterioration of water quality throughout many of the region's rivers and streams is potentially exacerbated by the proposed pine-to-pasture conversions in the upper catchments of the Waikato River. The large scale of these proposed conversions (60,000 ha) are likely to result in a further significant increase in cow numbers - which in turn is liable to see additional increases in nitrogen levels leaching into water.

If we are to maintain water quality in the Waikato at today's levels, and allow these pine-to-pasture conversions with their attendant economic benefits, it is estimated that industry will have to find ways of reducing average nitrogen leaching.

Apart from issue of water quality, the paper touches on another major problem arising from the proposed pine-to-pasture conversions, which is the potential impact on downstream landowners due to the increasing volumes of water run-off occurring in the converted land. This could have major flooding implications.

The paper stresses the importance of agriculture to the region's economy, which accounts for some 30% of regional GDP and employs 33,000 people. Therefore the paper not only discusses the range of policy instruments available to the regional council, but also challenges the lime and fertiliser research industries to provide scientific solutions to the issue of nitrogen pollution. We need to work together on these issues for the good of the nation’s economic and environmental future.

NUTRIENT MANAGEMENT PLANNING –
THE ENVIRONMENT WAIKATO APPROACH

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Fertiliser application is a Permitted Activity in the Waikato Regional Plan subject to conditions (Rule 3.9.4.11). This rule is operative now. One of the conditions is that farmers are required to have a Nutrient Management Plan (NMP) if they are applying more than 60 kg nitrogen fertiliser per ha and year. A NMP is based on a nutrient budget, summarising the inputs and outputs of the farm system. Using this information the NMP then requires the farmer to document the practical steps that will be taken to reduce or mitigate nutrient and sediment losses from the property.

The Clean Streams Accord target is for every dairy farm to have a nutrient budget by 2007. Environment Waikato promotes the concept and acknowledges the work that fertiliser companies are doing to meet this target.
However, a nutrient budget does not meet all the requirements of a NMP. Therefore farmers presenting a nutrient budget only will not be complying with Environment Waikato's fertiliser rule. The nutrient budget has to be acted on to avoid, remedy or mitigate adverse effects on the environment. The farmer needs to document the specific nutrient management actions taken on a property, which could be related for example to effluent storage and land application practices, riparian management, defusing nutrient hot spots or a change of wintering practices.

Environment Waikato is taking a staged approach with implementation of the fertiliser rule. The first stage is communicating this "new" rule, raising awareness amongst rural professionals and the farming industry, emphasizing why considerable changes are necessary. The focus therefore is on education now. Extension events are delivered at a staggering frequency in our region right now and farmers are actively seeking advice to get it right.

Environment Waikato is also working with stakeholders and the fertiliser industry to develop consistent messages and approaches across the industry. Implementation of best nutrient management practices will help future proofing the farming industry in the Waikato.

USING OVERSEER NUTRIENT BUDGET MODEL IN NUTRIENT MANAGEMENT PLANS

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The Overseer nutrient budget model produces nutrient budgets and indices linked to productivity or environmental impacts that may be useful for developing nutrient management plans. Thus the impact of supplements, fodder crops, effluent management systems, and nutrient conversion efficiency on the nutrient budget can be assessed. The Overseer nutrient budget model also allows different options that are been evaluated as part of developing a nutrient management plan to be compared. When coupled with farm system analysis, this provides a powerful tool to assess options considered as part of the development of a nutrient management plan. However when using the Overseer nutrient budget model for scenario evaluation, the assumptions behind the model need to be understood.

This paper will use case studies to demonstrate the assumptions behind the Overseer nutrient budget model, and outline some of the strengths and limitation in using the model for development of nutrient management plans.

FIVE YEARS IN THE FIELD: HOW TO EFFECT BEHAVIOUR CHANGE ON THE FARM THROUGH NUTRIENT MANAGEMENT PLANNING

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The major challenge confronting New Zealand's pastoral industry, and especially dairying, is how to maintain productivity and at the same time reduce the environmental impact of farming. To achieve these twin goals will require major changes in thinking and behavior.

agKnowledge Ltd has been preparing nutrient management plans for individual farmers for 5 years, using its Total Nutrient Management (TNM) system. In this paper we discuss the key components of TNM process and identify those factors which we believe are critical in assisting farmer to change their nutrient management practices. These include: spending sufficient time on the farm to understand both the farm and the farmer, providing the farmer with sound scientific information in a manner that is readily understood and explaining in detail the scientific basis for sound nutrient management practices. Experience, credibility and independence all appear to be vital when dealing with farmers.

The service industry assisting farmers in respect to nutrient management is assessed relative to these criteria.

SLUI WHOLE FARM PLAN PROTOTYPES

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Widespread storm damage across the Manawatu-Wanganui Region in February 2004 resulted in the establishment of SLUI (The Sustainable Land Use Initiative). Purpose of the initiative is to help farmers in-build greater resilience to future storm events through the voluntary preparation and implementation of Whole Farm Plans. Fifteen-hundred such plans are required for the Region's most at risk farm properties.

A Whole Farm Plan represents a documented assessment and time-bound plan of actions for dealing with on-farm risks and opportunities for sustainable resource management **and** sustained business growth. Integrating resource management and farm business recognises that these two factors cannot be treated separately when farm sustainability is the goal. Plans are tailored specifically to the situation and needs of individual farm properties.

This poster reports on the design and development of six Whole Farm Plan prototypes for SLUI, including an outline of plan components, the planning process, and an update on the transition from prototype to programme implementation.

FARMER PERCEPTIONS OF THE DAIRYING AND CLEAN STREAMS ACCORD

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The first record of dairy cows arriving in New Zealand was in December 1814. From this point on the dairy industry expanded throughout the country, and as technology and export markets grew so did the demand for more dairy produce. In the last 30 years the dairy industry in New Zealand has intensified at an alarming rate with dairy cow numbers close to doubling from 1975 to 2005. The impacts of this rapid growth are evident in the lowland waterways. In dairy intensive catchments elevated levels of nutrients and sediment have degraded water quality.

The Dairying and Clean Streams Accord was signed in May 2003 between Fonterra Cooperative Group Limited, The Ministry for the Environment (MFE), The Ministry of Agriculture and Forestry (MAF) and Local Government New Zealand. The purpose of the Dairying and Clean Streams Accord is to promote sustainable dairy farming in New Zealand. It focuses on reducing the impacts of dairy farming on the quality of streams, rivers, lakes, ground water and wetlands. There are five Accord targets to be implemented by Fonterra dairy farmers between 2007 and 2012.

This thesis examines the perceptions dairy farmers have of the accord. Anonymous surveys were posted to 1000 Fonterra suppliers throughout New Zealand who were selected randomly. The survey is designed to assess farmers' understanding of the accord and the issues surrounding its implementation. In addition the complex relationships between accord variables will be investigated.

Preliminary results demonstrated a lack of understanding of the five accord targets by dairy farmers. The research also shows variance in the level of implementation for the five accord targets throughout New Zealand. This has been influenced by prioritization of regional policy and varying regional issues. In addition the economics of dairy farming is contributing to several demographic trends that are highly visible. The combination of these findings suggests an increased level of implementation of the Dairying and Clean Streams Accord requires a more hands on and case-by-case strategy.

THE SENSITIVITY OF OVERSEER AS A NUTRIENT BUDGETING AND MANAGEMENT TOOL AT THE EXTREMES OF SOIL FERTILITY

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The nutrient budgeting model, OVERSEER, is widely used throughout New Zealand to determine whether fertiliser inputs are adequate to maintain soil fertility levels and to assess the losses of nutrients, particularly N and P, to the wider environment. The model, which predicts the fate of nutrients within a system, must be robust enough to make accurate predictions for a wide range of scenarios. This study examines the accuracy of OVERSEER predictions on sheep grazed hill-country pastures which have received either no fertility (NF), low fertility (LF) or a high fertility (HF) inputs in the last 25 years. These inputs equate to either below maintenance, maintenance or above maintenance fertiliser applications.

The models predictions for Olsen P were accurate, particularly for LF. The models predictions for N were accurate for LF, but poor for NF and HF. The predictions for N were largely influenced by the clover levels. The predictions for K, Ca, Mg and Na were for a small increase in each of these nutrient pools. Changes in soil test values indicate a small decrease in the amounts of exchangeable K, Ca, Mg and Na, suggesting that OVERSEER is either overestimating weathering rates or underestimating the loss of cations through leaching. The good relationship found with Olsen P suggests that the animal transfer factor in OVERSEER provides a reasonable guide to the amount of nutrient being transferred by animals during grazing.

The accuracy of OVERSEER's predictions for Olsen P and N varied, with the best predictions found at LF. In this study the LF system equated to a grazed pasture receiving an annual maintenance fertiliser input. At NF and HF, equating to below maintenance and above maintenance, respectively, OVERSEER did not model the fate of P and N as accurately, indicating that at the extremes of soil fertility the functions in the model have limitations. OVERSEER was not able to accurately predict the fate of cations, indicating that soil tests are still required to determine the actual changes in nutrient status occurring within the soil.

EFFECT OF P FERTILISER FORM ON P RUN-OFF – A CATCHMENT SCALE STUDY

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A three year study comparing the effect of fertiliser form on P run-off at a catchment scale was carried out in hill country near Waipawa in the Hawke's Bay. The trial was set up on two similar 12 ha catchments with a long history of water flow and P concentration records, which showed that the catchments were hydrologically very similar. Either reactive phosphate rock (RPR) or single superphosphate (SSP) was applied at the same rate of P to each catchment (alternating between catchments each year) and rainfall, catchment flow and runoff DRP (dissolved reactive phosphate) and TP (total phosphate) were measured throughout the period of annual flow, usually from autumn to late spring-early summer. In the 8 week period after fertiliser application average DRP and TP losses over the 3 year period were 212% and 94% higher respectively from the SSP fertilised catchment than from the RPR fertilised one. For the first two years, total annual losses of DRP and TP from the SSP catchment were on average 192% and 40% higher respectively than from the RPR catchment. Annual results for the third year are not yet complete. The results to date show that fertiliser form has a very significant effect on P losses from surface run-off – particularly DRP losses in the period immediately following fertiliser application. This high loss over a relatively short period represents a large proportion of total annual P losses, thereby showing that RPR fertilised pasture has significantly lower total annual P (TP and DRP) losses than pasture fertilised with SSP.

