Accurate and Efficient Use of Nutrients on Farms

This document contains the abstracts of all papers that were presented at the 26th Annual FLRC Workshop held at Massey University on the 12th, 13th and 14th February 2013. They are printed here in the order of presentation at the workshop and may assist people who wish to search for keywords prior to accessing the individual manuscripts.

Individual manuscripts are available from the website at:

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Tuesday 12th February

Professor Mike Hedley
Director, Fertilizer & Lime Research Centre, Massey University
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Mike Hedley
Fertilizer & Lime Research Centre, Massey University

Alastair MacCormick
Bay of Plenty Regional Council

Leo Fietje
Environment Canterbury

Helen Codlin
Hawkes Bay Regional Council

Clare Barton and Peter Taylor
Horizons Regional Council

Selva Selvarajah
Otago Regional Council

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Ron Pellow, S Lee, A Metherell, R McCallum, J Moir, A Roberts and D Wheeler
South Island Dairying Development Centre, Christchurch
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Roger Williams, H Brown, M Dunbier, D Edmeades, R Hill, A Metherell, C Rahn and P Thorburn
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Bill Carlson, Gina Lucci and Mark Shepherd
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Landcare Research, Palmerston North
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Ballance Agri-Nutrients, Tauranga
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Advanced Agricultural Additives (NZ) Ltd, Palmerston North
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Blair Cotching, G Kerse and R Simms
Ravensdown, Christchurch
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AgResearch, Mosgiel
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Tony J van der Weerden, J Luo, M Dexter and M Kear
AgResearch, Mosgiel
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AgResearch, Hamilton
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Institute of Agriculture and Environment, Massey University
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Neha Jha, S Saggar, S Bowatte, J Deslippe, R Tillman and D Giltrap
Institute of Agriculture and Environment, Massey University
CHANGES IN DENITRIFICATION RATE AND BACTERIAL DENITRIFIER GENES DISTRIBUTION AND ABUNDANCE IN DAIRY-GRAZED PASTURE SOILS TREATED WITH CATTLE URINE AND DCD

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Plant & Food Research, Palmerston North
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Anne-Maree Hill, H Di, K Cameron and A Podolyan
Department of Soil and Physical Sciences, Lincoln University
INHIBITION OF AMMONIA OXIDISERS TO CONTROL NITRIFICATION RATE UNDER SIMULATED WINTER DAIRY FORAGE GRAZING CONDITIONS: AN INCUBATION STUDY

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CSIRO Land and Water, Brisbane
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Simon Woodward, R Stenger and V Bidwell
Lincoln Agritech Ltd, Hamilton
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Chris Tanner
NIWA, Hamilton
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Andrew Hughes, L McKergow, J Sukias and C Tanner
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Environmental Research Institute, University of Waikato, Hamilton
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Stefanie von Bueren and I J Yule
NZ Centre for Precision Agriculture, Massey University
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Greg Costello and S A Petrie
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Jo-Anne E Cavanagh, B Robinson, R McDowell, G Rys, M Taylor, C Gray, A Roberts and W Catto
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Miko Kirschbaum
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Emily S Weeks, A Collins and D Medyckyj-Scott
Landcare Research, Palmerston North
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Andrew Cooke, D Lineham, K Saunders and G Ogle
Rezare Systems Limited, Hamilton
LAND AND LIVESTOCK DATA INTERCHANGE STANDARDS AS AN ENABLER FOR MODELS AND MANAGEMENT

Alan Palmer, D J Horne and J A Hanly
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Pierre Roudier and C Hedley
Landcare Research, Palmerston North
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Martin Hawke, B Longhurst and B Parker
Bay of Plenty Farm and Pastoral Research, Rotorua
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Roland Stenger, J Clague, S Woodward, B Moorhead, S Wilson, A Shokri, T Wöhling and H Canard
Lincoln Agritech Ltd, Hamilton
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Simon Gaul and A H C Roberts
Ravensdown, Christchurch
COULD MODIFYING THE PAKIHI SOILS OF THE AORERE VALLEY IMPROVE PRODUCTIVITY AND REDUCE P LOSS?

Bernard Simmonds, R McDowell and L Condron
Faculty of Agriculture and Life Sciences, Lincoln University
FACTORS THAT INFLUENCE PHOSPHORUS LOSS WITH THE DEVELOPMENT OF ORGANIC SOILS

Tash Styles, S Laurenson, R Monaghan, D Dalley and J Chrystal
AgResearch, Mosgiel
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Danilo F Guinto, A Holmes, H Rahman and W Rijkse
University of the South Pacific, Alafua Campus, Samoa
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Thursday 14th February

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Peter Barrowclough
Lincoln Agritech Ltd, Christchurch
PRECISION AGRICULTURE ASSOCIATION OF NEW ZEALAND (PAANZ)

Michael Mersmann *(Invited Presentation)*
T Sia and S Walther
AMAZONEN-Werke H. Dreyer GmbH & Co. KG, Germany
FERTILIZER APPLICATION - DRIVING THE FUTURE WITH INNOVATIONS

Session 9 : Precision Nutrient Management

Armin Werner
Lincoln Agritech Ltd,Canterbury
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Ian Yule and M Grafton
NZ Centre for Precision Agriculture, Massey University
NEW SPREADING TECHNOLOGIES FOR IMPROVED ACCURACY AND ENVIRONMENTAL COMPLIANCE

Craige Mackenzie
Agri Optics NZ Ltd, Ashburton
UTILISING VARIABLE RATE FERTILISER APPLICATION TO IMPROVE FARM PROFIT

Hayden Lawrence
Spatial Solutions Ltd, Eltham
A PRECISION FERTILISER PLAN: REAL MEASUREMENTS, REAL COSTS, REAL RESULTS

Pip McVeagh, R Pullanagari and I Yule
NZ Centre for Precision Agriculture, Massey University
MEASURING PASTURE QUALITY IN THE FIELD: A CASE STUDY AT LIMESTONE DOWNS

Stu Bradbury, C Mackenzie, J Mackenzie and C Hedley
Lindsay International (ANZ) Pty Ltd, Palmerston North
PRECISION IRRIGATION AS A TOOL TO REDUCE NUTRIENT LEACHING AND RUNOFF

NUTRIENT MANAGEMENT STRATEGIES FOR THE CHESAPEAKE BAY WATERSHED, USA: SUSTAINING AGRICULTURE IN THE FACE OF CHANGES IN SCIENCE, POLICY, AND CLIMATE

Tom Sims[1] and Jennifer Volk[2]

[1]Professor of Soil and Environmental Chemistry
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The Chesapeake Bay, located on the Eastern seaboard of the USA, has been referred to as a “national treasure” for its widely recognized value as a unique natural resource, it historical importance, and its critical value to state, regional, and national economies. The Bay is North America’s largest and most biologically diverse estuary, home to 3700 species of plants and animals and habitat for >3000 migratory and resident bird species. Its economic value, from fishing, tourism, property, and shipping, was estimated as > $1 trillion in 2004. Unfortunately, the ecological health of the Bay has been degraded for nearly 40 years by pollution from both “point” (direct pollutant discharge from industries and municipalities) and “nonpoint” (diffuse runoff from farms, cities, and suburbia) sources. Primary pollutants of concern are nutrients and sediments, as clearly stated in a recent report from the Chesapeake Bay Foundation: “The Chesapeake Bay and its tributaries are unhealthy primarily because of pollution from excess nitrogen, phosphorus and sediment entering the water. The main sources of these pollutants are agriculture, urban and suburban runoff, wastewater, and airborne contaminants.”

The Chesapeake Bay Program, a watershed partnership between six states that drain into the Bay (DE, MD, NY, PA, VA, WV), the District of Columbia, the US Environmental Protection Agency (USEPA), and citizen advisory groups, has formed binding agreements since 1983 focused on implementing practices that will reduce nutrient and sediment loading to the Bay. Progress has been slow, leading to the issuance of an Executive Order by President Obama in 2009 in which he stated, “Restoration of the health of the Chesapeake Bay will require a renewed commitment to controlling pollution from all sources as well as protecting and restoring habitat and living resources, conserving lands, and improving management of natural resources, all of which contribute to improved water quality and ecosystem health.” This order mandated the USEPA to: (1) Define the next generation of tools and actions needed to restore water quality; (2) Assess the impacts of a changing climate on the Chesapeake Bay; (3) Strengthen scientific support for decision making to restore the health of the

Chesapeake Bay and its watershed, including expanded environmental research and monitoring and observing systems; and (4) Develop focused and coordinated habitat and research activities that protect and restore living resources and water quality.

In response to the Executive Order and Clean Water Act requirements, USEPA has set pollution limits, called Total Maximum Daily Loads (TMDLs), for the Bay and required that all states in the Bay Watershed submit and put into practice "Watershed Implementation Plans" (WIPs) that will further reduce pollutant loading to the Bay, from all sources. For example, the Delaware WIP stresses the importance of implementing best management practices (BMPs) on agricultural lands not only because of the large portion of the landscape existing as agriculture in the State, but also because of the cost-effectiveness of these practices at reducing nonpoint nutrient pollution. Throughout the Bay Watershed, there is a serious need to develop effective strategies, management practices, and policies that reduce losses of agricultural sources of phosphorus (P) due to the high percentage of soils now saturated with P from long-term manuring and over-fertilization. Nitrate leaching and groundwater discharge to the Bay and its tributaries is another, perhaps more serious, problem.

Our goals in this presentation are to look to the future of nutrient management in the Chesapeake Bay Watershed, based on present day socio-political realities, emerging advances in science, and what we know today about expected changes in climate. We will present and critically analyze: (1) the "WIPs" now operative in the watershed for selected crop-animal systems; (2) the agricultural BMPs now in place and the growing interest in policies that link agriculture and urban areas in a cooperative effort to reduce nutrient loss (e.g., "nutrient trading"); and (3) how climate change is likely to affect both agricultural productivity and the future direction of nutrient management for the Chesapeake Bay Watershed.

THE NORTH WYKE FARM PLATFORM: A NEW UK NATIONAL CAPABILITY FOR RESEARCH INTO SUSTAINABLE GRASSLAND PRODUCTION

P J Murray, B Griffith, R J Orr, S Peukert*and A Shepherd

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The concept of being able to increase significantly output from the same area of land and at the same time reducing any possible environmental impact is outlined in the Foresight (2011) report 'The future of food and farming: Challenges and choices for global sustainability'. Modern farming practices have a major impact on the landscape and farmers can influence the wider environment in pursuit of higher agricultural production. Strategic research to achieve sustainable food production requires controlled experiments operating at the farm scale. The information that is required cannot be obtained from commercial farms as the intensity of monitoring involved and the sophistication of modern instrumentation employed needs a permanent presence of trained technical staff.

The North Wyke Farm Platform is a large, farm-scale experiment which was established during 2010 as a UK national capability for collaborative research, training and knowledge exchange in agro-environmental sciences which addresses agricultural productivity and ecosystem responses to different management practices. Since the farm platform was commissioned in April 2011 a standard beef and sheep system has been implemented across the site in order to obtain baseline data in hydrology, nutrient cycling and productivity.

The underlying principle is to manage each of three 20ha farmlets differently: improvement through use of mineral fertilisers; improvement through use of legumes; improvement through innovation. The connectivity between the timing and intensity of different management operations and the transport of nutrients and potential pollutants from the farm is being evaluated using the latest sensor technology coupled with more traditional field study methods. Detailed farm management records allow us to better understand processes and underlying mechanisms that will be used to model how agro-ecosystems will respond to changes in management and help us to respond to the challenges of sustainable grassland farming.

Reference

Foresight. The Future of Food and Farming (2011). Final Project Report. The Government Office for Science, London.

A REVIEW OF N LOSSES DUE TO LEACHING AND SURFACE RUNOFF UNDER INTENSIVE PASTURE MANAGEMENT IN AUSTRALIA

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Nitrate leaching and surface N runoff research is well advanced in New Zealand, whereas the recent focus of the Australian dairy industry has been on P and gaseous N loss. Although there have been some very informative studies examining N leaching and runoff under intensive dairy pasture systems in Australia to date, given the importance of N loss in terms of water quality, this review concluded that more research is required, particularly in the area of nitrate leaching and in specific areas of surface N runoff.

Nitrate leaching losses following N fertiliser treatments were higher in New Zealand studies (~40 kg N/ha for 0N and ~80 kg N/ha for 200N) compared to an Australian study (3.7-14.5 kg N/ha for 0N and 6-22 kg N/ha for 200N). Nitrate leaching rates following urine application are also generally higher in New Zealand compared to an Australian lysimeter study (26-33 kg N/ha/year under irrigation and 10-13 kg N/ha/year under rain fed conditions). It is often suggested that nitrate leaching losses are higher in New Zealand due to the prevalence of free draining soils. However, this review highlights that there are simply not enough Australian nitrate leaching data to undertake a rigorous comparison. A national nutrient budgeting study has recently reported that median N surpluses on Australian dairy farms are higher (198 kg N/ha) than those reported for an average dairy farm in New Zealand (135 kg N/ha). Given that many of the soils used for intensive pasture production in Australia are lightly textured or free draining clay loams and that water quality monitoring in dairy dominant catchments often indicate elevated N loads, it is possible that nitrate leaching could be a significant issue for the Australian dairy industry.

Australian data on surface N runoff are more prevalent, however, the overall contribution to N losses are likely to be low. Despite this, more research is required to quantify N runoff and leaching following effluent applications and to quantify losses of dissolved organic forms of N.

WATERSHED IMPLEMENTATION PLANS FOR AGRICULTURE IN THE CHESAPEAKE BAY WATERSHED, USA: OVERVIEW AND CRITICAL ANALYSES

J.A. Volk and J. T. Sims

College of Agriculture and Natural Resources, University of Delaware

The Chesapeake Bay along the Mid-Atlantic coast of the United States is the nation's largest estuary. The Bay and its tributaries have elevated levels of nitrogen (N), phosphorus (P), and sediment (S) contributing to poor water clarity and low dissolved oxygen. The Clean Water Act requires pollution limits, called Total Maximum Daily Loads (TMLDs), be established for all impaired waters.

The TMDLs established by the US Environmental Protection Agency (EPA) in December 2010 require a 25% reduction in N, 24% reduction in P, and 20% reduction in S from all jurisdictions within the Chesapeake Bay Watershed (Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and the District of Columbia). All of the actions to achieve the TMDLs must be in place by 2025, with 60% implemented by 2017. States were required to develop a Watershed Implementation Plan (WIP) detailing how load allocations will be achieved and maintained. The WIP work is being done in three-phases. Phase I plans were drafted before the final TMDL and informed that work. Phase II plans were developed after the TMDL and provided greater detail at refined geographic and temporal scales. Phase III plans are due in 2017 and will reflect adaptive management decisions. Additionally, jurisdictions have to exhibit accountability by achieving 2-year milestone goals or risk EPA imposed consequences.

The Chesapeake Bay Watershed is largely rural. Approximately 69% of the watershed is wooded, 22% is agriculture, 7% is developed, and 2% is water. The agricultural sector includes 6.5 million acres of cropland and several major animal production regions. In 2011, about 44% of the N load, 57% of the P load, and 59% of the S load to the Bay came from agricultural lands with the remainder coming from urban and natural areas. As such, many jurisdictional WIPs emphasized current and potential future agricultural best management practices to curb loads from this sector. State strategies range from reliance on incentive-based implementation to increased regulatory measures and permitting of animal operations.

This poster provides an overview of the agricultural components of WIPs, the challenges to success, and the consequences of failing to achieve goals.

SURVEY OF SOIL CARBON AND NUTRIENT SERVICES IN AUSTRALIAN APPLE ORCHARDS

Roberta Gentile, K Mason, C Robertson, S Sivakumaran, C van den Dijssel and B Clothier

The New Zealand Institute for Plant & Food Research Limited, Palmerston North

The Australian apple and pear industry is the third largest horticultural industry in Australia. To quantify the sustainability of orchard management, a better understanding of soil carbon, nutrient availability and soil health in Australian apple orchards is required. We conducted a survey of soil carbon and soil health characteristics in the main orcharding regions of Australia. These areas included Donnybrook and Manjimup in Western Australia, Adelaide Hills in South Australia, Orange and Batlow in New South Wales, Shepparton in Victoria, and Tamar and the Huon valley in Tasmania. The objective of the survey was to establish the soil's carbon status and determine the relationships between soil carbon and soil health parameters in these duplex orchard soils. A sampling protocol was established to determine soil carbon down to 1 m, which accounted for the spatially complex system of an orchard by sampling in the tree row, wheel tracks and the grassed alley. Bulk density samples were centred at the depths of 10, 20, 30 and 40 cm, and disturbed samples for laboratory analyses were taken at depths of 10, 20, 30, 40 and 60 cm. Analyses were made of the orchard soil's organic carbon, total nitrogen, mineral nitrogen, potentially mineralisable nitrogen, hot water extractable carbon, dehydrogenase activity and pH. Soil carbon stocks to 1 m varied from 6.2 to 16.2 kg C m^{-2} between the orchard sites. Soil carbon and soil health characteristics decreased rapidly with soil profile depth for all orchard soils. Soil carbon concentrations showed positive relationships with total nitrogen, hot water extractable carbon and dehydrogenase activity. Relationships between soil carbon concentrations and soil health characteristics will be discussed.

TOWARDS INNOVATIVE SOLUTIONS FOR RIVER MANAGEMENT IN NEW ZEALAND

Ian C. Fuller & Russell G. Death

Institute of Agriculture & Environment, Massey University, Palmerston North

Freshwater management in New Zealand needs connected, innovative and interdisciplinary science to empower end-users of New Zealand's rivers, which therefore embraces the whole of society, to better understand and manage the nation's rivers and freshwater resources. Modern river science involves highly specialised, rapidly developing and diverse fields and there is a need to provide an integrated and more holistic perspective in catchment and river science to sustainably manage these systems. The future of our rivers will be determined by how we manage their catchments. Innovative solutions for river management are needed, which recognise natural river dynamism in space and time, understanding rivers as responsive and sensitive landscape features that function as integrated catchments. This is best achieved by taking a holistic, integrated river science approach, which identifies causes of problems and issues rather than their symptoms and treats reaches in a connected catchment context. In turn this requires development of catchment-scale integrated modelling tools to assess land and water management strategies, which, at least in part, can be derived from establishing field laboratories with shared and multiple use field experiments and monitoring sites across the range of environmental sciences and, importantly, connected with key end-users such as Regional Councils and Unitary Authorities. This paper thus sets out a vision for future river management that is both innovative and integrated, based on examples and case studies of issues to be addressed if future river management is to be successful.

Key words: river management, catchment connectivity, integrated science

STONY SOILS ARE A MAJOR CHALLENGE FOR NUTRIENT MANAGEMENT UNDER IRRIGATION DEVELOPMENT

Sam Carrick [1], David Palmer [1], Trevor Webb[1], John Scott, Linda Lilburne[1]

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A resurgence in irrigation development is underway, with central government identifying irrigation as central to New Zealand's economic growth over the coming decades. However, irrigation development must also meet water quality objectives arising from the 2011 National Policy Statement on Freshwater Management and revised/proposed regional council plans. This paper presents a stocktake of the distribution, state of knowledge, and agricultural development on New Zealand's stony soils.

Stony soils (soil depth < 45 cm to gravels) are extensive with 1.68 million hectares mapped that have potential for intensive land use (land less than 15^{o} slope). Fifty-three percent occur in Canterbury, 12% in Otago, with 9% each in Southland and the West Coast.

Significant land-use change has occurred on stony soils since 2000. Using Agribase 2012 the major land uses are sheep and beef (427,000 ha), sheep (256,000 ha), and dairy (232,000 ha), representing a 38–43% decline in sheep farming, and increases in sheep and beef (22–44%) and dairying (47–95%) since 2000 (gaps in Agribase data preclude precise figures). Most dairy expansion on stony soils occurred in Canterbury, more than doubling to 143,000 ha in 2012. Similar dairy expansion occurred in the West Coast, Southland, and Otago, although the areas are smaller with 21,000 ha, 20,000 ha, and 12,000 ha, respectively, in 2012. In Canterbury, irrigation is also extensive on stony soils, with analysis of satellite images collected from 2008 to early 2011 estimating at least 196,000 ha irrigated.

Stony soils span 10 soil orders and 71 subgroups under the New Zealand Soil Classification. Our analysis shows that 42% of stony soils have low P-retention (<30%), 77% have moderate to rapid permeability, and 58% have low water storage capacity (30–90 mm). These attributes are all indicators of soils with high vulnerability to leach nutrients.

This research clearly shows that stony soils have been a hotspot of land-use change and intensification over the past decade that under irrigation may be creating conditions where there is a high risk of nutrient leaching. These areas probably need to have targeted management practices developed to reduce leaching losses.

IS THE GREY-WATER FOOTPRINT HELPFUL FOR UNDERSTANDING THE IMPACT OF PRIMARY PRODUCTION ON WATER QUALITY?

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It is widely recognized that globally agricultural production generates a significant proportion of the anthropogenic environmental impacts on water resources. Because of agriculture's large water usage, and its contribution as a non-point source of agrichemical emissions into freshwater, agricultural production is considered central to future attempts of overcoming the global stress on water resources. Locally, agriculture is the dominant land use in New Zealand, and it has the most widespread impacts on freshwater quality and quantity. The concept of grey-water footprint (grey-WF) has been proposed as a metric that indicates impacts of the agricultural production systems on the quality of water resources. It is calculated as the volume of freshwater that is required to dilute a pollutant so that its concentration meets the prevailing water quality standards.

The impacts of water use in wine-grape production on water resources were assessed for two regions in New Zealand: Marlborough and Gisborne. In our assessment, the vineyards were on 29 different soil types spread across 19 climatic regions, and approximately 12,600 ha under grapes were considered across both the regions. Nitrate-nitrogen (NO_3-N) was considered as the major pollutant. The soil-water dynamics and nitrate leaching in the vineyards were modelled using the Soil Plant Atmosphere System Model (SPASMO). The grey-WF was 40 and 188 L/kg of harvested grapes from Marlborough and Gisborne, respectively. However, the average concentration of NO_3-N in the leachate was well below the drinking water standard of 11.3 mg NO_3-N /L, being just 5.01mg NO_3-N /L and 8.7 mg NO_3-N /L for Marlborough and Gisborne. The grey-WF as a measure of the impact on water quality could be used to make comparisons between products and regions. However, the absolute value is less meaningful to understand the local impacts. From a resource management perspective, it is doubtful if the grey-WF provides sufficient information for regulatory or policy decisions. Furthermore, it is not that helpful to the grower to assist them with reducing the environmental impact of their production.

OLSEN P METHODS AND SOIL QUALITY MONITORING: ARE WE COMPARING "APPLES WITH APPLES"?

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Olsen P is a commonly used soil fertility and soil quality monitoring indicator. In New Zealand, Olsen P is widely used by the agriculture and horticulture industries to help assess on-farm nutrient management. It is also widely used by many regional councils in State of the Environment soil quality monitoring, and by many other researchers to study soil quality.

Soil can be measured on a volumetric (volume) or gravimetric (weight) basis prior to chemical extraction in a laboratory. For example, several large New Zealand commercial laboratories measure soil received in the laboratory prior to Olsen P chemical extraction by volume. Other laboratories and many researchers measure soil gravimetrically prior to chemical extraction.

We investigated if Olsen P results reported from these different methods by regional councils, the agriculture industry and other researchers are able to be compared. We also wanted to know if these soil results reported from these different methods were able to be compared with the established industry recommended guidelines, such as optimum levels for pastoral yield.

We report preliminary findings for several studies including the influence of laboratory method prior to chemical extraction, undisturbed field bulk density, sieving methods and soil sampling depth. These findings suggest that there are some key differences.

It is therefore important to increase awareness to those involved in soil monitoring of these differences and quantify them to help improve interpretation, reporting, comparison with guidelines, and for application of soil quality indicators in potential future national monitoring programmes.

This paper aims to raise awareness of some of the key differences of soil quality monitoring commonly used in New Zealand, and provides recommendations for improved interpretation, reporting and further research.

Keywords: Olsen P, soil phosphorus, soil quality, bulk density

VALIDATION OF A CRITICAL SOURCE AREA PREDICTION MODEL OF NITROGEN LEACHING

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Nitrogen (N) leaching has a major impact on fresh water quality and farmers are under pressure to reduce these losses. Lake Taupo farmers, working under a N cap, require mitigation strategies to reduce N leaching losses sufficiently to allow a stocking rate to maintain financial viability. Dicyandiamide (DCD) has been shown to reduce N leaching from grazed pastures but broadcast application is too costly for hill land farmers. However targeting DCD at stock camps is one cost-effective strategy that reduces N leaching loss. This study validated a stock camp prediction model based on the farms contour map. This assumes that 50% of cattle urine is excreted in these camps where they spend many hours resting. Eight paddocks on Taupo farms were surveyed with a RTK-GPS to enable a contour map to be generated. Areas having a slope $\leq 10^{o}$ were assumed to be suitable for cattle camping. In each paddock, several sites chosen as being representative of steep areas or campsites, were soil sampled and analysed for Olson P status, since this is known to accumulate at campsites but be depleted on slopes. Campsites almost invariably had Olson P >30 and slopes were generally Olson P <20. This confirms that campsites with about 50% of all urine deposits requiring mitigation can be selected from a contour map. Using this map, the farmer spray these areas, around water troughs and other areas close to shelter, etc., with DCD from a four-wheel motorbike. Verification of this spraying is mapped with a GPS system on the motorbike.