HYDROLOGIC APPROACHES TO THE DELINEATION OF CRITICAL OVERLAND FLOW SOURCE AREAS FOR NUTRIENT MANAGEMENT AND WATER QUALITY PROTECTION

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Surface transport of nutrients and sediment has resulted in water quality concerns in New Zealand and elsewhere. Since the 1960s, several hydrologic field studies and modelling approaches have attempted to identify and delineate the source areas of overland flow which mediate losses. However, very few of these studies have been applied for practical water quality management. This study reviews the ease of application and implementation of five hydrologic approaches or models, empirical as well as process-based, in delineating overland flow from critical source areas, which in-theory accounts for the vast majority of contaminant (e.g., nutrients such as phosphorus [P], and sediment) at a catchment scale.

The hydrologic models used were, (i) the P index (PI), a P management tool that assumes 50 m either side of the stream as the area to manage overland flow; (ii) the curve number (CN) model, which uses an empirical method to divide rainfall into runoff and infiltration; (iii) the topographic index (TI), which ranks catchment areas in accordance to their propensity to become saturated during rainfall events and generate saturation-excess overland flow; (iv) a process-based model that combines areas of saturation-excess (based on TI) and infiltration-excess overland flow; and (v) a drainage density model, which combines catchment topographic properties with rainfall data and the CN model. The five approaches were tested on the Silverstream catchment near Dunedin. All input data were derived from publicly available data sources: rainfall and stream flow data from 1988 to 2006 were collected at the outlet by the Otago Regional Council. Runoff volumes were predicted for a 1-year return period rainfall event (43.5 mm) under dry and wet catchment conditions.

Based on the preliminary results, it appears that depending on the availability of input data, a combination of two or more approaches/models with explicit spatial routing of overland flow might be needed for the prediction of overland flow in critical source areas.

WHAT HAPPENS TO LEACHED NITRATE AND BROMIDE IN THE SOIL AND VADOSE ZONE IN CANTERBURY

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We have been investigating the transport and transformations of nitrate and bromide in the vadose zone at a field site near Lincoln, on the Canterbury Plains since spring 2004. The vadose zone, formed through alluvial processes, consists of a matrix of coarse gravel, sand and silt underlying a ~1 m deep Templeton silt loam to a water table at approximately 9 m.

Nitrogen fertiliser (at 400 kg N/ha) and bromide (at 200 kg Br/ha, a conservative tracer) were applied together in October 2004 (to potatoes) and November 2006 (to pasture following potatoes). Irrigation was subsequently applied to transport nitrate and bromide through the soil profile. The transport and transformation of nitrate and bromide has been monitored using a combination of soil sampling, suction cups, monitoring wells and gas samplers. The site has been instrumented with suction cups inserted on an angle of approximately 15 degrees to depths of 0.6, 1, 3, 5, and 7 m. Gas samplers are attached to the suction cup access tubes at depths of 1, 2, 3, 5, and 7 m. Soil moisture has been monitored to a depth of 3 m using a neutron probe, combined with occasional gravimetric soil samples. The hydraulic properties and water holding capacity of the vadose zone have been characterised from large trenches, bucket auger holes, and exposed vertical faces.

Suction cup and gas samples have been taken at regular intervals over the study depending on expected rates of movement and transformations. There was significant rainfall in December 2004 and January 2005 that caused rapid movement of the bromide and nitrate through the soil and vadose zone. A similar pattern of nitrate and bromide transport has been observed from the November 2006 application of fertiliser and tracer, following rainfall and irrigation. Rapid movement of the tracer in the vadose zone to 7 m depth indicates a very low effective transporting volume of water. However, longer term observations of the tracer concentration indicate that a portion of the water and tracer is moving much more slowly, probably reflecting exchange with less mobile matrix solution.

N_2O EMISSIONS FROM GROUNDWATER UNDER AGRICULTURAL LANDUSE - A CASE STUDY FROM A SANDY AQUIFER IN GERMANY

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The research area is the Fuhrberger Feld aquifer (FFA) in northern Germany. It is situated about 30 km northeast of the city of Hannover and covers about 300 km^2. Our research focused on a representative strip under predominantly arable land along a groundwater flow-line.

Six multilevel sampling wells were sampled from the groundwater table down to a depth of 10 m below the soil surface for one year. We measured N_2O, CO_2, NO_3^-, SO_4^{2-}, DOC, pH, redox potentials and O_2 concentrations once a month.

N_2O accumulated at four out of six wells close to the groundwater table. About 20% of N_2O that occured between the groundwater table and 7-8 m below it resided in the top 0.4 m.

We identified an exchange zone for N_2O at the interface between the saturated and the unsaturated zone. It extended 0.55 ± 0.22 m below the groundwater table and acted as a source and sink for N_2O. N_2O below the exchange zone cannot contribute to indirect emissions. We estimated the upward fluxes from the groundwater into the unsaturated zone at the six wells to range between 0.0009 and 0.249 kg N_2O ha^{-1} $year^{-1}$. The yearly downward fluxes in the exchange zones of the different wells had about the same order of magnitude as the upward fluxes. The groundwater acted also as a sink for N_2O.

N_2O-N:NO_3-N ratios were highly variable with maximum values close to the IPCC EF5-g of 0.015 and the smallest values were two orders of magnitude lower.

A multiple regression for the monthly N_2O amounts in the exchange zone could explain 66% of the yearly variation. The significant variables were NO_3^-, CO_2, pH, and O_2. Therefore, a combination of the land-use (NO_3^-), the geochemical boundary conditions (pH) and the type of denitrification reaction (O_2 and CO_2 indicate the importance of a heterotrophic denitrification process) governed the N_2O dynamics in the surface groundwater of the FFA and its transfer into the unsaturated zone.

MATRIX-BASED FERTILIZERS:
A NEW FERTILIZER FORMULATION CONCEPT TO REDUCE NUTRIENT LEACHING

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We compared the efficacy of matrix based fertilizers (MBFs) formulated to reduce NO_3^-, NH_4^+, and total phosphorus (TP) leaching, with Osmocoate® 14-14-14, a conventional commercial slow release fertilizer (SRF), and with an unamended control in greenhouse column studies. The MBF formulations covered a range of inorganic N and P in compounds that are relatively loosely bound (MBF1) to more moderately bound (MBF2) and more tightly bound compounds (MBF3) mixed with $Al(SO_4)_3\ H_2O$ and/or $Fe_2(SO_4)_3$ and with high ionic exchange compounds starch, chitosan and lignin. When N and P are released, the chemicals containing these nutrients in the MBF temporarily bind N and P to a $Al(SO_4)_3\ H_2O$ and/or $Fe_2(SO_4)_3$ starch- chitosan- lignin matrix. One milligram (8000 spores) of *Glomus intradices* was added to all formulations to attempt to enhance nutrient uptake. In this first series of experiments, soil columns were planted to white soft spring wheat (*Triticum aestivum* L.cv. Frame). Three soils were used, a sand, a loam and a loamy sand. In several studies, SRF leachate contained higher amounts of NH_4^+, NO_3^- and TP than leachate from all other fertilizers. Although plant biomass and yield with MBF was reduced in the first series of experiments, follow-up studies have shown that formulation adjustments allow comparable plant responses among SRF and MBFs. We are continuing research to optimize formulations and application rates. There were no consistent differences in the amount of NH_4^+, NO_3^- and TP in the MBF leachates compared to the control leachate. Arbuscular mycorrhizal infection in plant roots did not consistently differ among plants growing in soil receiving SRF, MBFs and control treatments. The efficacy of MBF fertilizer strategy to reduce N and P leaching is expected to provide a new approach for groundwater protection, especially in easily drained soils. The approach has been submitted for patenting.

LOW GROUNDWATER N CONTAMINATION IN SPITE OF HIGH LAND USE INTENSITY - THE TOENEPI DAIRYING CATCHMENT EXPERIENCE

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The Toenepi Catchment is one of the ‘Best Practise Dairying Catchments for Sustainable Growth’ that have been investigated by various research groups. NIWA and AgResearch have focused on surface water and soil quality and on farm management, while LER and ARL have addressed knowledge gaps on subsurface water quality and nitrogen transformations. The catchment is a well-established, mainly flat or undulating dairying area near Morrinsville in the Waikato. In 2003, the average stocking rate was 3.2 cows ha^{-1} and the average N fertiliser application was 98 kg N ha^{-1}. Well-drained Allophanic soils together with Granular soils dominate, but there are poorly drained Topehaehae Gley soils in the lowest lying areas. Our work has focused on shallow groundwater sampled in seven well transects representing the major site and land use patterns. Each transect consists of 4 – 7 wells, which are typically 2.5 m to 3.0 m deep. The wells were sampled monthly from Dec 2002 to Dec 2004 and analysed for inorganic N. Surprisingly, nitrate concentrations in the shallow groundwater were generally very low. Eighty percent of the 843 samples had concentrations below the ANZECC trigger value for eutrophication (0.44 mg NO_3-N L^{-1}). Only 3% of all samples were above the WHO drinking water guideline (11 mg NO_3-N L^{-1}). AgResearch estimated long-term average leachate concentrations in the catchment using their OVERSEER model. Leachate concentrations ranging from 3 – 12 mg NO_3-N L^{-1} were estimated for the farms on which we have monitored groundwater concentrations. These concentrations, which are estimates for the bottom of the root zone (approx. 60 cm), are considerably higher than the concentrations measured in the shallow groundwater (median water tables between 70 and 210 cm below ground surface). Monitoring of soil solution concentrations showed consistent decreases from 60 to 120 cm depth, which were attributed to subsoil denitrification. While denitrification is considered the main mechanism that can explain the drop in nitrate concentrations between the bottom of the root zone and the groundwater, artificial drainage can in some instances additionally reduce the contamination of groundwater. However, that comes at the cost of providing an unwanted short-circuit for nitrate directly into Toenepi Stream.