CHALLENGES FOR LEACHATE MONITORING FROM ALLUVIAL SEDIMENTARY SOILS

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Agricultural land use has intensified in recent times, heightening the risk of environmental nutrient contamination. This contamination arises mainly from increased use of synthetic fertilisers, irrigation and the increase in animal dung and urine returns. As regulatory authorities start to set limits on permissible nutrient losses from agricultural land, there is an urgent need to better understand and manage such nutrient losses from farms. Computer models are now commonly being used to simulate and forecast losses, but accurate measured data are also needed to test the models and ensure the reliability of the model predictions.

This paper will present a review of the current methods available to monitor leaching on farm and outline some of the challenges associated with making such leaching estimates, e.g. the sampling devices and issues relating to scale and spatial variability, as well as the wide variation in farm management practices. We will identify some research gaps and discuss options for measuring nutrient losses on farm as well as make some recommendations for future research.

In addition, we will also present some preliminary findings from a study where we have investigated the lower boundary condition in lysimeters, and in which we explore whether suction is needed at the base of lysimeters containing alluvial sedimentary soils.

HOW NITROGEN IS ACCOUNTED FOR IN OVERSEER 6

Mark Shepherd and David Wheeler

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The pastoral model within OVERSEER® Nutrient budgets (*Overseer*) version 6 includes a change to a monthly input and calculation time step that had started to evolve in the previous version. Some of the important differences can be summarised thus:

- Model split into urine and non-urine ('background') sub-models
- The urine model is new and is based on
    - Monthly deposition of urine and a monthly calculation step
    - A modelled N load per urine patch of 700 kg N/ha
    - Other sub-models varying in complexity account for all other competing processes for N (denitrification, volatilisation, immobilisation, uptake)
    - Leaching driven by a relationship between drainage and soil Available Water Capacity (AWC)
    - Additive effects of the inorganic component of effluent and/or fertiliser on top of urine patches
    - Losses adjusted for other animal species by applying a scaling factor
- Background model now based on crop model and integrates fertiliser, effluent and other non-urine sources of N.
- Fodder crop model now based on the same principles in the crop and the urine patch models

When compared against measured N leaching data from farmlet trials, there was reasonable agreement with sites receiving <200 kg N/ha annually but a tendency to slightly underestimate losses (slope of line 0.92, r^2>0.8). This is a good performance for a biological model.

Some consequences for the revised model are:

- *Shallow soils* - The drainage and N leaching estimates are sensitive to changes in soil AWC. The soil AWC is modified by soil order, type of non-standard subsoil material (sand, stones) and depth to that layer.
- *High rainfall* - Validation sites do not include sites >1400 mm, and so the model (as with previous versions) is extrapolating into these conditions. This version generally has a steeper response to rainfall/drainage than previous versions.
- *Fertiliser and effluent* -Fertiliser N and the inorganic fractions of effluent or organic fertilisers are added to urine patches as part of the calculation. Leaching losses are sensitive to these additions and can increase leaching when applied later in the season. Thus:
    - Losses from effluent blocks can be larger than with previous versions
    - Effects of winter applied N are larger than with previous versions

FROM STOCK NUMBERS TO N LEACHING AND NITROUS OXIDE – THE PROGRESSION THROUGH OVERSEER

David M Wheeler and Mark Shepherd

AgResearch, Hamilton

Within OVERSEER® Nutrient budgets, there are several steps in calculating N leaching and nitrous oxide emissions from input data. The methodology used has been published and is available or referenced on the OVERSEER® website. However, there is no published information that shows the results from each calculation stage, and how they combine to provide a final answer as the results from each stage of the calcualtion are not readily available. In this paper, the results from internal calculations have been extracted for a typical Waikato dairy farm to show the progress from using input stock numbers to estimate ME intake, through to excreta estimation, N leaching and nitrous oxide emissions.

ASSESSING THE IMPACT OF INPUT CHOICES WITHIN OVERSEER (V6) ON THE MODELLED N LOSSES FOR LINCOLN UNIVERSITY DAIRY FARM (LUDF)

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Overseer users are required to make numerous decisions when inputting data into Overseer 6. A range of default values are available providing standardised data as an alternative to farm specific information.

Production data from the past five seasons at LUDF was used to model the N losses (to water) from Overseer for the LUDF milking platform using predominantly default values. Alternative scenarios were then compared considering the impact of varying some of these choices on the predicted N losses.

Changing milk components (utilising actual milk fat and protein supplied to Fonterra), mature cow liveweight, selecting the farm based on its region rather than local town, or standardising wintering-off herd numbers and duration of winter grazing, had little effect on the predicted N loss in any of the years compared.

The impact of the number of blocks (soil types), higher rainfall, and specifying monthly cow numbers were also considered in each year.

Choices around irrigation, both in time and volume had substantial effects on predicted N losses. The 'Active irrigation' option reduced predicted N losses, while specifying both the volume and months of irrigation increased predicted losses in all years.

Changing from the default clover content and pasture quality parameters to farm specific clover content and pasture quality decreased predicted losses at LUDF. Using the most detailed LUDF data increased the predicted N losses in all years except one.
Comparisons of losses between years and between farms are influenced by the Overseer user's decision rules regarding default values and the availability of credible farm specific data. Apparently similar farm systems / inputs over time do not necessarily result in similar predicted N losses.

A CRITICAL EXAMINATION OF THE ROLE OF OVERSEER® IN MODELLING NITRATE LOSSES FROM ARABLE CROPS

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Loss of nitrate from farmland to freshwater can harm the environment and diminish drinking water quality. In response to this, and the National Policy Statement for Freshwater Management (2011), regional authorities across New Zealand are developing plans to manage water quality. Many of these plans include use of OVERSEER®, a computer model originally designed to assist farmers and their advisors with on-farm nutrient use, for estimating nitrate losses from individual farms.

Given this emerging and new regulatory role for OVERSEER®, and the relatively recent addition of crop modelling to the programme, FAR commissioned a review of the arable cropping model of OVERSEER®. The purpose of the review was to assess the strengths, weaknesses and further developments that would improve the usefulness and usability of the cropping model of OVERSEER®.

To do this FAR assembled an expert panel to review the available information regarding development and testing of the OVERSEER® crop model and compare this to other plant/soil interaction models.

The review concluded that OVERSEER® is the best tool currently available for estimating nitrate leaching losses from the root zone across the diversity and complexity of farming systems in New Zealand. This presentation and manuscript will include more specific findings.

ACCURACY, PRECISION AND UNCERTAINTY: A BEGINNER'S GUIDE

Mark Shepherd, David Wheeler, Diana Selbie and Mike Freeman

AgResearch Ltd, Ruakura Campus, Hamilton

Summary

When debating the performance of models e.g. Overseer's ability to estimate of whole farm nutrient losses, four terms seem to be used almost interchangeably: accuracy, precision, error and uncertainty. However, the terms are not interchangeable and it is important to consider the implications of the commonly used terminology, set in the context of farm-scale nutrient budgeting models.

Accuracy is the degree of closeness of measurements of a quantity to that quantity's actual (true) value. The concept of accuracy has limited application to the estimation of whole farm nutrient loss where it is not practicable to measure directly, for example, the whole farm annual quantity of N leached to water.

Precision, also called reproducibility or repeatability, is the degree to which repeated measurements under unchanged conditions show the same results. This concept has some applicability to Overseer nutrient loss estimates.

Error is the level of disagreement between a measured value and the true or accepted (where actual measurement is difficult) value. The concept of an error clearly has limited application where actual measurement is not practicable, e.g. whole-farm nutrient losses.

Uncertainty in the context of a model such as *Overseer* can be defined as a potential limitation in some part of the modelling process that is a result of incomplete knowledge. The concept of uncertainty is the most applicable to the use of Overseer, i.e., given the number of assumptions and errors involved in the model there will be a level of uncertainty about the estimate of nutrient losses.

Uncertainty is a fact of life with all models; as is that uncertainty tends to increase when models are used outside the conditions under which they were developed. A critical issue is how uncertainty relating to a whole farm nutrient loss estimates is taken into account, along with other sources of uncertainty, in any catchment nutrient management policy development and/or policy implementation process.

VARIABILITY OF DRY MATTER PERCENTAGES OF WINTER FORAGES – GETTING FEED ESTIMATES RIGHT

Gina Lucci, M Shepherd and B Carlson

AgResearch, Ruakura, Hamilton

Forage brassicas are an important part of winter feeding systems in both the North and South Islands. The overall aim of this Sustainable Farming Fund project (SFF 11/010) is to improve the efficiency of forage crop production in dairy systems on the pumice soils of the Central Plateau whilst minimising the environmental footprint. This poster reports data from yield assessments made across the properties of some of the participating farms.

An unexpected but important issue that we came across when measuring yields was that the percentage dry matter content of the crops (kale and swedes), and therefore yields, were often less than the farmers' expectations. While the measured percentage dry matter contents for kale were often within quoted ranges, the dry matter values measured for swedes were 20-30% lower than quoted values.

This variation only adds to the complexity of calculating and managing dry matter intake through the winter, together with the uncertainty around utilisation rates. The result of getting these estimates wrong is cows not getting enough feed, and possibly not reaching the desired body condition score at calving, with consequences for animal health and future milk production losses.

Farmers need to understand the variability underpinning published reference values, and that they cannot replace actual measurements made in the field at grazing time. For farmers who want to maintain or improve body condition, an accurate estimate of the available standing feed, along with ensuring that break sizes are properly calculated, is vital.

SIMULATED EARLY AND LATE WINTER GRAZING: EFFECTS ON NITROGEN LEACHING

Bill Carlson, Gina Lucci and M Shepherd

AgResearch, Hamilton

Wintering of dairy cows on forage crops is an increasingly common management strategy. Forage crops can provide large amounts of quality feed suitable for wintering cows or growing young stock. A cropping phase in a pastoral system also provides an opportunity for pasture renewal. Grazing of brassica winter forage crops returns large amounts of excreted nitrogen (N) to the soil. Previous work has shown that N leaching losses from a June-grazed winter brassica crop could be 100-150 kg N/ha, with 50-100 kg N/ha remaining in the soil in the spring. The purpose of this study was to measure the effect of grazing timing and dicyandiamide (DCD) application on the amount of nitrate nitrogen (NO_3-N) losses from simulated cattle urine patches applied to a winter forage brassica crop, and to pasture as a comparison. The hypothesis was that later grazing would leach less N than the early grazing. A small plot scale trial was established on free draining pumice soils near Mangakino in the upper Waikato River catchment in the winter of 2012. Grazing of plots was simulated by manual removal of the forage brassica crop, and by mowing of the pasture plots in early June (early grazing) or July (late grazing). At the time of simulated grazing artificial cattle urine was applied. Half of the plots received DCD. Leaching losses of nitrogen were measured using porous cups installed in the plots before simulated grazing, and by soil sampling for mineral nitrogen to a depth of 60 cm before simulated grazing and at the end of drainage.

Total N leached was significantly lower ($P<0.001$) for the late grazing for both the brassica crop and for pasture. Retained N in the soil was also significantly higher ($P<0.005$) for late grazing in both the crop and pasture.

Application of DCD did not result in a significant reduction in N leached, or in a significantly higher retained N in either the crop or pasture. Monitoring of the plots will continue into a second winter to look for carry-over effects of the N remaining in the soil at the end of the first winter.

COMPARISON OF N-DYNAMICS ACROSS DIFFERENT MODELS

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Nitrogen (N) dynamics in soil play a crucial role in determining agricultural production. Although N is essential for plant growth, in excess it can lead to environmental pollution via leaching and greenhouse gas emissions. Field studies can measure only some parts of the N cycle. Process-based models have the potential to simulate the entire N-cycle, but contain a large number of processes that need to be validated.

A large number of models have been developed to simulate different aspects of the soil-N cycle. These models include different assumptions and simplifications, depending on the original purpose of the model. Comparing the behaviour of different models for the same dataset can be a useful way of determining which processes lead to significant differences in model output, and therefore where greater understanding of the underlying processes may lead to model improvement.

Here we report on existing and planned comparisons between the NZ-DNDC, CenW, APSIM, and OVERSEER models.

CLEARVIEW (BALLANCE PGP) – A FIRST LOOK AT NEW SOLUTIONS FOR IMPROVING NITROGEN AND PHOSPHORUS MANAGEMENT

Aaron Stafford

Ballance Agri-Nutrients, Tauranga

Ballance recently embarked on a 7-year research program -entitled 'Clearview' -under the Primary Growth Partnership scheme that is jointly funded with the Ministry for Primary Industries. The Clearview program of work is largely focussed around increasing nitrogen and phosphorus use efficiency and reducing losses. This presentation gives an overview of the high level objectives of this program, and provides a first look at two product and/or service development initiatives that are nearing commercialisation.

The first of these, 'MitAgator' is a GIS-based water quality decision support tool that links with OVERSEER to refine the latter models output. In doing this, MitAgator will provide greater insight into the spatial variability of nutrient (as well as sediment and microbial) loss within a farm landscape. This will allow users to identify critical source areas ('hot spots') for nitrogen, phosphorus, sediment and microbial loss within the farm landscape. Targeted application of mitigation and management strategies to these critical source areas will help to provide more cost-effective environmental management solutions for farmers.