THE EFFECTIVENESS OF A NITRIFICATION INHIBITOR, ECO-N, IN REDUCING NITROUS OXIDE EMISSIONS IN DIFFERENT GRAZED PASTURE SOILS

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This paper reports a study of the effectiveness of a nitrification inhibitor, dicyandiamide (DCD), commercially known as 'eco-n', to reduce nitrous oxide (N_2O) emissions from animal urine patches in four different soils. Nitrous oxide is a potent greenhouse gas and, in New Zealand, about a third of the total greenhouse gas emissions from the agricultural sector are of N_2O, mostly derived from animal excreta in grazed pasture soils. The four soils used in this study are Templeton fine sandy loam and Lismore stony silt loam in Canterbury in the South Island, Horotiu silt loam in the Waikato region, and Taupo pumice sand near Lake Taupo, both in the North Island. Results showed that the application of a fine-particle-suspension nitrification inhibitor, DCD (commercially known as eco-n), to grazed pasture soils was very effective in reducing N_2O emissions in all four different soils. Total N_2O emissions from animal urine patches ranged from 1 to 20.9 kg N_2O-N ha^{-1} without DCD. These were reduced to 0.31-5.7 kg N_2O-N ha^{-1} by the use of DCD, representing 61-73% reductions (with an average of 70% reduction). The N_2O-N emission factor from animal urine N, EF_3, was reduced from an average of 0.9% to 0.3% by the use of DCD. These results demonstrate the potential of using nitrification inhibitors to mitigate N_2O emissions in a wide range of grazed pasture soils under different climatic and management conditions.

SUMMARY OF NZ SUSTAIN TRIALS TO DATE

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SustaiN is the trade name for a nitrogen (N) fertiliser product based on Agrotain treated urea. Agrotain is a patented urease inhibitor (NBPT) that is applied to urea to slow down the hydrolysis of urea into ammonium once it is applied to pasture and crops. By slowing down the hydrolysis process, direct losses of fertiliser N are reduced and the fertiliser N is made more available to the plant. The product has been available in NZ for almost five years and agronomic trials began at the end of 2003. To date there have been 14 individual trials completed/still running situated throughout NZ with 96 individual same rate N comparisons between SustaiN and urea. In these trials SustaiN has averaged N responses 57% higher than urea, with lower rates of application producing more significant increases than higher rates. More recent trial work however, would suggest that more frequent applications of lower rates (every 3 weeks), reduces the advantage of lower rates over higher rates. Possible explanations for SustaiN's significant performance improvements over urea and variations in the response from different rates of application are discussed. Overall, the results from the trials show that SustaiN holds considerable promise for improving both N use efficiency and fertiliser N cost efficiency over standard urea, making it a more preferred N fertiliser choice. The full extent of the product's mode of action and response in varying conditions are not yet fully understood and more work is continuing to answer remaining questions.

IMPROVING MARKET-BASED INSTRUMENTS THROUGH ROLE-PLAYING-GAMES:
NITRATE TRADING IN NEW ZEALAND

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Market-based instruments (MBI) such as tradable permits have been shown to be effective and efficient policy instruments. In many circumstances they can lead to better results than more traditional policy approaches. Yet MBIs often face opposition from stakeholders. This may be due to uncertainty about how they will operate in practice and their economic, environmental, and social consequences.

Water quality in Lake Taupo – the largest freshwater lake in Australasia – has decreased significantly over the last 30 years through increased nitrogen inflows, primarily from pastoral farming. The local authority has proposed a catchment-wide limit on the amount of nitrate leaching activity from each farm or other rural property, with ability for land users to trade "nitrogen discharge allowances". The proposed mechanism faces opposition from a variety of stakeholders.

We tested whether a role-playing-game involving the simulation of the proposed cap and trade regime for nitrate runoff would affect stakeholders' attitudes towards the proposed instrument, and whether it would help to identify consequences of trading and provide useful information for policymakers on instrument design.

The role-playing game involved several players with hypothetical properties over a number of years, making decisions about how to manage the property (e.g. change the land use) and whether to buy or sell nitrogen discharge allowances. The game was designed to reflect policy settings as proposed by the local authority.

In order to assess attitudinal change, participants completed a survey prior to the game and repeated it immediately afterwards. The results showed a significant positive shift in participants' views about the willingness of landowners to sell nitrate allowances and indicative positive shifts on several other attitudinal statements. Of the 28 participants, seven showed a significant overall positive shift in their attitudes towards nitrate trading in the Taupo catchment, and one showed a significant negative shift (90% confidence). Of the seven positive shifts, five had an interest in farming and five were over age 50.

SOIL QUALITY ASSESSMENT MEASURING BIO-PHYSICAL PROPERTIES OF TWO APPLE ORCHARDS IN HAWKE'S BAY

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Apple production has increased over the past decades. Concerns in the marketplace and within the orchard about possible negative impacts of conventional food production practices on human health and environmental quality has increased. These concerns led to increased grower interest in developing environmentally sound and sustainable management practices. One of the objectives of sustainable land use is to maintain a high soil quality.

We will focus on an organic and a neighbouring integrated apple production system in Hawke's Bay. The two orchard production systems operate for more than 10 years under a different soil carbon management. In the integrated system, there is no pasture in the tree rows as they regularly receive herbicides. Regular compost application, and pasture in the tree rows characterizes the organic management system. For one year we measured soil biological activities (microbial biomass, basal respiration, dehydrogenase activity) in the topsoil as a sensitive indicator of soil quality. We will relate the differences in microbial activities to the land-management induced differences in soil carbon.

In the next step we analyze if the differences in soil carbon and microbial activities also have an impact on the soils ability to facilitate water movement (= infiltration rate) and resist the degradation of soil structure (= aggregate stability).

In November 2006 we measured these two soil physical functions together with microbial soil properties (microbial biomass, dehydrogenase activity) at one soil profile in the organic and one in the integrated orchard at several depths. We will analyze and discuss how much differences in the physical functions are indicated by differences of the microbial properties.

TESTING LUCI: PREDICTIONS AND MEASUREMENTS OF NITRATE LEACHING AND RISK FOR A RANGE OF LAND-USE SCENARIOS

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The LUCI Framework Model (LFM) is a collection of crop, pasture and soil models that allows the simulation of changes in soil status, N leaching and plant productivity over arbitrary lengths of time using arbitrary sequences of crops and pastures. The model requires a physical and chemical description of the soil profile, and uses daily weather data to drive the simulations. That means it is able to assess the effects of rain and irrigation events in a way not possible for systems that use much longer timesteps. LFM allows the assessment of the effects of a change in land-use on soil status and N leaching over an extended period of time. It can also be used to generate probability distributions of production, soil status and leaching by using fixed initial conditions but repeating simulations using different weather scenarios, for instance using a moving time slice of weather data from a 100 year record. Some of the individual crop models within LFM have been rigorously validated and subject to scrutiny in peer reviewed papers. Until recently, much less attention had been given to validating the predictions of percolation and leaching. In this paper, we present results of model tests with experimental data from crops at Lincoln and in the Waikato.

PROXIMAL SENSING OF SOIL AND PASTURE DEVELOPMENT UNDER "FOREST TO FARM" LAND USE CHANGE

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Current "forest to farm" land use changes are generating concerns relating to reduced forest sinks for carbon sequestration, water quality and increased pressure on water resources for irrigation. The challenge is to design new pastoral farms within the limitations of their environs. However to enable this process the impacts of land use change on soils and their environment must first be measured.

We selected sites under recently converted pastures (1-yr, 3-yr, 5-yr conversions) and permanent pasture at three farms in the Taupo-Rotorua Volcanic Zone. An ASD FieldSpec Pro Vis-NIR spectroradiometer was used to collect diffuse reflectance spectra of soils and pasture. Soil and pasture reflectance targets were sampled for physical and chemical analysis. EM mapping, using a Geonics EM38 electromagnetic sensor attached to a farm-bike, with on-board RTK-GPS, enabled real-time mapping of soil variability.

Soil fertility results show rapid increase in Olsen P, with soils reaching their optimum agronomic range within 3 – 5 years, after conversion, at two of the three farms. Soil pH decreased and CEC tended to increase with conversion to pasture. Soil C increased by approximately 0.7 % per year for the first 5 years after conversion at two of the farms. This equates to a soil C sequestration rate of 15 T CO_2/ha/yr. C:N ratios reduce from 16 – 18 in 1-yr conversion pastures to11 in permanent pastures, suggesting that in initial years of pasture establishment, N leaching to freshwater is reduced due to its immobilization into soil organic matter.

Diffuse reflectance spectra were used to successfully predict variation in soil C and N. EM maps indicated highly variable soil profiles in newly converted soils and provide information to allow site specific management, i.e. variable rate fertilizer application and precision irrigation.

Our research indicates that "forest to farm" land use change, with inputs of N, P, K and S to soils, allow significant soil C sequestration (15 T CO_2/ha/yr) for at least five years after conversion. Decreasing C:N ratios during this time minimize N leaching risk. The design of these new pastoral farms can be facilitated by proximal sensing tools which allow real-time mapping of soil properties across the landscape.

FOREST TO PASTURE CONVERSION – THE SOIL QUALITY CHALLENGE

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In New Zealand land-use changes between plantation forest and pasture have continued for many years, driven mainly by a combination of changes in government policy and economic conditions. Declining returns from forestry and increased demand for land for pastoral farming has lead to increased conversion from forest to pasture in many areas, including Canterbury. The ecosystem balance (or imbalance) developed after many years of forest cover coupled with an intrusive harvest operation, and mulching of residue wood material leaves behind a soil that is acidic, containing toxic levels of available aluminum, low available nitrogen and a very high C:N ratio, devoid of earthworms and structural integrity. This range of inadequacies would easily place such a soil in the category of poor quality.

A major challenge of the conversion process is in overcoming the chemical, physical and biological hurdles posed by the soil such that pasture can be successfully established and maintained by methods that are environmentally sustainable and cost effective. Low pH and low available N were highlighted as major limitations and a trial was pursued to determine the best regime of lime and nitrogen. An experiment was established in April 2005 to determine the effect of different pasture and cropping sequences on pasture establishment and growth, weed populations and soil properties.

This presentation briefly outlines some of the land management solutions currently being trialed and highlights some results obtained from assessment of chemical, physical and biological parameters.