Currently, there are few 'precision-ag.' tools available to pastoral farmers to assist them in targeting nitrogen fertiliser application within the farm landscape to maximise nitrogen response efficiency and return on their investment. Within the Clearview work program we have described/quantified the relationship between soil nitrogen content and pasture responsiveness to nitrogen fertiliser application. We are currently developing a graphical user-interface that will allow farmers to evaluate and optimise fertiliser nitrogen application strategy specific to their property.

NITROGEN RESPONSE EFFECT OF LESSN – A META-ANALYSIS

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Donaghys LessN is a microbial bioactives product promoted as increasing nitrogen response in pasture offering potential economic and environmental benefits. The LessN system comprises 3 L/ha product applied with 18.4 kg N/ha as dissolved urea. This was compared with the same rate of sprayed dissolved urea without LessN in 57 replicated pasture trials throughout New Zealand, with capacitance probe pasture measurement at application and after a single grazing rotation duration (between 14 and 47 days, mean 25.6 days). The trials with significant nitrogen response (52 trials) were subjected to meta-analysis (combined analysis).

The majority of the 52 trials (62%) showed a statistically significant ($p<0.05$) LessN effect when comparing the LessN system with the same rate of sprayed urea only. The meta-analysis on daily pasture growth effect of LessN system over sprayed urea at the same rate was also statistically significant at a mean 16 kg DM/day ($p<0.001$).

The effect of soil temperature at start of trial, soil test levels and region were assessed. Soil temperature was significant ($p=0.002$), due to an apparent reduction of LessN effect when local soil temperature was below the product label minimum of 10^oC (four trials affected). One outlier trial commenced within 2 days of an over 200 mm rainfall flood event and showed no apparent LessN effect.

Further treatments in the trials included one or more of sprayed urea at 36.8 kg N/ha, solid urea at 18.4 kg/ha and solid urea at 36.8 kg/ha. Without low soil temperature trials and the one flooding trial, these treatments were compared individually with the LessN system for (18.4 kg N/ha and 36.8 kg N/ha) on a ratio basis for total kg DM grown above control. The calculated mean ratio of the LessN system over sprayed urea at 18.4 kg N/ha was 2.7 (2.0 for independent trials only), over sprayed urea at 36.8 kg N/ha was 1.0 (1.2 for independent), over solid urea at 18.4 kg N/ha was 2.2 (2.1 for independent) and over solid urea at 36.8 kg N/ha was 1.1 (1.0 for independent). These results were consistent with mean doubling (or more) of nitrogen response with LessN.

USING HUMIC COMPOUNDS TO IMPROVE EFFICIENCY OF FERTILISER NITROGEN

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Over recent years the need to improve the efficiency with which fertiliser inputs are used has become increasingly important. In particular nitrogen (N) fertiliser applications commonly used to increase pasture production in dairy pastures have come under scrutiny for many reasons. The increasing cost of energy is driving the price of N fertilisers upwards. The effect of nitrogen leaching on groundwater as well as rivers and streams in New Zealand's main dairying districts is also becoming apparent. Currently all the local authorities have implemented or are in the process of implementing regulations aimed to reduce contamination of groundwater by nitrate (NO_3) leaching from farmland.

We have been evaluating the use of humic compounds applied with nitrogen fertiliser at Cloverdale a 730 Ha, 2900 cow dairy unit near Ashburton since December 2009. The trial work has consisted of half paddock (6 ha) plots where treatments have been applied in conjunction with the regular fertiliser applications on the farm. Pasture dry matter production is assessed by cutting 4 x 0.5 square metre sample areas at each harvest date for each treatment.

Three trials are discussed. Granular urea was applied on its own at a rate of 30kgN/Ha or with 3 kg/ha of soluble humic acid granules. We recorded between 3% and 12% greater dry matter production where soluble humic acid was included with the granular urea applications.

We compared applications of granular urea with liquid fertiliser consisting of dissolved urea, bio-stimulants and humic compounds. The comparison of dry matter production per unit of fertiliser N applied shows that dissolved urea with humic compounds and bio-stimulants produced approximately three times more dry matter per unit of applied nitrogen than solid urea applications.

When dissolved urea was applied either on its own or with the addition of humic compounds and bio-stimulants we found 12.5% greater dry matter was achieved by adding humic compounds and bio-stimulants to dissolved urea applications.

These results are discussed in relation to farm profitability, pasture quality and animal health and the N leaching requirements that are proposed by Environment Canterbury.

EFFECTIVENESS OF SCREENED AG-LIME – A REVIEW

Peter Bishop and Mike Hedley

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The fineness of agricultural limestone and its agronomic effectiveness are reviewed with respect to the proposed removal of fines (< 0.325 mm) by Grafton (2010) and Grafton et al. (2011) to prevent bridging of lime in aircraft hoppers during application. The review of the existing literature describes the rate of agricultural lime dissolution as a function of particle size and uses lime dissolution models to explain crop and pasture yield responses to agricultural lime.

Lime dissolution models predict that the removal of fines (<0.325 mm) from a typical Ag-lime will reduce the short-term (first 50 days) liming potential by approximately 17%. Over a longer term (1yr) the dissolution of both Ag-lime and Ag-lime with fines removed will be similar, with the total dissolution of each product converging at day 266.

If liming equivalence was required within 6 months, then to achieve the same agronomic response, 1.5 to 1.65 times of the coarser lime would be required compared to common agricultural lime.

ECONOMICS OF FERTILISER APPLICATION ON HILL COUNTRY

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The profitability of hill country farming within New Zealand has been relatively poor over the last decade, as evidenced by a (nominal) average Economic Farm Surplus per Hectare of $105, and a (nominal) average Farm Surplus for Reinvestment (the funds available after all costs including tax, interest and personal drawings have been made) of approximately $38 per hectare – available for development, capital spending, and debt reduction.

A major driver of pasture growth, which flows directly through into profitability, is fertiliser use. On hill country fertiliser usage dropped off through the decade due to a combination of poor profitability, drought, and the rising cost of fertiliser, although application rates have risen in the last 2 years.

The study investigated the economic returns from a capital application of fertiliser, and subsequent increased maintenance dressings, on two hill country sites; a low production potential site (7.5TonnesDM/Ha) and high production potential site (11 TDM/Ha), in order to lift Olsen P levels by 5 and 10 units respectively, up from a base P level of 8 and 15. The analyses on these scenarios were conducted on both a sedimentary and volcanic soil type.

The potential levels of pasture production relative to Olsen P are based on the generic calibration curves for Olsen P, as calculated by the AgResearch PKSLime econometric fertiliser model.

The results show a positive economic return from the increased fertiliser application, more so for the volcanic soil type relative to the sedimentary, given the greater responsiveness of volcanic soils to increasing P applications, notwithstanding the greater requirements of fertiliser P to achieve these lifts. Greatest returns were obtained from lifting P levels from relatively low levels (8) up to higher levels (13-18), compared with lifting levels above the base of 15. The lift in fertility was obtained via a capital and increased maintenance fertiliser input. At the margin, returns were negative above an Olsen P level of 20.

The analysis assumed that the farm was in a position to utilise the extra dry matter grown (e.g. with respect to subdivision). If capital stock were required to be bought in, the analysis still showed a positive result.

MICRO-NUTRIENTS UPTAKE EFFICIENCY AS A FUNCTION OF FORM AND PLACEMENT – A REVIEW

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A review of micro-nutrients in arable and pastoral farming systems has found low uptake efficiencies for copper and zinc of between 0.01 to 8.5% of the applied micro-nutrients. The uptake efficiency of copper and zinc was strongly affected by application method compared to solubility, with the best results from the incorporation of fine powders and solutions into soils. This was followed by seed row application of copper or zinc coated granules or fluids. Some advantages have also been seen with the application of metal chelates, however at a significantly higher cost. In contrast to the cationic micro-nutrients, the uptake of anionic micro-nutrients borate and molybdate have shown lower susceptibility to soil fixation with uptake efficiencies of between 1 to 20%, however this may lead to localised phyto-toxic effects if applied as high concentration granules.

A REVIEW OF RPR vs SUPERPHOSPHATE ON PUMICE SOILS

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Quin and Zaman (2012) reassessed data from the New Zealand 'National Series' of RPR *vs* superphosphate trials. Zaman and Quin (2012) made revised farmer recommendations based on this and on the results of a farmer survey. However the National Series contained only one trial on pumice, and this ran only for 3 years before becoming a somewhat difficult to interpret residual effects trial.

This paper summarises results from the significant number of RPR trials that have been conducted on pasture on pumice soils over the period 1967 – 1996, and interprets them in the context of the findings of Quin and Zaman.

It was concluded that-

(a) On pumice soils with a wide range of P retention (ASC), RPR (with elemental S added) will definitely come to equal the performance of high-quality soluble P at least by the 4th year of use (ie, a maximum lag-phase) of 3 years, even where the initial Olsen P is very low and soluble P responses are very large.
(b) The use of phosphoric-acidulated PAPR (and therefore intimate DAP/RPR or TSP/RPR mixes) can be used for the first few years if it is wished to avoid any lag-phase.
(c) The performance of RPR on pumice soils lies approximately mid-way between non-pumice low P retention soils and high P retention allophanic soils.

AMELIORATION OF Al, Mn AND Fe TOXICITY IN RICE, WHEAT, CLOVER AND RYEGRASS BY POLY-CARBOXYLIC ACIDS

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The ability of the sodium salt of poly-carboxylic acid (AlpHa™) produced by Advanced Agricultural Additives (NZ) ltd to alleviate the symptoms of Al, Mn and Fe phytotoxicity have been tested in pot and solution culture trials. Pot trials showed that in acid soils (pH 4.2) AlpHa™ added with fine limestone could achieve equivalent lime response of up to 2115 kg of lime flour per litre of AlpHa™ for ryegrass while less effect was found for white clover and wheat.

The mode of action of AlpHa™ was investigated in solution culture studies on ryegrass, rice and wheat with five levels of Mn and Fe, and six levels of Al. All metal levels were tested with three levels of AlpHa™ and replicated for five times.

The results showed that AlpHa™ reduced the phytotoxicity of:

- Al in annual ryegrass and rice, increasing both herbage and root growth.
- Mn in annual ryegrass, wheat and rice with increases in herbage and root growth.
- Fe in annual ryegrass and wheat with increases in herbage and root growth. However no effect was seen in rice due to the rapid drop in pH, which occurred only in the paddy rice plant solutions as a result of oxidation of the Fe^{++} to Fe^{+++} and its precipitation.

This reduction in metal toxicity due to the addition of AlpHa™ explains its ability to complement or replace lime as the current method of amelioration for metal phytotoxicity.

COMPARISON OF THE SOLUBILITY OF TWO GIBBERELIC ACIDS FOR AGRICULTURAL USE

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Some formulations of Gibberellic Acid (GA) have been reported to be less soluble than a 400g/Kg water soluble granule formulation (ProGibb SG), when used at recommended rates. The reduced solubility caused residues to be left on spray equipment, decreasing the amount of active ingredient applied and reducing effectiveness in 7 out of 10 trials.

The degree of dissolution and solubility of Express (400g/kg water soluble granule formulation of GA) was compared with ProGibb SG. The degree of dissolution after 5 min was tested at a concentration of 20g product/50L of water, which is twice the standard recommendation for both products, in order to stress potential differences. To test the solubility, the time taken to fully dissolve under agitation (stirring) was tested at the theoretical solubility of the active ingredient (5g ai/L which equates to 12.5g product/L of water).

At twice the recommended dilution rates, residues were not detected with Express (<0.001%) and negligible residues detected with ProGibb SG (0.003%). In the solubility trial it took 9 minutes for Express to completely dissolve with nil detectable residues, whereas with ProGibb SG there was a slight residue (1.2%) present after 30 minutes. From a practical perspective no significant differences were found in the solubility or dissolution between the two GA products tested.

The results confirm on-farm experience on the solubility of both products and show there should be no issue with the solubility of Express and its efficacy should not be compromised when used as directed.

THE STABILITY OF A GIBBERELIC ACID IN COMBINATION WITH LIQUID UREA AND THE EFFECT ON PASTURE GROWTH

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The use of Nitrogen in conjunction with gibberellic acid (GA) has been identified as desirable for improved pasture production. Dissolving Urea in water increases the solution pH, which may affect the stability and effectiveness of GA response rates.

GA stability in Urea solutions was tested using HPLC at different time periods (0, 1, 3, 4, 5 and 24 hours). The Urea solution used contained 390g per litre Urea (18%N w/v equivalent). The addition of Urea increased the pH of the GA solution from 6.1 to 8.1. For some treatments this solution was buffered to pH 4.5 (acid) with a commercial buffering agent, and to pH 9 (alkaline) with sodium hydroxide. Express (400g/kg soluble form of GA) was added to the respective Urea solutions at 40.3g per 100 litres of water. 'Widespread' (non-ionic adjuvant) was added to all treatments (50mL per 100 litres of water).

The GA remained chemically stable (>98%) over a 24hour period at ambient temperatures over all pH/GA solutions tested.