MOVEMENT OF N, P, AND C FROM SOILS TO WATERS IN HILL COUNTRY PASTURES

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Movement of N, P and C from soils to waters varies with fertiliser treatment, soil fertility, stocking rate and rainfall. Two "long-term farmlets" at Ballantrae (No-P and High-P with 375 kg/ha/y superphosphate) have seepage zones that generate spring water, allowing us to study nutrient movement from soils to waters in mini-catchments at these fertility extremes. Winter 2006 had above average rainfall with many rain storms; there were two intense storms where surface flow occurred. During other storms water perched at about 30 cm in the subsoil, and moved to the springs solely by subsurface flow. Mean NO_3-N concentration at High-P was higher in 2006 than in 2005, as was the surface and subsurface runoff, giving a calculated loss of 41 kgN/ha/y, compared with 21 kgN/ha/y in 2005; at No-P it was 3 kgN/ha/y. Mean losses in drainage for High-P and No-P, respectively, were 0.9 and 0.2 kgN/ha/y for NH_4-N, 0.7 and 0.1 kgN/ha/y for dissolved reactive P, 8 and 4 kgN/ha/y for dissolved organic N (DON), and 140 and 230 kgC/ha/y for DOC. The DOC/DON ratio was wider at No-P (55) than High-P (17).

During an intense storm on July 6th 2006 the water table was at the soil surface, and surface flow occurred. The P concentration in surface flow at High-P was very high (1.2 mgP/L) compared to that in subsurface flow (mean 0.1 mgP/L, median 0.04 mgP/L). Similarly, the NH_4-N concentration during this storm was high (0.4 mgN/L) compared with that in subsurface flow (mean 0.09 mgN/L, median 0.03 mgN/L). This indicates that DRP and NH_4-N (possibly from dung and urine) were not strongly sorbed in the top of the A horizon, whereas they were sorbed and filtered in the deeper soil. NO_3-N concentrations in surface flow, however, were lower than in subsurface flow (1 mgN/L compared with 7 mgN/L) suggesting that NO_3-N was generated within the soil. The processes governing release of N, P and C from soil will be discussed together with implications for Overseer, and for leaching in hill country in different seasons and rain events.

MANAGEMENT OF IRRIGATED AGRICULTURE TO INCREASE CARBON STORAGE

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Continued fossil fuel burning at the present rate, will double atmospheric carbon dioxide (CO_2) in this century, raising air temperature 1.5 to 5 ^oC. Sequestering carbon (C) in soil can reduce atmospheric CO_2 concentration. We measured inorganic and organic C in southern Idaho soils having long term land use histories of native sagebrush vegetation (NSB), irrigated moldboard plowed crops (IMP), irrigated conservation- (chisel) tilled crops (ICT) and irrigated pasture systems (IP). Soil Organic C (SOC) decreased in the order IP>ICT>NSB>IMP. We used our findings to estimate potential amounts of organic C sequestered if irrigated agriculture expanded**.** If irrigated agricultural land were expanded by10% worldwide and NSB were converted to ICT, 2.5 x 10^9 Mg organic C (4.38 % of the total C emitted in the next 30 yr) could potentially be sequestered in soil. If irrigated agricultural land were expanded by 10% worldwide and NSB were converted to IP, a possible 9.3 x 10^9 Mg organic C (16.32 % of the total C emitted in the next 30 yr) could be sequestered in soil**.** Irrigated agriculture produces twice the yield compared to non-irrigated land. Irrigation increases soil C relative to native semi arid or arid sites. Since irrigated agriculture produces higher yields, less land area needs to be put into production compared to rainfed agriculture. Altering land use to produce crops on high output irrigated agriculture, while returning less-productive rainfed agricultural land to temperate forest or native grassland, could further reduce atmospheric CO_2. Inorganic carbon increases with irrigation were less consistent and much smaller than SOC. Irrigating these soils also increased microbial biomass and changed microbial diversity.

ENERGY FARMING AND BIOREFINING

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BioJoule Limited is a biofuels and biomaterials company formed by Genesis Research and Development Corporation Limited and the Lake Taupo Development Company. The major business driver is opportunity arising from the global need to reduce dependency on crude oil and increase domestic production of transport fuel. With escalating demand for crude oil from giant emerging economies such as China and India, there are strong commercial drivers for the development of locally sustainable, economic sources of alternative feedstocks. Biomass is a sustainable industrial feedstock to produce ethanol as a transport fuel as well as being a source of chemicals to replace a number of petrochemicals. BioJoule has developed and assembled technologies that make possible the economic production of ethanol and other products from a specific plantation grown short rotation, coppicable hardwood genus called *Salix*. These cover the complete process from farming including selection and propagation of plant species, nursery production, agricultural techniques, harvesting, and biorefining including enzymatic digestion of wood, refinery engineering design, fermentation and distillation. The key competitive aspect of the business is the opportunity to produce ethanol and valuable co-products not available from other source-materials such as sugarcane and corn. These co-products, unsulphonated natural lignin and xylose, have global demand and dramatically alter the economics of ethanol production. The growth of the ethanol industry in the world has to date competed with food for sugar and corn for its industrial feedstock. BioJoule has selected *Salix* or shrub willow as a key feedstock based on the capacity of *Salix* to be repeatedly harvested through successive rounds of coppicing and to grow on marginal lands with high biomass yields while having a low requirement for fertiliser use. *Salix* is a hardwood with a wood composition that favours processing. One consequence is that *Salix* is suited to efficient solvent extraction pre-treatment and provides multiple valuable products. The commercial strategy is to coordinate in parallel, the development of both the feedstock and the biorefining technology for a commercial refinery.

ENERGY FARMING FOR LAKE TAUPO – A NEW MITIGATION LAND USE?

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Global energy use projections predict that biomass will be an important source of renewable energy in the coming decades. Short rotation woody crops will be the prime source of this biomass. Are woody crops sustainable? An assessment of willow biomass crops indicates that they are sustainable compared to agricultural land and the fossil fuel-based energy systems they will replace. Biomass from willow crops can be used to produce energy with no net addition of CO2 to the atmosphere. Productivity over multiple rotations will depend on the implementation of good management practices. Rural development and environmental benefits associated with deployment and use will accrue to the local community because of the willow's short supply chain. The economic valuation of these benefits is necessary for the deployment of woody crops, which in turn can help society become more sustainable.

Water quality is the paramount issue for Lake Taupo, and new regional and national initiatives are required to protect the water quality and enable economic land use activities. One new initiative is farming biomass for energy and high value extractives. Lower fertiliser inputs and deeper rooted plants reduce N leaching. Less fuel-dependent activities required over a rotation reduce gaseous emissions to the air.

A biomass trial was established in the Taupo district in 2005. The trial was designed to determine best current practice in establishing and growing the crop, giving attention to species choice (trialling willow, poplar and eucalyptus spp), cutting length, ground preparation, fertilisation and weed control.

The trial has established well and growth measurements after the first season will be reported. Based on results to date best practice for establishment will be suggested.

TOWARDS A BETTER UNDERSTANDING OF THE VARIABILITY OF SOIL WATER AND PRODUCTION IN A HILL COUNTRY PASTURE

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Hill country slopes are, arguably, the most vulnerable landscapes in New Zealand: they face a number of environmental risks associated with adverse climatic events and meeting the demand for increased farm productivity. Therefore, there is a need to identify sustainable management practices for at-risk, hill country soils. The long-term aim of this study is to formulate such practices based on a greater understanding of the interactions between soil water and nutrient dynamics and pasture production of hill country soils.

Among the most obvious physical features of hill country landscapes are variations in slope and aspect. To date, there is only a limited understanding of how slope and aspect affect soil water dynamics. The first phase of this research will be to develop a soil water balance for hill soils of differing slope and aspect.

A trial site has been established (April 2006) in two sub-catchments in an area about 35 km SE of Pahiatua. The farm is a summer-dry, winter-wet sheep and beef system with the terrain predominately classified as steep hill country prone to erosion during periods of high rainfall intensity. Runoff plots have been installed on a north aspect (steep and shallow slopes), a south aspect (steep and shallow slopes), and two east aspects (steep slopes). In addition to runoff, soil moisture content, climate variables and pasture production are monitored at the site.

Preliminary data was collected during 2006. The northern aspects displayed some evidence of hydrophobicity in autumn where a very significant portion of the rainfall was directed as runoff. In winter and spring, when the north-facing soils were fully 'wetted', no significant runoff was observed and nearly all rainfall (900 mm) infiltrated. The ability of the north-facing slopes to absorb rainfall without any significant runoff during winter is very interesting. In contrast, the south-facing slopes re-wet very quickly in autumn. Subsequently, there were very large quantities of runoff from south-facing slopes in winter and spring (often more than 50% of the rainfall).

The effects of slope and aspect on incident solar radiation and the implications of these relationships to pasture production will also be discussed.

MODELLING HILL-PASTURE PRODUCTION AND PASTURE RESPONSES TO NITROGEN AND PHOSPHOROUS FERTILISER IN NEW ZEALAND

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A decision tree was applied to model annual and seasonal pasture production and pasture responses to phosphorus (P) and nitrogen (N) fertiliser using data collected from historic pasture trials in New Zealand. Only environmental factors (such as topography, climate and soil features) and P fertiliser history were used as model inputs when developing models for annual and seasonal pasture production, such that the models would predict a “base level” of pasture production for a site. The modification of pasture growth through current year fertiliser management could then be predicted by the models for pasture responses to P and N fertiliser.

The results of this study indicated that rainfall, P fertiliser history and slope were major variables determining the amount of annual pasture production available at a site. Pasture response to P fertiliser differed with whether the P source was from manufactured phosphate fertiliser or phosphate rock, with soil Olsen P level and annual rainfall being the most significant variable influencing pasture responses to the former and latter, respectively. The time to apply N fertiliser was the most influential factor in determining the amount of pasture response to N fertiliser, with August and September, being the best.

A validation for the decision tree model for pasture response to N fertiliser indicated that the model adequately predicted 69% of the cases examined. The validation for the decision tree models for pasture response to P fertiliser was not conducted as no suitable dataset were available.

It is concluded that a decision tree is a suitable approach to modelling pasture production and pasture responses to fertiliser with advantages such as high predictive accuracy and dealing with different types of variables (e.g. interval, ordinal and nominal) without difficulty. These models can be used as decision support tools in pasture management for planning feed budget, setting pasture carrying capacity and making fertiliser recommendations with both economic and environmental considerations. However, the models for pasture response to P fertiliser have a high uncertainty in prediction, indicating the complex interactions among the factors influencing pasture response.