This indicates Express can be tank mixed with dissolved Urea without significant degradation of GA over a 24hr period. In a practical sense, this allows adequate time for product application post mixing, under normal circumstances, without adversely affecting the GA stability and therefore ensuring maximum efficacy of the application. Further work could be done to investigate the pasture response from the application of GA and dissolved urea under different solution pH.

SOIL CARBON, LIFE CYCLE ASSESSMENT, AND THE NEW ZEALAND APPLE

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Soil carbon sequestration can mitigate climate change, enhances the provision of ecosystem services, contributes to global food security, and ensures the sustainability of food production systems. But it could also benefit farmers by reducing the carbon footprint (CF) of their products. The CF is part of a Life Cycle Assessment (LCA); it is a measure of the sum of greenhouse gas emissions during the life cycle of a product. However, due to current CF methodologies and practical measurement difficulties, to date, soil carbon is not integrated into accredited schemes of carbon footprint calculations, such as, for example, the PAS 2050.

Considering soil carbon in CF calculations demands accurate monitoring of soil carbon stocks and statistically significant and powerful detection of small carbon stock changes over time. The number of samples required depends primarily on the spatial variability of soil carbon stocks. Inputs of carbon into the soil are predominantly from the rhizosphere, particularly in the deeper soil horizons. Very little soil carbon stock data are available for orchards. The objective of this study is to investigate the spatial variability of soil carbon stocks at the scale of trees and an orchard block.

At the tree scale, we measured carbon stocks in the top metre of a soil in both the tree row and the inter-row of a four year old commercial apple orchard block (variety Jazz, M.9 rootstock) located in Hawke's Bay. Soil carbon stocks decreased rapidly with increasing depth and ranged from 40.7 t C/ha in the top 10-cm layer to 3.1 t C/ha in the bottom 10-cm of the soil profile.

At the scale of an orchard block, the variability of carbon stocks to one metre depth was assessed by intensively sampling ten locations across the orchard block.

According to our measurements, we will develop guidelines for verifying changes in soil carbon stocks, which are urgently required to allow the incorporation of carbon stocks in CFs.

ASSESSING THE RISK OF NUTRIENT AND MICROBIAL RUNOFF FROM RAINFALL FOLLOWING SURFACE APPLICATION OF SLURRIES AND MANURES WITH VARYING DRY MATTER CONTENT

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Facilities that confine animals off-paddock are increasingly being used to house dairy cows over winter (non-lactation season) and strategically during the lactation season. This has resulted in greater amounts of manures and slurries being collected and subsequently applied back to land. Guidance on tactical timing of surface applied manures is based on our understanding of nitrogen (N), phosphorus (P) and faecal microbial losses to water via surface runoff and leaching relative to time of application and first rainfall event. This study investigated the risk of nutrient and faecal microbe (E.coli) loss in surface runoff in relation to increasing time by varying periods between manure application and first rainfall event.

The trial was conducted using simulated rainfall and soil monoliths contained in wooden runoff boxes. Manures of varying dry matter (DM) content ranging from 7 to 14% were investigated. The greatest risk to water quality occurred when rainfall was received within two days of manure application. If however the period between manure application and first rainfall event was 10 days or more, the risk to surface water quality decreased considerably and was generally comparative to losses from grazed pasture. This was applicable to N, P and faecal microbial losses.

There appears to be limited effect of varying DM content in this trial on measured runoff concentrations. Current guidelines recommend surface application of manures to soils no less than 10 days prior to rainfall however a minimum of 2 days is essential. Results gathered from this trial support these recommendations. However as a precautionary measure a minimum of 10 days should be planned in order to reduce the risk to surface water quality. We suggest therefore that the current guidelines relating to the tactical timing of manures surface applied to soils remain unchanged.

SOIL AND LANDSCAPE RISK FRAMEWORK FOR FDE APPLICATION TO LAND IN HIGH RAINFALL REGIONS (WEST COAST)

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On the West Coast, nutrient loss from the direct discharge of farm dairy effluent (FDE) contributes a significant nutrient loading into Lake Brunner. In this environment, anthropogenic phosphorus (P) inputs to the lake are of greatest ecological concern. Therefore curtailing P loss from farms is important for ensuring water quality. Application of FDE to land, at suitable irrigation depth and rate, can help reduce surface water pollution associated with direct discharge. However, it is apparent nationally adopted recommendations for land application of FDE will not be practical on the West Coast where rainfall can be extremely high (e.g. up to 5 m per year). This means a large volume of water is collected from dairy shed catchment areas and also limits the potential for soil water deficits large enough to safely apply FDE to high risk soils.

This project aimed to (1) quantify the amount of nutrients lost in the direct pond discharges of FDE to streams throughout the year, and, (2) assess the suitability and practicality of a low rate FDE application system to land in the Lake Brunner Catchment. Pond discharges on three farms were monitored for 12 months and total nutrient loadings throughout this period were determined. On one property an irrigation trial was established where 10 mm of FDE was applied irrespective of the magnitude of soil water deficit. Surface run-off (concentration & volume) was monitored during three irrigation events in spring, summer and autumn.

Based on our findings, we estimate P loss from FDE can be reduced by approximately 80% when it is applied to land rather than directly discharged. Here we present a modified version of the Soil and Landscape Risk Framework for FDE management in high rainfall areas, such as the West Coast. Essentially, this adaption to the framework incorporates desirable management practices with what is practically achievable in these environments.

EVALUATION OF PHYSICAL, CHEMICAL AND MICROBIAL CHARACTERISTICS OF STAND-OFF PAD MATERIALS DURING WINTER USE AND RELATIONSHIP WITH COW BEHAVIOUR

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Stand-off pads are now being used by at least 20% of New Zealand dairy farmers with the main aim to protect susceptible soils from treading damage during wet winters. However, as the use of stand-off pads is a relatively new practice there are still large gaps in information such as what is the best type and quality of carbon material to use for its longevity thereby reducing expensive replacement costs.

This project investigated the physical, chemical and microbial characteristics of stand-off pad materials so that recommendations could be made as to the best materials to use. 8 stand-off pads were sampled (in Northland, Waikato, Otago and Southland) that used different media (wood chips, post peelings, chipped pallets, bark chip and sawdust). Cow behaviour was also assessed at North Island sites when pads were being used to ascertain which material performed best from an animal welfare perspective.

Key findings were that bulk density of materials increased with time due to material settling. The coarser materials (bark, wood chip) performed better whereas post peelings tended to compact with stock usage, particle size decreased and drainage was impeded. Nutrient concentrations increased with stock use while the C/N ratio decreased. Pad drainage was high in potassium. *Escherichia coli* concentrations in pad materials were found to be at high concentrations, similar to those found in fresh faeces. In some cases cow were reluctant to lie down on pad surfaces and the characteristics of acceptable and unacceptable surfaces will be defined. Recommended pad management strategies are outlined in the paper.

THE EFFECT OF DAIRY EFFLUENT APPLICATION ON AMMONIA VOLATILISATION AND NITROUS OXIDE EMISSIONS FROM NEW ZEALAND PASTURE SOIL

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Dairy farm effluents (manure and liquid effluent) are commonly applied to soil as a source of organic N fertiliser. However, these applications increase soil inorganic N, and may therefore increase ammonia (NH_3) volatilisation and nitrous oxide (N_2O) emissions. Various approaches have been used to reduce NH_3 and N_2O losses derived from agricultural sources. One approach is using N process inhibitors such as urease inhibitors (UIs) and nitrification inhibitors (NIs). Two field experiments were conducted to study the effect of a UI - N-(n-butyl) thiohposphoric triamide (NBPT, commercially named Agrotain® nitrogen stabiliser) and NI - dicyandiamide (DCD), applied with different forms of dairy effluent on urea hydrolysis and NH_3 and N_2O emissions, using a chamber technique. Treatments included fresh manure, stored manure, fresh farm dairy effluent (FDE) and stored FDE, with and without Agrotain® or DCD, applied to a well drained soil. The application rate of the FDE and manure, which had differing dry matter (2% and 22.5%, respectively) was about 100 kg N ha^{-1}. Results showed that application of manure and FDE both in fresh and stored forms to the pasture enhanced NH_3 emissions. Adding UI had a significant effect ($P<0.05$) on NH_3 losses from both fresh manure and fresh FDE, which decreased NH_3 emission by 48% and 38%, respectively. All types of effluent have the potential to produce N_2O, particularly fresh manure and fresh FDE. The emission factors (amounts of N_2O-N emitted as percentages of applied N) of fresh manure, fresh FDE and stored FDE were 0.11%, 0.10% and 0.03%. DCD was effective in decreasing N_2O emissions in the stored FDE, fresh manure and fresh FDE by 11%, 27% and 51%, respectively. Results from this study suggest that mixing DCD or Agrotain® with different types of dairy effluents to mitigate NH_3 and N_2O emissions can be a viable strategy.

THE OPPORTUNITY FOR MUNICIPAL WASTEWATER IRRIGATION IN THE LOWER NORTH ISLAND

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Many New Zealand communities discharge their wastewater to waterways after treatment in oxidation ponds. There is the potential for these discharges to be applied to land, especially during low flow conditions which are common over the summer periods. The switch from water to land discharge provides an opportunity to lessen the environmental impact associated with surface water discharges, improve recreational water quality, address cultural concerns and provide an opportunity for agronomic financial gain. However, there are management limitations with year round land application and industry bodies are conscious of the market perception of using wastewater for production purposes.

Much has been said with the potential for improvement in surface water conditions by using land application; however the practicalities are often not thought through. Not many areas in New Zealand have the potential to receive high rates of land application year round, as winter application can adversely affect crop/pasture production. Further, industry bodies are becoming increasing aware of land management practices which could limit access of produce to international markets, with Fonterra already placing significant limitations on wastewater use on dairy farms. A solution to the land management issues is consideration of combined land and water discharges (CLAWD).

In an area extending from Wairoa to Martinborough, and Pukerua Bay to Wanganui, there are 426,000 people. They typically produce 58.4 million cubic metres of wastewater, or 137 m3 per person annually. In this same area deficit irrigation would require 5,970 to 18,480 ha for combined discharges or land only application respectively. Using a non-deficit approach this area reduces to 11,370 ha for non-deficit application. Storage for these options ranges from 37,459,000 to 45,396,000 m3 for the land only application options and 1,583,000 to 2,340,000 m3 for the combined options. Non-deficit irrigation requires about 82 % of the storage and 73 % of the land area requirements when compared to deficit irrigation.

Careful consideration of the wastewater quality and the receiving land and water environments provides realistic opportunities to improve water quality in our rivers. Additional benefits come for agricultural production, but a realistic approach is needed to avoid over application affecting farm management and placing communities under significant financial burden.

ESTABLISHMENT AND ENVIRONMENTAL RISKS OF WINTER FORAGE CROPS ON PUMICE SOILS – EXPERIMENTAL RESULTS WITH A FARMERS PERSPECTIVE

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The incorporation of forage crops into pastoral production systems in the Upper Waikato catchment is essential to mitigate feed shortages at key times of year. This Sustainable Farming Fund project (SFF11/010) aims to identify best practice for managing the environmental impacts of forage cropping between pasture phases. This experiment set out to compare conventional establishment of a kale swede mix crop with establishment using direct drill techniques, plus test a range of nitrogen fertiliser rates (seedbed only, and 100, 200, 300 or 400 kg N/ha).

Yields from crops established with direct drill methods were comparable with traditional methods with lower costs. Total dry matter yield was c. 11 t DM/ha at harvest (29/5/2012), and increasing N fertiliser did not significantly increase yields. There were some differential effects on the proportions of kale and swede crops at the different N rates; more N fertiliser resulted in a shift from swedes to kale, not an increase in total yield.

Mineral N remaining in the soil at the time of harvest increased with fertiliser N inputs, but amounts were relatively small (37 kg N/ha to 60 cm @ 400 kg N/ha applied). Our assessment was that the N leaching risk from growing the winter forage crop in this year was small. Thus, the key times for minimising environmental effect are before the crop (establishment of annual ryegrass in autumn as a lead-in) or after the crop (returning c. 280 kg N/ha to the soil post grazing in winter, with much of that as urine).

The normal practice of farmers in the group is to apply two split applications of 100kg at 6 and 12 weeks, and they were surprised by the crop yields and minimal leaching risk with one application of 200 kg N. Response to this work has been to reconsider the way nitrogen is applied to winter forage crops with a single application of 200kg N now recommended, thus reducing application costs with no risk of increased leaching. These preliminary results have also led the group to consider if higher yields would be achieved by growing Swedes and Kale separately.