THE USE OF DIFFUSE REFLECTANCE SPECTROMETRY FOR IN SITU SOIL QUALITY MEASUREMENTS

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There is increasing demand for rapid field techniques to measure and monitor changes in soil organic matter content, created by needs to assess: (1) soil carbon stocks as part of carbon accounting for compliance with the Kyoto protocol, (2) the dynamics of soil organic N in areas with nitrate sensitive ground or surface waters and (3) soil quality as it relates to protecting the soil's potential for producing food, fibre and fuel. Root fineness and turnover rate are recognised as key factors that contribute to spatial and temporal variation in rates of soil organic matter synthesis. This paper reports the development of a field method for rapid *in-situ* assessment of soil carbon (C), nitrogen (N) and root density using a portable Vis-NIR (350-2500nm) reflectance spectroradiometer (Analytical Spectral Devices FieldSpecPro). For C and N assessment, the technique was evaluated at 3 field sites in permanent pasture on Pumice soils. The root density assessment technique was evaluated on permanent pasture at 2 sites on Ramiha silt loam (Allophanic soil) and Manawatu fine sandy loam (Recent alluvial soil) in Manawatu. After spectral reflectance had been recorded a 15 mm soil slice was collected from each surface for analysis of total soil C and N. A 3 mm soil slice taken at each depth was collected for root density measurement in the laboratory.
The Pumice soil samples had a wide range of total C and N (0.26-17.88 % C; 0.02 – 0.68 % N) and the Allophanic and Recent soil samples exhibited a wide range of root densities (1.53 – 37.03 mg dry root /g soil).

Spectral data were pre-processed using waveband filtering, smoothing (Savitzky-Golay filter), data reduction, derivative calculation and averaging. The ability of 5nm spaced first derivative data to predict known values of soil C, N and root density was assessed using partial least squares regression. Differences in the spectral derivative data successfully predicted soil carbon content, nitrogen content and root density.

This study indicates that rapid *in-situ* assessment of soil C, N and root density by VIS-NIR spectral reflectance has considerable potential for mapping soil chemical physical and biological properties, for soil fertility description and measurement of the impacts of land-use change on soil organic matter stocks and potential rates of soil organic matter synthesis via root density.

APPLICATION MODELLING OF GROUND-BASED SPREADING VEHICLES

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Collecting accurate fertiliser distribution information from large field trials is difficult and very labor intensive. Methods such as transverse tray testing, mathematical and discrete element modelling have been used to successfully explain the interaction of key spreader machine parameters (i.e. disc, vane and orifice etc.) on fertiliser particle distribution under controlled testing conditions. However, these methods are often found to be inadequate in assessing field application variation due to the variable nature of field deposition.

A computer analysis method was developed for analysing field application variation of fertiliser distribution from any spreading vehicle. The tool used measured machine parameters including geographical position and a series of static spread patterns from the spreading vehicle to create application surfaces. The tool proved to be effective for calculating an accurate representation of field application variation and should have many uses in fertiliser application research.

MODELLING PARTICLE BALLISTICS FROM A FIXED-WING AIRCRAFT

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Predicting the deposition of granular fertiliser from aircraft is valuable from an environmental and economic perspective. From the environmental point of view, the ability to avoid contaminating sensitive areas, regardless of wind conditions or aircraft speed, is a major advantage, whilst the impact of fertiliser deposition on pasture growth will enable analysis of economic return of different application scenarios without the need for large field trials. Although a single particle trajectory model can yield useful information about the factors influencing the lateral and longitudinal displacement of particles from their release point, it would be more useful if it could calculate and summarise the deposition of fertiliser on the ground, under varying conditions, such as those experienced in agricultural aviation. Many of these factors have been examined in previous work, but their overall effect on field scale application has been difficult to measure.Particle parameters, such as fertiliser size distribution, flow profile, sphericity, density, ejection angle, and ejection velocity, as well as the environmental parameters: prop turbulence, wind speed and direction were accounted for in the model. The model accurately predicted (R^2 = 0.98) the lateral distribution pattern of a fixed wing aircraft under ideal operating conditions (no wind).

INTERPRETATION OF LABORATORY RESULTS – ISSUES SURROUNDING THE SETTING OF OPTIMUM LEVELS

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Most commercial agricultural laboratories nowadays have a reporting option which shows the results as a histogram. This enables a quick assessment to be made, i.e. whether the result is low, medium or high. One would imagine defining the "normal range" criteria would be reasonably straightforward, and could be taken from the literature. This is not always the case, and this presentation outlines the problems faced with setting "normal ranges" for histogram reports.

Generally, it is a desirable result if the analysis result falls into the middle range of the histogram. There is no likelihood of deficiency, nor an excess of that particular element. But what to call that range is not as simple as one might imagine. Options considered were medium, normal, optimum, target range, agronomic optimum or economic optimum. Each one of these has specific implications that can not always be specified because of an incomplete knowledge base.

An alternative approach being explored at Hill Laboratories is to is to utilise the historical data in their commercial database. Analysis of variance has been used to identify varietal and seasonal variability in plant tissue analysis values for selected crops. Ranges between the upper and lower quartile and sextile values may be considered typical for a specific crop under New Zealand conditions. Medium ranges based on these values are then set in consultation with industry input. It is especially useful where literature ranges do not match locally observed values. Differences in growing conditions between New Zealand and countries where literature ranges have originated probably account for the mismatch between literature and observed element concentrations.

Selected examples are presented to illustrate typical guidelines obtained by this alternative approach for setting medium ranges. Benefits are that the utilisation of data from large sample populations adds to the robustness of the proposed ranges that can eventually be expanded to accommodate seasonal variability and differentiate between varieties, rootstocks and regions. Although this method is not a substitute for classical methods based on extensive trial data for establishment of medium ranges it is a useful source of information for crop management in the absence of such trial data.

EFFECT OF FREQUENCY AND INTENSITY OF SPRING AND SUMMER GRAZING ON NITROGEN LOSSES, PRODUCTION AND QUALITY OF PERMANENT GRASSLAND IN SOUTHERN CHILE

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The intensification of cattle production in Southern Chile in recent years has created a high potential for environmental impacts through nitrogen (N) losses. Cattle production in the Southern of Chile is based on the grazing. Through grazing, N is returned to the pasture through urine and dung deposition by the animals and through decomposition of plant residues. However, incorrect grazing management can result in the loss of N via gaseous emissions and leaching and can influence herbage quality. The objective of this study was to evaluate the effect of the different frequencies and intensities of cattle grazing over the spring-summer season of 2005-2006 on the N-losses (ammonia volatilisation and nitrate leaching) and herbage quality on a permanent pasture in Southern Chile.

Four grazing management systems were evaluated: frequent-heavy, frequent-light, infrequent-heavy and infrequent-light (together with a no-grazing control), with three replicates of each in a randomised block design. Different criteria were established for each system as to when grazing occurred, based on the availability of pasture herbage dry matter (DM). Ammonia emissions were estimated using static chambers, and nitrate leaching estimated using mini-lysimeters installed on each plot. Furthermore, herbage DM production, crude protein (CP), metabolizable energy (ME), neutral detergent fibre (NDF) and acid detergent fibre (ADF) were measured. Ammonia volatilization was greater from the grazed treatments than from the control in both spring and summer (although not always significantly at P=0.05). In spring, mean emission from the frequent grazing treatments was *c.* 12% greater than the mean emission from the infrequently grazed treatments. In summer there were no significant differences between any of the grazed treatments (P>0.05). Nitrate leaching losses were greatest from the frequent-heavy grazing treatment in both spring and summer. Herbage DM yield was greater in spring (2.7-3.9 tons ha^{-1}), depending on the treatment, as was herbage quality. Herbage quality was best in the frequent-heavy treatment with 21.4% DM, 18.2% CP, a production of 576 CP kg ha^{-1}, 46.9% NDF, 26.2% ADF and ME of 2.54 Mcal kg ha^{-1}.

LANDSCAPE GRASS FILTER STRIPS IN THE ROTORUA LAKES CATCHMENT

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Several lakes within the Rotorua district have degraded water quality as a result of nutrient enrichment. While the cause of water quality degradation varies from lake to lake, it is clear that land use intensification has increased the contribution from agriculture in recent decades. Grass filter strips (GFS) are one potential BMP for intensively grazed pastures. Filter strips can remove pollutants from surface runoff by a combination of deposition, physical filtering, and infiltration. Currently, GFS are generally placed in riparian areas where their performance may be compromised by channelised flow, inundation (Dillaha et al., 1989) or saturation (McKergow et al., 2004). By placing GFS on hillslopes these limitations may be overcome. This study reports preliminary results for GFS established on planar hillslopes at Lake Rerewhakaaitu catchment (dairy) and Kaharoa (drystock). Adjacent retired pasture and phalaris (*Phalaris aquatica* cv. Maru*)* filter strips, and controls are monitored and inputs and outputs of surface runoff and suspended sediment (SS), total phosphorus (TP), total nitrogen and *E. coli* are measured after runoff events. Widespread surface runoff was measured during the winter at Rerewhakaaitu. Preliminary data were collected for the retired pasture GFS during establishment. Runoff entering the filter strip had SS concentrations between 64 to 1800 mg/l (median 450 mg/l, n=21) and concentrations declined with time since grazing. *E. coli* concentrations are in the order of 10^5-10^6 MPN/100ml. The median TP input concentration was 2.5 mg/l (n=10, max 4.8 mg/l) and particulate forms dominate TP (80-90%). Two small runoff events have occurred at Rerewhakaaitu since GFS monitoring commenced in Sep 2006. Trapping has been variable, with > 40% reductions in SS and TP concentrations and loads from the inflowing runoff (compared to outflow) in the retired pasture GFS. These preliminary results suggest that GFS could be a valuable BMP, particularly for SS and TP. We hope to integrate landscape GFS into grazing systems and site them below paddock breaks. Grazing trials are underway at both sites to evaluate less-palatable grass species (tall fescue, phalaris, cocksfoot, tall fescue/cocksfoot mix) for use as GFS without the need for fencing.

USE OF STAND-OFF PADS AND HERD-HOMES FOR WINTERING COWS

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New Zealand farmers are increasingly using improved winter management systems involving moving cows off grazing paddocks primarily to protect wet soils from damage. These improved systems include temporarily holding cows on specially constructed stand-off pads and in herd-homes. Cows could spend up to 20 hours per day over about three months in these systems, thereby resulting in the accumulation of considerable amounts of excreta. There is a need to develop best practices to achieve sustainable management of excreta under these wintering systems. Both laboratory and field studies were conducted to monitor nutrient transformations in excreta in stand-off pads and herd-homes. The value of natural materials, including sawdust, bark and soil, to control nutrient losses and to retain faecal bacteria was also examined.