REDUCING OVERLAND FLOW AND SEDIMENT LOSSES FROM PADDOCKS USED FOR DAIRY WINTER FORAGE GRAZING

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The scale and extent of dairy farming in southern New Zealand has grown considerably in recent years. However, environmental concerns associated with the loss of nutrients, faecal microbes and sediment to waterways during winter grazing of dairy cows remains an issue in vulnerable landscapes. Winter forage grazing paddocks are believed to contribute a disproportionately large part of annual farm nutrient and contaminant losses as a result of intensive stock grazing on soils with high moisture content. A paired catchment study was established at Telford Farm, South Otago to investigate alternative winter grazing management strategies that may reduce the volume and concentration of contaminants in overland flow. Strategies were targeted towards protecting vulnerable areas of the catchment that contribute the greatest amount of contaminant loading i.e. critical source areas (CSAs). We hypothesised that losses of sediment, phosphorous and *E. coli* could be reduced considerably through protection of the CSA, which accounted for less than 2% of total paddock area. In the control catchment the cows strip-grazed the crop from the bottom of the catchment and moved upslope with unrestricted access to the CSA. In the treatment catchment the cows strip-grazed from the top of the catchment and moved downslope with the CSA protected. Automated sampling and monitoring of flow and contaminant concentrations in overland and subsurface flows indicated smaller and shorter duration overland flow events in the treatment catchment compared to the control catchment, leading to a reduction in yields of contaminants lost. These findings indicate that simple and low cost techniques that take into account paddock topography, slope, soil type and stock management can significantly reduce overland flow and contaminant losses from winter forage crop paddocks.

DOES ADDING STRAW OR SAWDUST TO CATTLE EXCRETA REDUCE AMMONIA, NITROUS AND METHANE EMISSIONS DURING STORAGE?

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Animal shelters are increasingly being used to house dairy cows off-paddock over winter (non-lactation season) and strategically during the lactation season when soils are wet. Shelters have either a solid or slatted floor, depending on design and generally include inputs of carbon-based materials such as sawdust or straw that act as a bedding material. Adding these materials will change the manure properties, both physically and chemically, which may result in reduced greenhouse gas (GHG) emissions such as ammonia (NH_3), nitrous oxide (N_2O) and methane (CH_4) during manure storage. Consequently, addition of sawdust or straw may provide a GHG mitigation option for dairy farmers.

The objective of this study was to compare NH_3, N_2O and CH_4 emissions from stored manures with different amounts of bedding material added. Manures were prepared by mixing fresh dairy cow excreta (dung:urine 1:1.3) with carbon-based materials (straw or sawdust) at two different ratios. A control (excreta only) was also maintained. Manure treatments were stored outdoors for 7 months in a series of 0.5m long columns, during which time NH_3, N_2O and CH_4 emissions were periodically measured. A second set of columns, containing the same mixed excreta and bedding material treatments, were destructively sampled for chemical and physical analysis. The impact of straw and sawdust amendments on cumulative GHG emissions from stored manure will be presented.

CAN NITROUS OXIDE EMISSIONS FROM SOIL BE REDUCED BY FEEDING LAMBS WITH FRESH FORAGE RAPE (*BRASSICA NAPUS* L.)?

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In New Zealand, agriculture is predominantly based on outdoor animal grazing systems. Animal excreta have been identified as a major source of nitrous oxide (N_2O) emissions. Forage brassicas have been increasingly used due to their faster growing ability, higher dry matter yield and higher nutritional value having less neutral detergent fibre and more non-structural carbohydrates than perennial ryegrass. The aim of this study was to determine the partitioning of dietary N between urine and dung in the excreta from sheep fed forage brassica rape (*Brassica napus subsp. Oleifera L.*) and to measure N_2O emissions when the excreta are applied to the soil. A sheep metabolism study was used to collect urine and dung from sheep fed forage rape or perennial ryegrass (*Lolium perenne L*.). Urine and dung collected from this study were then used in a field plot trial for measuring N_2O emissions. The experimental site contained white clover (*Trifolium repens L*.) and perennial ryegrass pasture on a poorly-drained silt-loam soil. The treatments included urine from sheep fed forage rape or ryegrass, dung from sheep fed forage rape or ryegrass, and a control. N_2O emission measurements were carried out using the soil chamber technique and gas samples were analysed using a gas chromatograph. Total N_2O emissions and the emission factors (EF3) for each excreta type were calculated. Excreta N transformations in the soil were also regularly measured. The results indicated that N use efficiency by sheep was equivalent for both forage rape and ryegrass. Urine from sheep fed ryegrass showed slower N transformation rates in soil from organic N to ammonium-N and to nitrate-N, compared with that from those fed forage rape. As a consequence, the EF3 was higher for urine from sheep fed ryegrass compared to forage rape. However, dung for sheep fed ryegrass showed higher N transformation rates from organic N to ammonium-N and to nitrate-N and as a result, the EF3 was lower, although the difference was not significant. EF3 for sheep dung was substantially lower than that for sheep urine.

MEASURING BACTERIAL DENITRIFIER GENES DISTRIBUTION AND ABUNDANCE IN NEW ZEALAND DAIRY-GRAZED PASTURE SOILS

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A detailed knowledge of the abundance and distribution of soil denitrifiers is pre-requisite to mitigate N_2O emitted during denitrification. *Nos*Z is the gene regulating the N_2O reductase enzyme which is responsible for conversion of N_2O to N_2 during denitrification. The objectives of this study were to determine the distribution and abundance of denitrifier genes (*nir*S, *nir*K and *nos*Z) in New Zealand pasture soils and to correlate gene abundance to measured N_2O emissions and denitrification rates. We collected 10 New Zealand dairy pasture soils with contrasting physico-chemical characteristics and denitrification potentials. We determined the distribution and abundance of the total bacterial gene (*rpo*B) and denitrifier genes (*nir*S, *nir*K and *nos*Z) on field moist soils. *Nir*S, *nir*K and *nos*Z gene distributions were estimated using Terminal Restriction Fragment Length Polymorphism (T-RFLP) and their abundances were measured using quantitative Polymerase Chain Reaction (qPCR). Nitrous oxide emissions and denitrification rates were also measured.

Our results suggest that the distribution and abundance of *nir*S, *nir*K, *nos*Z and *rpo*B genes varied among the soils. The average number of gene phylotypes for *nir*S, *nir*K and *nos*Z varied from 4 to 33, 3 to 31 and 12 to 27 respectively. Similarly the gene copy numbers of *nir*S, *nir*K, *nos*Z and *rpo*B varied from 4.5×10^4 to 2.2×10^6 kg^{-1} soil, 8.4×10^7 to 4.9×10^8 kg^{-1} soil , 6.9×10^3 to 9.6×10^5 kg^{-1} soil and 1.8×10^8 to 1.2×10^9 kg^{-1} soil respectively. The correlation analysis between distribution and abundance of denitrifier genes with soil chemical characteristics and N_2O emissions using Carl Pearson's correlation coefficient suggested that average number of phylotypes and abundances of denitrifier genes correlated significantly (P<0.05) with soil texture, Olsen P, microbial biomass carbon, total C, total N and mineral N. *Nir*S and *nir*K gene copy numbers correlated positively with N_2O emissions. We found no clear relationship between *nos*Z gene copy numbers and N_2O and N_2 emissions in our field moist soils, suggesting that the *nos*Z copy number may only predict N_2O and N_2 emissions under anaerobic conditions.

CHANGES IN DENITRIFICATION RATE AND BACTERIAL DENITRIFIER GENES DISTRIBUTION AND ABUNDANCE IN DAIRY-GRAZED PASTURE SOILS TREATED WITH CATTLE URINE AND DCD

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The uneven excretal deposition by grazing farm animals in the form of urine leads to very high concentrations of available N in relatively small volumes of soil and results in high N_2O emissions. Application of the nitrification inhibitor, dicyandiamide (DCD), can inhibit nitrification (and consequently denitrification) and result in lower N_2O emissions from urine affected soils. However, the effect of urine and DCD on denitrification may vary among soils and may depend on the soil's inherent capacity to denitrify. This study was undertaken to assess the effect of addition of DCD to urine patches on the denitrification process, including N_2O emissions and the distribution and abundance of denitrifier genes.

We collected surface samples from 3 New Zealand dairy pasture soils with contrasting denitrification potentials (Manawatu Fine Sandy Loam, Tokomaru Silt Loam and Otorohonga Silt Loam). Three treatments were applied to the soil samples; urine (700mg N kg^{-1} soil), urine +DCD (10 mg DCD kg^{-1} soil) and control (deionised water). Samples were saturated with water and incubated at 25^{o}C for four weeks. Gas samples and soil extracts collected during the incubation were analyzed to determine the changes in denitrification enzyme activity (DEA), denitrification rate (DR), N_2O and N_2 emissions, soil pH, mineral N, and microbial biomass carbon. We also are estimating the distribution of denitrifier genes (*nir*S, *nir*K and *nos*Z) using Terminal Restriction Fragment Length Polymorphism (T-RFLP) and their abundance using Quantitative Polymerase Chain Reaction (qPCR). The results of this study will be discussed at the Workshop.

EFFECTS OF SOIL AMENDMENTS ON SOIL BACTERIAL DIVERSITY

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Normal fertile soils contain hundreds of millions to billions of microbes in a single gram. These bacteria are responsible for many soil processes, especially cycling of carbon, nitrogen, phosphorus and sulphur. Soil additions such as compost alter the physical properties of soil, changing organic carbon content, moisture and aeration levels and soil pH. Hence they impact on the bacterial composition of the soil which is strongly dependant on these conditions. Here the effect of adding compost, biochar and both is studied by measuring the relative abundance of bacterial phyla and certain genes of nitrogen metabolism using Quantitative PCR. Soil samples (ten for each treatment) were taken from the top 10 cm of soil and mixed thoroughly before extracting DNA. Resulting analysis showed wide variation within between the ten samples for each treatment, yet all treatments showed similar amounts of each bacterial phyla: Bacteroidetes and Firmicutes were most abundant, while Alphaproteobcateria were found at levels a millionfold less as the least abundant of the phyla tested. A step-wise discriminate analysis was able to mostly separate the treatments, with the addition of biochar increasing the abundance and Alphaproteobacteria and the genes involved in converting nitrite into nitrogen; this often occurs in less fertile soils as a way of increasing energy in the soil. The addition of compost increased Firmicutes, fungi and cyanobacteria, all bacteria phyla associated with decomposition.

INHIBITION OF AMMONIA OXIDISERS TO CONTROL NITRIFICATION RATE UNDER SIMULATED WINTER DAIRY FORAGE GRAZING CONDITIONS: AN INCUBATION STUDY

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The microbial process of nitrification plays a key role within the soil nitrogen cycle. Nitrification is the process where ammonia is oxidised to nitrite and then to nitrate and this process can have major environmental implications. It has previously been determined that both ammonia oxidising bacteria (AOB) and ammonia oxidising archaea (AOA) mediate the first step of the nitrification process, i.e. the ammonia oxidation process in soil but it is unclear which group is important under wet winter forage grazing conditions. The reduction of nitrification rates is an important factor in reducing NO_3^- leaching from winter forage systems. A key mitigation tool is the use of the nitrification inhibitor dicyandiamide (DCD) to treat winter forage grazing systems. The aim of this study was to improve our knowledge and understanding on the effect of cow urine and dicyandiamide (DCD), on AOA and AOB in dairy winter forage grazed soils.

While this study indicated that AOA were present within the soil, it was AOB that played the dominant role in ammonia oxidation. In the urine only treatment (applied at 500 kg N/ha), the AOB *amoA* gene copy numbers were 11.7 times that of the control on day 21. The urine plus DCD treatment applied at 10 kg DCD/ha and urine plus DCD treatment applied at 20 kg DCD/ha, respectively, showed a 91.3 % and 96.6 % reduction in AOB *amoA* gene copy numbers at the same point in time. By day 112, the nitrate concentration for the urine only treatment was 8.4 times the control. Whereas, the urine plus DCD (10 kg/ha) and urine plus DCD (20 kg/ha) treatments had an 84.4 % and an 88.5 % reduction in nitrate concentration, respectively, compared to the urine only treatment.

These results illustrate that while both AOA and AOB were present within the soil only one group of microbes were actively involved in the ammonia oxidation process. The results also show that using the nitrification inhibitor DCD is a highly effective way to inhibit the growth of AOB, leading to a reduction in NO_3^- concentration in the soil under a winter forage grazing system.

SUBSURFACE HYDROLOGY OF RIPARIAN ZONES RELEVANT TO NITRATE REMOVAL

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Surface water and groundwater systems are connected with the head gradient between the river and the nearby aquifer controlling the magnitude and direction of the exchange flux between the two systems. The direction of the flux dictates whether the river gains water from the nearby aquifer, or loses water to it. The exchange between groundwater and rivers is a key component influencing not only river discharge/recharge (from a quantitative perspective), but also affects water quality, geomorphic evolution, riparian zone character and composition, and ecosystem structure. A number of processes contribute to the exchange flux between surface and groundwater, most importantly they include: aquifer recharge (including diffuse recharge, recharge from irrigation return, and recharge from overbank flow), bank storage, groundwater extraction, and evapotranspiration.