A laboratory scale study showed that the transformation of nitrogen (N) and the subsequent loss of N through gaseous emissions depend on the proportion of dung and urine in the excreta. The study also indicated that a range of natural materials, including soil and sawdust, can be used to alter the transformation rates of excreta organic N to mineral N, thereby reducing potential N losses to the environment. This reduction was caused by absorption/adsorption or immobilisation of excreta N by the natural materials.

A field-scale uncovered stand-off pad study indicated that carbon-rich materials can be used as stand-off pad materials with effective retention of N and faecal bacteria. At nine months after use, less than 5% of the deposited excreta N was collected in the drainage from pads containing pine bark or sawdust. Gaseous N losses due to denitrification accounted for about 12% and 4% of the deposited excreta N in the sawdust and bark pads, respectively. These natural materials also significantly reduced *Escherichia coli* (*E. coli*) bacteria in the drainage. This was not due to die-off as *E. coli* remained viable in pad materials for several months after the cows had been removed from the pads.

Monitoring of prototype herd-homes indicated that natural materials, such as soil and wood shavings, were effective at retaining excreta nutrients. Soil was the most promising material for N retention with about 67% of deposited excreta N retained in the herd-homes at nine months after use. This compared with only 30% retention when no natural materials were used. It is likely that the loss of N is mainly due to ammonia volatilisation from the deposited excreta.

ROOT DEVELOPMENT OF VERONESE POPLAR ON HILL SLOPES

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Poplars are commonly planted on moist, unstable pastoral hill country to prevent or reduce soil erosion, thereby maintaining hillslope integrity and pasture production. Mechanical reinforcement by poplar root systems aids slope stabilisation. Coarse root (≥ 2 mm diameter) mass and distribution were determined for three *Populus deltoides* × *nigra* 'Veronese' trees aged 5, 7 and 9.5 yr planted from 3 m poles at 8 m x 8 m spacing on a hillslope near Palmerston North. Most of the roots occurred in the top 40 cm of soil. Vertical roots penetrated to about 1.0 m, being the depth of the soil above a fragipan. Total root mass was 0.6 kg, 7.8 kg and 17.9 kg for the trees aged 5, 7 and 9.5 yr respectively. Total root length was 79.4 m at age 5 yr and 643.7 m at age 9.5 yr. Surrounding trees increased root mass density to 3 times and root length density to 4-5 times the contribution of the single tree at 9.5 yr. The study showed that root development of wide-spaced poplar trees on hillslopes was minimal in the first five years but then increased rapidly. We concluded that the minimum coarse root network required for poplar trees to effectively bind soil does not develop until at least five years.

NITRIFYING ARCHAEA?
YES! THEY ARE IN OUR SOILS TOO

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Nitrification is the process which controls the forms in which nitrogen becomes available to plants and is vulnerable to loss processes. In nitrification soil NH_4^+ converts to NO_3^- through NO_2^-. Conversion of NH_4^+ to NO_2^- is called ammonia oxidation and is the rate limiting step in nitrification as NO_2^- rarely accumulates in soil. Bacteria have so far been considered as the main contributor to ammonia oxidation until recent studies revealed a group of micro-organisms from the domain Archaea may predominate among ammonia oxidizers in soils. The Archaea are a group of microrganisms that are best known for producing methane in ruminants but until now have not been known to be involved in soil N cycling. This is a significant finding for the global nitrogen cycle and particularly for New Zealand pastoral agriculture which had paid lot of attention to nitrate leaching and nitrification inhibitors recently.

In this work we investigated whether ammonia oxidizing Archaea exist in New Zealand soils. We used polymerase chain reaction (PCR) amplification targeting the archaeal ammonia monooxygenase gene for directly extracted soil DNA. Three contrasting New Zealand pasture soils (sandy soil from Manawatu**,** gley soil from Northland and a volcanic ash soil from Taranaki) were tested. Soils from four different depths were tested in volcanic ash soil. Archaeal ammonia monooxygenase genes were easily amplifiable from all the tested soil DNA indicating the presence of ammonia oxidizing Archaea in the tested soils. This is the first time, in New Zealand soils; ammonia oxidizing Archaea presence has been reported.

These findings raise important questions; 1) how much is the archaeal contribution to total soil nitrification activity in New Zealand pastures? 2) how does archaeal nitrification in deeper soil layers affect contamination of ground water by nitrogen? 3) are the current nitrification inhibitor products able to effectively inhibit the activity of the ammonia monooxygenase enzyme produced by Archaea?

IMPACT OF PLANTS ON THE BIOLOGICAL HEALTH OF CU-CONTAMINATED SOIL

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Copper (Cu) is an essential element for living organisms but proves to be toxic at high concentrations. Although generally Cu levels are not high enough to cause acute toxicity problems, increased concentrations may effect soil microbial health and thus decrease the quality of soils. It has been demonstrated that the presence of plants can increase the microbial activity in the soil. Root exudates, mucilage and organic matter from the roots have beneficial effects on microorganisms' live cycles. In this study we have investigated the impact of plant species with different levels of tolerance to copper on the microbial activity in a low copper concentration soil (10 mg/kg) and in a high copper concentration soil (180 mg/kg). Three different plants, *Agrostis capillaris* Parys tolerant for Cu, *Agrostis capillaris* Highland not tolerant and *Helianthus annuus* (sunflower) tolerant and a hyperaccumulator for Cu were used. The dehydrogenase activity, the microbial biomass and the basal respiration by CO_2 capture were measured to quantify and evaluate the microbial activity. The experiment was conducted over a period of 9 weeks. Results display that high copper concentrations decrease the microbial activity or generate a stress. Generally this activity increased significantly with the presence of plants. This improvement seems to be mainly related to the plant health and the root density. With the tolerant *plant Agrostis capillaris* Parys the microbial activity increase faster compared with the other plant species. The non-tolerant plants overcame the toxicity 50 days after sowing, and the microbial activity recorded came close to the values recorded by the presence of the tolerant plant. Tolerant plants to heavy metal seem to be a valuable alternative to raise the microbial activity in a contaminated soil, and increase the soil quality.

LONG TERM ECONOMIC AND ENVIRONMENTAL SUSTAINABILITY WITH FARM FORESTRY

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Plantation forestry is recognised as having a number of environmental advantages over pastoral farming including markedly reduced soil erosion, reduced nutrient loss, enhanced biodiversity, and carbon sequestration benefits. Many farm foresters have found that with long term planning, whole farm performance and profitability can be sustained and enhanced through implementation of farm forestry practices. This is achieved not just by planting trees, but by adopting an holistic approach to overall farm management.

Two examples of second generation farm forestry operations are given. "Raumati" is located at Patoka, western Hawke's Bay, with deep gorges intersecting areas of rolling ash based soils. Fencing of gorges for livestock safety preceded planting for erosion control, timber production, and shelter from prevailing winds. Willows and poplars were planted in boggy areas prone to side slumping and hosting liver fluke bearing snails. In years of severe drought these trees have proved invaluable as a renewable source of stock food.

"Rangitoto" is close to Bulls on Foxton phase sand dunes. A deliberate policy of afforestation of the dunes with pastoral farming on the flats has been practised over the last 50 years, along with shelter planting and fodder trees on some wet corners.

Both properties can demonstrate returns of at least $1000/ha/annum net of harvest costs for radiata pine plantations harvested up until the early years of this decade. Recent returns from plantations of pruned cypresses, mainly *C. macrocarpa,* have been in excess of $1,500/ha/annum.

Ground-spread rather than aerial fertiliser application allowed greater accuracy and better targeting of the product, while minimising wastage and keeping fertiliser out of waterways. Areas inaccessible to spreader trucks were retired from intensive grazing and planted in trees for timber production.

Overall efficiency of land utilisation has increased as livestock were removed from less productive and more fragile land, and this land planted in production trees. With the use of modern techniques in farm planning and applications such as the NZFFA Green Solution Calculators, the relative profitability of trees versus livestock can be ascertained and better informed decisions made.

WORKING WITH FARMERS TO IMPLEMENT SUSTAINABLE FARM SYSTEMS

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Farm plans have been used in Hawke's Bay since 1954 to assist farmers manage their eroding landscapes.

Up to 1998, 184,000ha, comprising 368 properties had farm plans. Since 1998 two types of plan, a comprehensive farm plan (CFP) and an erosion control plan (ECP) have been used with a total of 157 plans completed covering, 111,696ha. Fifty two of these were comprehensive farm plans and 105 erosion control plans. This paper discusses the comprehensive farm plan.

Comprehensive farm plans are based on a whole farm assessment by a specialist land management advisor. Following a request by a farmer, the land management advisor has initial discussions regarding their property and their goals and objectives. A comprehensive resource inventory and land use capability assessment is undertaken on the farm with compilation and report writing in the office. An initial 5 year work programme is prepared for discussion. The draft document is then presented to the owner(s) and staff at a meeting during which its content is fully discussed and alterations made.

A plan contains two sections:

- Section 1 comprises analyses of the farm's physical resources. This includes a resource inventory and land use capability assessment which are interpreted to provide the base for sustainable development. From these analyses land use recommendations are made. The section also includes information on soils, watercourses, and biodiversity.
- Section 2 lists the farm's resource management options and the significant environmental issues from which a five year work programme is developed with the farmer.

What are the advantages of these plans? A plan allows a farmer to adopt a planned annual programme to sustainably develop the property. As it is based on the physical resources, the limitations and potentials of various land use options can be assessed within the context of the physical capability of the land to sustain that development. This ensures that the farmer can be confident with their decision making. A further benefit is the financial support from Hawke's Bay Regional Council to assist with minimising soil erosion risk and to maximising biodiversity protection.

Many farmers after 5, 10, or even 15 years are still applying the process to ensure developments are physically sustainable.