Riparian zones can provide a protective buffer between streams and adjacent land-based activities by removing nitrate from shallow groundwater flowing through them. The flow of shallow groundwater through the biologically active root zone of riparian vegetation, which is inherently rich in organic carbon, facilitates the denitrification process. Hydrological factors are an important influence on the effectiveness of riparian buffer zones in reducing pollutant loads delivered to streams. Nitrate-bearing water can interact with sediments in many forms. The classical conceptual model for nitrate attenuation during base flow conditions in gaining streams suggests that groundwater travels laterally and interacts with the riparian soil before discharging to the stream.

In this work, conceptual models for surface water-groundwater interactions are presented along with analytical mathematical functions that describe nitrate removal in riparian zones. These concepts are incorporated within a GIS modelling framework to assess the potential of riparian zones to reduce nitrate delivery to streams. The GIS modelling framework can be adopted to prioritise riparian rehabilitation in catchments with high-priority areas defined as those having a high potential for riparian denitrification and nearby land uses that generate high nitrogen loads. The results of this research, which identified key factors and sub-surface processes controlling nitrate removal, have been used as a basis for providing practical guidelines for riparian zone management in Australian catchments.

USING STREAM FLOW AND CHEMISTRY DATA TO ESTIMATE CATCHMENT SCALE GROUNDWATER AND NITRATE FLUXES

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Groundwater is the dominant flow path carrying land surface recharge, including dissolved contaminants, to surface waters draining a catchment. The dominance of the groundwater pathway poses a challenge to management of water quality in agricultural catchments, because groundwater quantity and quality are difficult and expensive to monitor, and groundwater assimilative capacity for nitrate is generally unknown. On the other hand, rainfall and evapotranspiration as inputs, and stream flow and nitrate concentration as outputs, can be recorded relatively easily, especially if inexpensive in-stream nitrate sensors can be developed.

The eigenmodel approach has previously been used to estimate the land surface area and groundwater discharge contributing to stream flow in a small hill catchment. We extended this approach to explain seasonal patterns of nitrate and silica concentrations observed in the Toenepi Stream, which drains a lowland dairying catchment near Morrinsville, and to estimate the water and nitrate fluxes driving these observations.

The model was calibrated for the 4-year period 1 April 2007 to 31 March 2011, and cross-validated using data from the period 1 April 1995 to 31 March 1997. Estimated discharge, nitrate concentration (as nitrate-N) and nitrate load from near-surface, fast groundwater, and slow groundwater flowpaths were then calculated. On an annual basis, stream flow was dominated by discharge from fast, shallow groundwater. In summer however, slow, deeper groundwater dominated both flow and chemistry.

The total catchment input load was estimated to be 40 kg ha^{-1} y^{-1}. Nitrate attenuation in the groundwater components accounted for 20 kg ha^{-1} y^{-1} of this, with the remaining 50% being discharged to the stream. At the catchment scale, nitrate assimilation appears to occur dominantly in the shallower flow near the redox boundary, despite the greater reduction of nitrate concentration in the deeper groundwater.

The ability to estimate catchment water and nitrate fluxes from weather and in-stream data offers an inexpensive and widely applicable tool for management of catchment resources. The approach should be valid for other catchments with evidence of parallel oxidised and reduced groundwater flowpaths, and where stream flow leaving the catchment matches net recharge over the catchment area.

BOTTOMS OR TOPS?
– OPTIMISING LOCATION OF WETLANDS IN CATCHMENTS TO MAXIMISE EFFICIENCY

Chris C. Tanner

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One of the key ecosystem services wetlands can provide in agricultural landscapes is attenuation of flows and diffuse pollutant loads. The answer as to where in agricultural catchments wetlands should optimally be located for water quality enhancement varies depending on the landscape of interest, the flow regime, and the particular contaminants being targeted. Recognising that hydrology is the most fundamental factor influencing pollutant removal performance, a simple dynamic model for wetland pollutant removal was used to explore potential wetland nitrate removal performance from surface waters at various locations within an agricultural catchment. Annual nitrate removal performance over two annual periods were compared at up- and down-stream locations within two Waikato catchments with contrasting flow regimes where contemporaneous hourly flow records were available. Overall performance is shown to be substantially better when flows are steady or show low variability. This suggests that wetland performance for nitrate-N will tend to be better near the bottom of catchments where flow regimes tend to be more buffered than they are at the top of catchments. A range of other considerations influencing the costs and benefits of top and bottom-of-catchment wetlands will be discussed including: targeting critical source areas, equitable spread of costs across landowners and biodiversity benefits.

INFLUENCE OF LIVESTOCK GRAZING ON WETLAND ATTENUATION OF DIFFUSE POLLUTANTS IN AGRICULTURAL CATCHMENTS

Andrew Hughes, L. McKergow, J. Sukias and C. Tanner

NIWA, Hamilton

Pastoral seepage wetlands are common features in the hilly and undulating parts of New Zealand. The potential of these wetlands to attenuate upslope derived pollutants is starting to be recognised, however, there have been few attempts to quantify their effectiveness. In many cases, cattle have unrestricted access to these wetlands and are attracted to the water and forage material available within wetlands. Livestock access can adversely affect wetland biodiversity, reduce vegetation biomass, change plant composition, and deposit faeces and urine directly into water. Extensive stock trampling can also entrain wetland material, resulting in increased fluxes of sediment and organic material entering streams.

The aims of this study were to i) quantify the efficiency of a pastoral wetland (Toenepi catchment Waikato) at attenuating pollutants (e.g., TSS, E. coli, N and P), and ii) measure the water quality effects of unrestricted cattle grazing within the wetland. Wetland flow was recorded at the wetland outlet and near the top, directly downstream of a spring area. Water quality samples were obtained from both sites during baseflow and storm flow conditions. Results indicate that the concentrations of all analytes are lower at the lower weir than the upper weir, regardless of flow conditions or season. Flow monitoring, however, indicates that only a small amount of flow enters through the upper weir and suburface pathways probably dominate the flow exiting the lower weir. Limited water quality analysis suggest highly spatially variable concentrations of N and P entering in the groundwaer. Further analysis of groundwater is required to determine the significance of these pathways. Despite this, sampling to date has given us confidence that the wetland is very efficient at denitrifying NO_3-N entering in subsurface flow.

Data obtained from time-lapse cameras indicate that cows do not spend much time grazing within the wetland. Limited cattle entry into the wetland may be due to cattle being wary of becoming entrapped due to wetland substrate depth. This is exaccerbated by the steep terrain adjacent to much of the wetland which makes both entry and exit difficult. Despite the limited grazing, fluxes of cattle derived pollutants and damage to wetland margins and vegetation have been detected.

OVERVIEW OF DETAINMENT BUNDS FOR MITIGATING DIFFUSE–SOURCE PHOSPHORUS AND SOIL LOSSES FROM PASTORAL FARMLAND

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New Zealand relies upon phosphorus (P) to sustain agricultural productivity. However, P loss from farming systems to freshwater ecosystems can promote eutrophication; a global problem. Most P and sediment is transported from farm systems to freshwaters via ephemeral streams which flow for short periods of time in response to intense rainfall and runoff events. The objective of this MSc research was to quantify performance of a new type of detainment bund (DB) being trialled to specifically attenuate P and sediment loss from pastoral farms in the Lake Rotorua catchment, Bay of Plenty. The DBs have been initiated in collaboration with Bay of Plenty Regional Council, DairyNZ and Rotorua catchment farmers and consist of low profile earth bunds (c. 1.5 m high) designed to temporarily pond ephemeral storm flows across high quality farmland without compromising pastoral production. The structures have a choked riser outlet to regulate water storage and control residence time. A storage capacity of at least 100 m^3 per hectare of catchment was used in the design of DBs. Ponded water is released slowly, with the aim of promoting settling of suspended sediments and associated particulate P in the DB basin (on the pasture), thereby enhancing soil fertility. Deposited sediment was sampled by deploying synthetic turf mats and sediment trays across the ponding area. Grab samples of in– and out–flowing water were collected at various stages during storm events and analysed for suspended solids, particle size distribution, total P, dissolved reactive P, and dissolved inorganic nitrogen. Water level was recorded to help derive a mass balance of water, sediments and nutrients for two different DB systems. Results show steady decreases in total suspended solids in the ponded water over time and retention of P in the deposited sediments (mean total P =1.998.95 mg P kg^{-1}). This research will contribute to refinements of the DB design for P-mitigation purposes and a code of 'best management practice' for the use of similar DBs on farms. If results confirm that specifically 'sized-to-catchment' DBs are effective P mitigation tools then there may be opportunities for widespread and collaborative on-farm implementation in the Lake Rotorua catchment and in agricultural landscapes throughout New Zealand.

FATE OF A DAIRY COW URINE PULSE IN A LAYERED VOLCANIC VADOSE ZONE

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Nitrate-N leaching from dairy cow urine patches has been identified as one of the major contributors to diffuse groundwater contamination in dairying catchments. To investigate the transport and transformations of nitrogen (N) originating from a urination event between the ground surface and the water table, fresh urine was amended with a conservative tracer (Cl) and applied onto a pumice soil in the Lake Taupo Catchment in early August. The resulting fluxes of the different N components and the conservative tracer leached from the urine patch were monitored at different depths through the vadose (unsaturated) zone using automated equilibrium tension lysimeters (AETLs). These were installed in triplicates at each of five depths between 0.4 and 5.1m.

Textural variability, hydrophobicity, and the coarse gravelly pumicious materials in the vadose zone resulted in heterogeneous flow patterns with high variability in the N and Cl masses captured. The measured N uptake by herbage, 123 kg N/ha in the 67 days following the application of the urine, represented 27% of the applied urine N. The breakthrough of concentrations of organic-N, ammonium-N and nitrate-N, measured at the bottom of the root zone (at the 0.4m depth), exhibited distinctively different dynamics reflecting urea hydrolysis and subsequent nitrification. By the 1.0m depth, effectively all the N present was in the mobile nitrate-N form. In the lower part of the vadose zone at 4.2m, an average of 32.7% of the applied urine-N was recovered; all of it was nitrate-N. This recovered N fraction was not significantly different (95% CI.) from the fraction measured at the bottom of the root zone, indicating that no assimilation of the nitrate-N being leached from the root zone was occurring in the vadose zone. This is despite significant denitrification capacity being found in laboratory incubation experiments where anaerobic conditions are artificially created. However, significant evidence of nitrate removal by denitrification has been observed in the shallow groundwater system at this site. No substantial urine-N or conservative tracer was measured below the top of a Palaeosol layer at approximately 4.2m depth. This result is consistent with results from a previous conservative tracer experiment and suggests that unsaturated lateral flow was occurring at the interface between the Taupo Ignimbrite and the Palaeosol.

THE 'WATER WHEEL' - A TOOL FOR FINDING BALANCE BETWEEN ECONOMIC AND ENVIRONMENTAL OUTCOMES

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To meet water quality and quantity objectives, limits are now required to be set on the extent to which water quality and water flows can be changed relative to a benchmark, such as their natural state. It also requires all land and water users – urban and rural – to collectively operate within the agreed limits. In most catchments difficult trade-offs are involved in setting standards and limits, and in operating within them.

The Water Wheel is a graphic that presents the current state (based on monitoring data), or the expected state (based on scenario analysis, for example) of indicators of economic, social, cultural and environmental wellbeing at a specified catchment location. The status of each indicator is normalised with reference to indicator-specific thresholds that collectively define Excellent, Good, Average, and Poor outcome bands. Comparison of sets of Water Wheels produced through scenario analysis as part of the limit setting process readily identifies any trade-offs between and within the "four well-beings".

A tool has been developed that enables Water Wheels to be evaluated at multiple points within New Zealand's river network, exploiting data contained in the Ministry for the Environment's River Environment Classification (REC) system.

This paper describes the Water Wheel concept, the tool that has been developed for populating a Water Wheel as part of limit-setting scenario analyses, and the tool's application to illustrate the types of trade-offs often involved in the setting of water quality and quantity standards and limits.

INTRODUCING THE AGRI-ROVER: AN AUTONOMOUS ON-THE-GO SENSING ROVER FOR SCIENCE AND FARMING

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Precision agriculture is a technology-rich approach to farming that can achieve markedly improved efficiencies through the identification and management of within-paddock variations in soil and pasture. However, precision technologies can be expensive and complicated to use, and there is a lack of agriculturally-robust sensor delivery systems that can achieve regular, affordable, high resolution data collection across large areas.

This paper examines the potential of automated unmanned ground vehicles (UGVs) as one promising option for delivering a wider variety of sensor technologies for pastoral farming, and reports on a prototype agri-rover UGV being developed by AgResearch.

MULTISPECTRAL AERIAL IMAGING OF PASTURE QUALITY AND BIOMASS USING UNMANNED AERIAL VEHICLES (UAVS)

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In recent years, the management of grassland systems has focused on site-specific management practises which require accurate, reliable and near-real time data. In order to optimise daily farm management decisions remote sensing data products have to fulfil specific requirements. While space borne remote sensing is limited by its temporal and spatial resolution and proximal sensing methods are laborious when it comes to mapping an entire farm, airborne sensors mounted on unmanned aerial vehicles (UAVs) offer a number of advantages: high spatial resolution imagery can be obtained quickly, reliably and at a relatively low cost. However, as research on civil use of UAVs is still at an early stage, they need to be trialled and compared to other remote sensing methods.