FUTURE PROOFING FARMERS WITH WHOLE FARM PLANNING

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A farm system is a complex interaction of many components. To implement change on one front often means detailed consideration regarding the impact on several other fronts. Whole farm plans provide the opportunity to future proof farmers and their systems by demonstrating that farm activities are both calculated and sustainable. To do this, Whole farm flans need to consider the whole farm system rather than individual components in isolation. Whole farm planning works through a process enabling farmers to understand their land resources. A detailed knowledge of the land resources, their inherent strengths, limitations and conditions of use, will underpin the ability to make decisions about the farm business and the impact that this will have on the farm system. Whole Farm Plans provide a strategic plan for the farm business with the objective to future proof the property against climatic, political, social, and market forces.

MATCHING LAND USE WITH LAND TYPE TO ACHIEVE SUSTAINABILITY

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The key to long term sustainability is matching land use with land type. In today's climate there is increased pressures from rising land values, the need to achieve yield gaps, reaching return on investment, the impact of climate change, political pressures from local and central government, and market driven forces that all affect the farm business. In order to achieve this requires three steps. The first is to understand the physical requirements and impacts of the land use in question. The second step is to know the land resources in terms of geology, soils and slope, and whether they will be able to handle the impacts and physical requirements of the land use. The third factor is to understand the land processes occurring and the impact of the land use on those processes. An understanding of these three points provides an opportunity to predict how the land resources will behave under different situations. The level of resource information required is dependent on the land use type and its intensity. The scale of this information needs to reflect the intensity of the land use. This recipe applies to all types of land use, whether it is sheep breeding, bull beef techno-systems, commercial forestry, horticulture or cropping to name a few.

GIS AND VARIABLE RATE TECHNOLOGIES FOR OPTIMISED PASTURE MANAGEMENT IN HILL COUNTRY

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Hill country farmers are under increasing pressure to intensify production and improve their environmental servicing. One possible method of achieving this is to recognise the variability of the farm production and adjust fertiliser inputs accordingly. Earlier studies (Murray & Yule 2006) have indicated a hypothetic 23% increase in production from such an approach. These methods would give a better fit between land use and land capability, which in turn would give greater economic resilience while improving environmental services, particularly to river water quality. What has been missing in the past is a method of determining the fertiliser requirements of different land units within the farm, and an adequate system to deliver the fertiliser with sufficient accuracy to realise the benefits of this approach.

Current uniform management of hill country sheep and beef farms, ignores the fact that in the southern and eastern North Island, a major proportion of steeper north facing aspects have serious water limitations, grow little pasture and are uneconomic under current sheep and beef management. They also generate more spring, summer and autumn runoff than other aspects, with the potential of carrying higher phosphorus loads from spring and autumn topdressed fertiliser to surface waters.

In order to implement a higher level of pasture management, two elements are required. A pasture production decision support system embedded in a geographic information system (GIS) and the development of GIS-GPS (global positioning system) controlled, placement and variable rate aerial topdressing system. Both of these areas are currently being heavily researched at Massey. The use of GIS is essential to the solution as landform dictates production potential. Decision tree models have been used to develop fertiliser programmes for land of differing growth potential. The means of fertiliser delivery through aerial topdressing is better understood and the behaviour of different fertilisers and aircraft systems can be more readily predicted, increasing the likelihood of achieving a more targeted and precise fertiliser application.

THE EFFECT OF LIMING POLICY ON SUSTAINABILITY AND NUTRIENT REQUIREMENTS

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We used a modelling approach to investigate the effects of applying lime to pasture on productivity and profitability.

The results of our study suggest that applying lime will reduce the nutrient requirement per unit of production by either reducing the overall loading needed to obtain a given level of production, or by allowing productivity to improve without further inputs of capital fertiliser. Either of these outcomes should reduce farming's environmental impact.

The economics of production will be improved through the lowered capital fertiliser requirements and through lower maintenance needs when lime is used to support a constant production level.

The contrast between annual liming and infrequent capital liming is examined and appears to show that a policy of regular small lime applications designed to maintain soil conditions will produce superior outcomes to irregular large applications and use less lime overall.

Finally, a modelling study showed us that if the effect of liming in improving pasture utilisation is real, then even relatively minor improvements could have significant effects on the economics of lime use.

ON-OFF FARM WINTER MANAGEMENT PRACTICES: POTENTIAL ENVIRONMENTAL BENEFITS AND ISSUES

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The winter period of the dairy farmers' calendar sets the scene for the success of the following lactation. Farmers are concerned with putting condition on stock during this period, and yet at the same time they are aware that treading damage to pastures and soil compaction will severely limit spring pasture growth. As cows can consume around 80% of their feed requirements in just 4 hours, it is not necessary to keep cows on pasture for the whole day. Removing cows off pasture for part of the day onto a specialised facility has become an attractive option to farmers for managing their stock during wet winters. There are several on-off grazing options available to farmers such as using stand-off pads, tunnel houses, wintering barns, and more recently Herd Homes. Confining stock on a specially designed structure accumulates a large amount of urine and dung, thereby creating a nutrient point source "hot spot". All wastes generated are required to be contained and appropriately treated to preserve the nutrient value and to reduce adverse environmental effects. Handling the accumulated excreta under the different off-grazing options requires different management strategies for treating the wastes as either effluent, slurry or solid. Each waste stream presents its own challenges and has its own environmental issues to consider. The different wintering options along with their waste management systems are described and the positive and negative effects on the environment explored.

APPLYING NUTRIENT MANAGEMENT ON FARM – COMPARISONS WITH EUROPE

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Rarely in the development of legislation, best management practices and social responsibility do we have the benefit of hindsight. Yet in New Zealand agriculture as in other less regulated agricultural nations we have the ability to do what more regulated agricultural nations failed to do. We can prove that we have our house in order before central government legislates, and thereby we will be able to set the legislation based on best management practice, rather than trying to develop a management practice out of blanket and often impractical, ideological legislation.

The European fertiliser industry was guilty of too little too late - inactivity driven by a mixture of arrogance and fear of loss of competitive advantage if seen to be siding with environmentalists by often blinkered and arrogant farmers.

Responsible modern business operating within NZ agriculture has a duty to keep reality as close to perception as possible with regard to our clean green image and ensure that our standards are up to those being practiced in the markets in which we choose to sell our produce.

In the face of food miles, travel miles and an increase in the intensity of New Zealand farming, we must act now with practical solutions before organic manure regulations and Nitrate Vulnerable Zones become a reality. We have the ability to make environmental stewardship a voluntary and satisfying part of our practices whilst assisting the industry that we service to maintain its competitive “perception based” marketing advantages by acting before our industry is threatened by the ideology of the uninformed. To make this easy we have the benefit of hindsight by looking to Europe should we choose to, to help map the potential path ahead for New Zealand. This paper looks to the European example for direction to help guide initiatives for applying nutrient management on New Zealand farms.

GETTING SPATIAL WITH NUTRIENTS IN NEW ZEALAND PASTORAL AGRICULTURE

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Soil nutrients exhibit magnitudes of spatial variability that are often too high for practical everyday farm management. Accordingly, pastoral farmers manage soil nutrients somewhat coarsely by dividing land into units or blocks with known differences in soil, fertiliser history, or management practice (e.g. effluent irrigation). This may be adequate for most farming purposes, but it is less than ideal for environmental modelling and nutrient budgeting.

Variation in landscape processes can have similar implications for modelling and budgeting. Phosphorus associated with runoff is an important example, whereby surface hydrology has a large determining influence on P-transport and the amount of P that can potentially enter water bodies. Better representation may be achievable if P-transport is modelled in a spatially explicit framework, which promises not only more reliable environmental modelling, but also allows critical source areas to be weighted in terms of their risk for contaminating water bodies.

Improved representation in modelling is not the only reason for spatially explicit nutrient models. From a practical perspective, users are increasingly familiar with, and have better access to, geographic information systems (GIS) and spatial datasets. They desire more effective use of these resources, and are interested in the efficient production of nutrient related maps (for communication and extension) and new spatial datasets (to feed into secondary models). There is also a greater incidence of nutrient modelling across extensive areas (*i.e.* many farms), for which GIS and spatial modelling is particularly suited.

This paper is in three parts. Firstly we examine why there is greater justification for investigating and modelling nutrients in a spatially explicit context. Secondly, a software prototype is reported, which is designed to expand the spatial functionality of nutrient modelling and budgeting. Lastly, we present exploratory modelling of P-transport mechanisms that seek to account for rainfall, surface hydrology, and complex topography.

IRRIGATION REQUIREMENTS FOR GRAPES IN MARLBOROUGH

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Water is a critical issue in the Marlborough District. Irrigated vineyards are expanding rapidly across the region and this is putting added pressure on surface and ground water resources that in some places are almost fully allocated. Improvements in irrigation efficiency that are needed to sustain vineyard development can only be achieved by better matching irrigation volumes to the water needs of the vines. That means identifying how much water the vines are using, and determining 'when' and 'how much' irrigation will satisfy the vine's water demands. Excess irrigation is inefficient for it promotes vine vigour, which leads to a 'luxury consumption' of water, and can also increase drainage losses of water, nutrients and agrichemicals beyond the root-zone soil.

Here we report on a series of laboratory and field experiments on grapevines. A measurement and modelling approach is used to relate the daily vine water use (T_A, L day^{-1} vine^{-1}) to the total leaf area (L, m^2 vine^{-1}) and the prevailing microclimate (ET_O, mm day^{-1}). Drip irrigation that wets only part of the root-zone soil makes difficult the task of assessing water stress and irrigation demands from soil-based measurements alone. A qualitative stress index can be derived from the ratio of TA:ET_O, and this index can help with irrigation scheduling. Research results from our field trails are providing 'local parameters' to improve the Council's assessments of the region's irrigation needs. Furthermore, the research is contributing to a better understanding of the impacts of water stress on vine productivity and wine quality attributes.

IRRIGATION MANAGEMENT STRATEGIES TO MINIMISE NITRATE LEACHING LOSSES FROM ARABLE SOILS

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Nitrate leaching losses from cropped soils in New Zealand have mainly been measured during the winter when excess rainfall results in drainage. There are very few published measurements of nitrate losses from irrigated cropped rotations over a 12-month period. This study is measuring irrigation and fertiliser management effects on annual losses from crop rotations.

A replicated field experiment was established in spring 2004 with two different crop rotations (potatoes-winter wheat-winter fallow-potatoes or potatoes-winter fallow-spring peas-winter fallow-potatoes). Each crop received three different rates of fertiliser N (N0, N1, N2) and two different rates of irrigation (W1, W2). For each crop N1 and W1 represented the optimum rates of fertiliser and irrigation. For each of the crops, W2 either represented a different frequency or amount of irrigation compared to W1.

Nitrate leaching losses varied considerably during the trial in response to the irrigation and fertiliser treatments, crop rotation and winter rainfall. Losses during the spring and summer of 2004/05 from the first year potato crop ranged from about 10 to 90 kg N/ha, and increased with both irrigation and fertiliser application rate. There was no measurable leaching loss over the winter of 2005 due to low autumn and winter rainfall. Nevertheless, the winter wheat crop reduced the amount of potentially leachable nitrate during the winter compared with the winter fallow. During the spring-summer of 2005/06, leaching losses from both the winter wheat and spring peas were also very small due to the conservative irrigation management that was used in this year. Consequently, the amount of mineral N remaining in the soil at harvest in February 2006 varied widely between treatments. Subsequent rainfall over the winter of 2006 resulted in leaching losses that ranged from about 90 to 310 kg N/ha. Results from this experiment will be used to validate the nitrate leaching loss estimates provided by farm-scale decision support tools produced by Crop & Food Research (the Wheat and Potato Calculators).

SIMULATING CHANGES IN SOIL MINERAL NITROGEN DURING MAIZE CROPPING UNDER VARIABLE FERTILISER MANAGEMENT

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AmaizeN is a computer decision support system (DSS) designed to aid in the N-fertiliser and irrigation management of maize crops. The DSS incorporates a mechanistic simulation model of maize growth and development with responses to water and N, and including a soil percolation and leaching model with a simplified N-mineralisation description. The model requires a physical description of the soil to rooting depth, information about the initial conditions, and then uses daily weather data as input to simulate the daily dynamics of the soil-crop system, including water and N flows. Extra N is recommended in a schedule if soil mineral N levels are predicted to fall below the amount necessary to satisfy crop demand. Daily outputs are available of crop biomass, soil moisture and N status. During the 2005-06 maize growing season, crops at five sites in the North Island were managed using AmaizeN (version 0.9) or by conventional best management. Crop phenological and leaf area development were monitored, silage and grain yield and quality were measured, together with soil mineral N status at the beginning and the end of the season. Comparisons were made between observations and AmaizeN simulations for all treatments. In all but one case, simulations and observations matched well. This paper concentrates on the comparison of simulated soil and crop N balance predictions with soil measurements made before sowing and after harvest, and crop measurements made at harvest.

APPROPRIATE FERTILIZERS FOR IRRIGATED DAIRY PASTURES

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Water authorities in Australia and elsewhere are imposing increasingly strict legislation for maintenance of water quality. For farmers this means matching soil nutrient status to fertilizer type and application method with an appropriate management system. Although on-ground cost has been the major driver influencing fertilizer choice in the past, these new restrictions, reflecting increased environmental awareness globally, is affecting the overall cost – that is on-ground, plus environmental impacts. Despite the increasing strictures, farmers continue to apply water-soluble fertilizers in environments where losses are likely.

This experiment was established to investigate the environmental consequences associated with different forms of phosphatic fertilizer application to an irrigated dairy pasture in north-central Victoria, Australia.

Superphosphate, Pro-DAP, and PAPR were surface-applied at 50 kg P/ha in March 2005 to a border-check, flood-irrigated dairy pasture (ryegrass-white clover) ten-days prior to a scheduled irrigation. Olsen P status at the beginning of the experiment ranged from 39 to 79 mg P/kg soil, with an average of 59. Run-off was assessed from whole bays on one replicate and from micro-plots on all 3 replicates. Five irrigation events and two storm events were recorded. Dissolved P and total P were measured in runoff.

In all runoff events and despite fertilizer being applied ten days before irrigation (the recommended time delay is 3 days), concentrations of both total and dissolved P in runoff greatly exceeded water quality guidelines for this region (0.02-0.05 mg/L P). Additionally there were clear differences between fertilizers with superphosphate giving much higher concentrations of phosphorus in runoff than the less water-soluble fertilizers which in turn greatly exceeded the control.

By irrigation five, seven weeks later, runoff from the water-soluble fertilizers exceeded the control (approximately 1.5 times) whereas PAPR was similar to the control. The results from the auto-analyzers were supported by data from the microplots where statistical analysis revealed significant differences in the first two irrigations: P in runoff from superphosphate > Pro-DAP > PAPR > control.

These results suggest that there are significant environmental savings to be made in maintenance situations from using PAPR. They also suggest that the current recommendation, the three-day withholding period for irrigation after fertilizer application, is insufficient.

ROLE OF THE CODE OF PRACTICE FOR NUTRIENT MANAGEMENT IN SUSTAINABLE FARMING

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New Zealand Fertiliser Manufacturers' Research Association

New Zealand is not alone in its drive for sustainable farming systems, but it is in a favourable position to lead the way in using innovative tools and bridging the gap between prescriptive regulatory controls and providing farmers with a flexible approach to manage their production systems.

The Code of Practice for Fertiliser Use was first introduced in the 1990's to provide a non-prescriptive, site specific framework to help agricultural producers to meet their obligations under the Resource Management Act (RMA) yet retain the flexibility to follow best management practices for improved efficiency. The success of the Code of Practice for Fertiliser Use is demonstrated through acceptance by regulatory authorities and most importantly by its incorporation into a range of primary producers' quality assurance programmes.

The Code of Practice for Fertiliser Use focuses on best management practices to improve efficiency and reduce nutrient 'losses' as they apply to whole farming systems. It is designed to be a 'living' evolving document.

An update in 2002, introduced new addenda and information on environmental and production issues which had gained higher prominence over the preceding years.

A current major revision introduces greater acknowledgement of nutrients from sources other than fertiliser, with a greater emphasis on nutrient budgets and nutrient management plans for land management units and whole farm systems. New templates, information and guidance for the management of wider sources of nutrient provide a valuable resource for land users, nutrient advisors, farm consultants, policy analysts and planners. It also takes account of water quality and climate change initiatives.

Sustainable agriculture requires economic, social and environmental viability of farming systems operating now and well into the future. The Code of Practice for Nutrient Management provides a non-prescriptive, site specific and well structured framework of information, templates and guidance. With improvements in documentation and monitoring requirements and based on current science it is designed to provide land users with the means to ensure nutrient use efficiency and satisfy community environmental expectations, while at the same time giving regulators and markets ongoing confidence in the uptake and use of best management systems for agricultural production.

THE ROLE OF AGRICULTURAL FORECASTING IN IDENTIFYING FUTURE NUTRIENT AND ENVIRONMENTAL IMPACTS

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Animal agriculture is recognised as a major influence on the impacts of nutrient cycling in the New Zealand environment. Agricultural forecasts provide a key tool that can be used to assess the future consequences of nutrient loading in agroecosystems at the national scale. Forecasting can also be important when assessing the consequences of proposed industry strategies and for developing appropriate policy responses/mitigation approaches to balance industry goals and Government priorities for the environment.

The Ministry of Agriculture and Forestry develops forecasts for agricultural product prices, production and animal numbers on an annual basis. These values are fed into Treasury economic forecasts. As part of Ministry of Agriculture and Forestry responsibilities for climate change greenhouse gas (GHG) inventory reporting, estimates of current GHG emissions in the immediate past year and forecasts out to 2010 (the mid point of the first Kyoto Protocol commitment period, 2008 -2012) and 2020 (as required by National Communication requirements under the UNFCCC) are made. These forecasts provide estimated values for animal numbers, nitrogen fertiliser use, animal nitrogen excretion and methane emissions for the four main animal species: sheep, beef cattle, dairy cattle and deer at the national level. As dung and urine deposition by animals is recognised as a major contributor to nitrogen leaching and nitrous oxide emissions, total nitrogen output and changes between species provide important information by which to assess the future environmental impacts of livestock agriculture. For example, total national nitrogen throughput by all major animal species is expected to increase from 1.394 million tonnes in 1990 to 1.661 million tonnes in 2010, or just under 1% increase per annum.

Coupled with these forecasts, satellite imagery has the ability to provide real time national estimates of forage nitrogen content and quality, and as such improve national estimates and forecasts. Robust national datasets, updated annually, have been created for each of these major animal species and provide a valuable resource for future research. The paper will provide further details of methodology, species outputs and estimates of uncertainty in forecasting GHG and nitrogen values.

USING LRIS ON THE FARM

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How can the LRIS national land and soil database (particularly its component S-Map) inform farm enterprise planning and management, and how may farm-level data feed value back to the LRIS? We explore these questions by looking forward over the next 5 to 10 years.

The LRIS can assist farm mapping and planning by; (1) providing definitions of local soils and keys for quick and efficient recognition of important soil features, (2) providing access to rich LRIS soil information sets for farm soils, and (3) assisting land unit mapping via landform modelling techniques.

Farm mapping can assist the LRIS by bolstering LRIS data collection. This can then feed back to strengthen the quality of information flowing back to the farm. Access to the regional and national big picture will assist industry planning, technology transfer, and analysis of off-farm effects. It will help a larger array of communities of interest to be better informed in decision making.

The soil attributes chosen for storage in the LRIS and made available on-farm are those that will be useful for identification of opportunities, constraints and risks. They must also help identify land management units and provide inputs for production and environment models.

The spatial data resolution for a farm is a judgement based on land type, land-use and cost factors. Coarser-resolution national data will be relevant to finer-resolution farm mapping if the national database can accurately identify finer scale patterns and predict their location. S-map soil classes are expected to be sufficiently precise for application at farm scale, so that most of the effort in farm mapping will involve finer delineation of soil classes already identified in the in S-map database.

People working at national- and farm-levels have much to learn from one another to ensure relevance of the national database, consistent standards from national- to farm-levels, and interoperability between data sets.

IS THE SPATIAL INFORMATION TAIL WAGGING THE FARM SUSTAINABILITY DOG?

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The use of spatial information to help inform farm decision-making is increasingly commonplace in New Zealand. However, the ability to provide reliable information and support is compromised when spatial principles are ignored, limitations of individual datasets are overlooked, and when people feel forced to use inappropriate data because they are the only data available.

This paper looks at the opportunity to build upon farmers' use of spatial information, and how that use may be improved with new types of information, better specifications of precision and accuracy, and a greater degree of self-regulated responsibility from those who use spatial information (and data) to support the farming industry.