The current project uses a multispectral (Tetracam) and a converted infrared camera (Canon) that are mounted on a remotely controlled Mikrokopter UAV. Specific filters on the camera are used to acquire imagery of pasture reflection in six different wavebands. In order to obtain quantitative data on pasture relevant parameters such as crude protein and biomass, the systems must be precisely calibrated and a data processing chain must be developed. This involves atmospheric and radiometric corrections and accurate georeferencing of images. Statistical methods are then applied to correlate spectral image data to ground reference data.

Successful application of the UAV based multispectral imaging system will produce high quality multispectral image data and ultimately lead to an increased understanding of the spatial and temporal variability of pasture quality cover and biomass. Moreover, robust and improved calibration models for airborne remote sensing of pasture relevant parameters will be developed and trialled against hyperspectral and multispectral proximal sensors.

PASTURE DRY MATTER YIELD RESPONSE FOLLOWING AN AUTUMN AND SPRING APPLICATION OF ECO-N™ AT THE SOUTHLAND DEMONSTRATION FARM

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Nitrogen (N) losses from urine patches in New Zealand grazed pastures are a major source of N loss from our pastoral systems via nitrate (NO_3-) leaching and nitrous oxide emissions (N_2O). The nitrification inhibitor, eco-n (fine particle DCD suspension) has been shown to mitigate such N losses. Eight half paddocks on the Southland Demonstration Farm near Wallacetown, New Zealand were treated with the nitrification inhibitor eco-n according to the manufacturer's specifications i.e., eco-n was applied at 10 kg/ha in autumn and spring to half of each of 8 separate paddocks. These permanent paddocks were measured each grazing using a rising plate meter to quantify pasture dry matter yield responses to eco-n following a strict measurement protocol. The half paddocks were grazed evenly and urea applied at 170 kg N/ha across both the treated and untreated halves. This paper will present the dry matter results measured over the 2011-12 dairy season at the Southland Demonstration farm.

Keywords: eco-n, dicyandiamide, inhibitors, N2O, NO3-, pasture, urine

CADMIUM – WHERE ARE WE AT? WHAT DO WE NEED? HOW DO WE GET IT?

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The National Cadmium Management Strategy, developed by the Cadmium Working Group (comprised of representatives from central and regional government, agricultural sectors and the fertiliser industry), was released on 10 February 2011. The strategy has the objective of ensuring “that cadmium (Cd) in rural production poses minimal risks to health, trade, land use flexibility and the environment over the next 100 years”. A key component of the strategy is a tiered fertiliser management system (TFMS) that comprises increasingly restrictive fertiliser management practices that must be implemented according to increasing soil Cd concentrations, specified largely on the basis of guideline values used internationally. Farmers are encouraged to include Cd in soil analyses when determining fertiliser requirements, and thus enable application of the TFMS. The strategy also outlines the various actions to be taken to manage the risks associated with Cd.

The strategy is based on research undertaken from the 1990s to the early 2000s and acknowledges a lack of information that is constraining management of Cd risks. Knowledge gaps were prioritised within the strategy, although the relative emphasis may differ between stakeholders. While a limited amount of research has been undertaken more recently to address these gaps, many remain. A report in 2012 identified what research needs to be undertaken in order to develop soil guideline values specific to New Zealand (i.e. could be used to update or validate the values currently used in the TFMS). The fundamental need (to fill these gaps and extend options for managing Cd) is to better understand the movement and effects of Cd in New Zealand soil–plant–animal systems and the off-site impacts. This information could then be applied in several contexts: better quantification of the potential risks associated with Cd – in particular, uptake into food products; flexibility of land use within agricultural systems; potential environmental and productivity impacts – and options to mitigate or manage the risks, including on a site-specific basis.

This paper gives an overview of the current status of Cd management and research in New Zealand and provides a perspective on the key research needs and potential options for addressing those needs.

THE RELATIVE IMPORTANCE OF METHANE AND NITROUS OXIDE FOR CLIMATE CHANGE IMPACTS, AND THE USE OF CLIMATE CHANGE IMPACT POTENTIALS AS AN ALTERNATIVE TO GLOBAL WARMING POTENTIALS

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All greenhouse gases contribute to global warming, but they have different absorption properties of infrared radiation and different longevities in the atmosphere. The comparison of different gases, or the importance of the release of the same gas emitted at different times, is currently quantified through their Greenhouse Warming Potentials, which are based on the cumulative radiative forcing attributable to each gas. However, those calculations are not explicitly linked to an assessment of the climate-change impacts that result from the emission of different gases.

A new metric is proposed here that explicitly starts from an assessment of climate change impacts to derive a quantitative assessment of the importance of each gas. This new metric would reduce the relative importance of methane emissions and increase the importance of nitrous oxide emissions.

THE NATIONAL LAND RESOURCE CENTRE BUILDING CAPACITY AND PARTNERSHIP ACROSS ALL SECTORS INTERESTED IN LAND RESOURCES

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The National Land Resource Centre (NLRC) is a new centre recently established by Landcare Research that has the goal of enabling businesses, government, researchers and the public to understand, effectively use, and enhance New Zealand's land resources. The NLRC provides access to information for a wide range of user interest groups, assisting organisations to, for example, report on the state of the environment, plan development within environmental limits, and ultimately match land use to the capacity of land resources.

The NLRC aims to develop communities of stakeholders with common interests, and over time work to produce information tailored to meet their specific needs. It also aims to help develop the capability of those researching, governing, and managing the land resource by focusing on capturing knowledge from those experts approaching retirement and developing ways in which to share this knowledge effectively with others.

LAND AND LIVESTOCK DATA INTERCHANGE STANDARDS AS AN ENABLER FOR MODELS AND MANAGEMENT

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Farming is becoming a data rich activity. Most biophysical processes from soil nutrient management to cow performance have both paper-based and organised databases recording status, productivity, and intentions. There are a significant number of tools covering livestock, nutrition, and financial management, including over 127 that have been developed for rural professionals (Allen J, Wolfert J, 2011).

In the future there will be an evolving demand for areas such as environmental compliance and improving system productivity and profitability rather than raw production. Approaches to address these will ultimately draw together disparate data such as location, soils, climate, livestock feeding, animal genetics and fertiliser applications.

Farmers will benefit from a highly innovative technology sector that delivers applications that are simple to use and access, which source the information they need without impedance and deliver value. From the farmers’ perspective, any data collected about their land or herd should be kept with due custodianship and be available for a variety of uses as and when required, all with minimal overhead.

In order to encourage appropriate data sharing with minimal overhead, DairyNZ, Rezare Systems, and Farm IQ Systems are coordinating an industry programme to develop technical standards for interchange of livestock and land data relevant to the pastoral industry, and to facilitate discussions about a code of practice for organisations that manage farm data.

Any work on standards needs to take into account existing New Zealand projects and international work in this area, including pan-industry initiatives such as the Open Geospatial Consortium spatial data standards.

FARM SCALE SOIL MAPPING FOR BETTER PRODUCTION AND ENVIRONMENTAL MANAGEMENT ON DAIRY AND CROPPING FARMS

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In the current regulatory, social and business environment that New Zealand dairy farmers find themselves, purchasing a detailed soil map and compilation of soil properties would be a wise decision. However, many of the existing soil maps, which are mostly at scales of 1:63,360 or 1:50,000, are beset by errors even when reinterpreted with topographic and landscape control. These errors could potentially be costly to a farming business and to the environment. Only a few areas of the country have existing soil maps at a useful scale. It has been demonstrated that 1:10,000 is adequate for most farms although farms with rapidly changing soil types and environmentally sensitive soil types may need to be surveyed at 1:5000.

During a soil survey, an experienced pedologist collects information on: soil colour (organic matter, drainage, mineralogy, soil age and soil forming processes); soil texture (drainage, moisture storage, parent material, hydraulic conductivity, infiltration rate, fertility); and structure (drainage, moisture storage, rooting depth, hydraulic conductivity) amongst other information. The concept of functional soil horizons is useful in this regard. These parameters assessed qualitatively in the field, or related quantitative measures are the basis for soil assessments.

A detailed farm soil map (FSM) can help dairy and cropping farmers manage many production and environmental issues. A FSM will aid these farmers in the selection of soils and/or best management practises for: nutrient and fertiliser management, dairy effluent application, irrigation, cropping and future planning. A series of real and hypothetical case situations are used to illustrate the value of a FSM.

SMART SAMPLING TO ASSIST ON-FARM NUTRIENT MANAGEMENT

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On-farm accurate and efficient use of nutrients requires advanced decision support tools for assessing and managing the soil resource and its fertility status. Informed selection of sampling posithawkeions to assess soil fertility is key to any subsequent fertiliser recommendation.

A prerequisite to develop a soil sampling strategy is the availability of good quality on-farm spatial data. The selection of sampling positions should acknowledge the spatial and temporal variability that occurs in agricultural paddocks.

To improve the efficiency of the soil sampling procedure, lowering costs, while accounting for variability, optimisation methods for sampling positions can be implemented. Such a sampling method is using a stack of environmental proxies, such as LIDAR, EM maps and high-resolution elevation models, to find positions that sample the full range of variability encountered in the soilscape.

Flat land (Massey University dairy farm) and hill country (Pohangina pastoral farm) case study sites will be used to demonstrate an operationally constrained sampling method for selection of optimal soil sampling positions to proportionally represent the full range of soil and landscape combinations encountered at each site.

RESULTS AND EXPERIENCE IN AUDITING MITIGATIONS SPECIFIED IN A FARM NMP AS PART OF THE CATCHMENT PLAN FOR LAKE REREWHAKAAITU

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Lake Rerewhakaaitu, near Rotorua is surrounded predominantly by dairy farms and farm practices are encouraged that protect lake water quality. A series of Sustainable Farming Fund projects, commencing in 2002 have highlighted and indeed advanced the awareness of practical steps that pastoral farmers in the catchment can take to improve lake water quality.

On- farm mitigations are a priority in this lake catchment, but they have to be audited independently to 'satisfy' the Regional Authority and the farmers themselves that steps are being taken to improve environmental outcomes. An audit procedure was designed by the Service providers' team and agreed to by the farmers and Regional Council. Each farmer agreed to a list of mitigations in 2010 with an open-ended time scale for completion. The first audit of these mitigations was completed in 2012, by the auditor visiting each farm and assessing progress.

Progress was determined by what percentage of each mitigation had been achieved in total, partly or not started. Totals for all farms were added up and a catchment % calculated. 49% of the agreed mitigations had been achieved completely, 13% achieved >50%, 8% achieved <50% and 30% were not started.

There were many reasons why mitigations on individual farms had not commenced or been completed. For example, effluent nutrient analysis and measuring effluent irrigation depth was in the 'still to do' box and reductions in P fertilizer were common, but they hadn't shown up in reduced Olsen P levels as yet. An excellent season for pasture growth had negated the need to implement new technologies such as Eco-N and substantial capital costs were a constraint for some farmers. The value of this auditing approach is that farmers can see and in some instances measure progress, neighbours can discuss and combine efforts to monitor mitigations and the Regional Council can be assured that 'down on the farm', progress is being made.

A further audit will be done before this phase of the Rerewhakaaitu project is completed in 2015. New mitigations will be added as the need arises and we are confident that the 49% completion total will increase substantially.

DENITRIFICATION – THE KEY COMPONENT OF A GROUNDWATER SYSTEM'S ASSIMILATIVE CAPACITY FOR NITRATE

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For environmental as well as economic reasons, minimising nitrate losses from the root zone should be given highest priority in agricultural nitrogen management. However, even the best management practices available for a given land use may result in root zone losses that are incompatible with water quality limits, especially in sensitive catchments (e.g. Lake Taupo). It has become evident in recent years that denitrification can significantly reduce the mass of nitrate in some groundwater systems before the contaminated groundwater reaches a water supply well or a surface water body. Taking this natural assimilative capacity into account when making decisions on land use type and intensity can therefore provide a second line of defence with regard to contamination of freshwater resources.

Denitrification converts nitrate (NO_3^-) to gaseous forms of N. In contrast to unsaturated zone denitrification, where incomplete denitrification can result in substantial emissions of the greenhouse gas nitrous oxide (N_2O), complete denitrification to inert dinitrogen (N_2) prevails under the usually more stable redox conditions of reduced groundwater zones. For denitrification to occur, four requirements must be met. Apart from nitrate being present, there need to be oxygen-depleted conditions, a suitable electron donor, and microbes with the metabolic capacity for denitrification. Nitrate and suitable microbes are considered ubiquitous under agricultural land use. Accordingly, the occurrence of denitrification at a particular location is largely determined by the existence of oxygen-depleted conditions (< 2 mg/L dissolved oxygen) and the availability of electron donors. Heterotrophic denitrification is fuelled by organic matter, while reduced inorganic iron and sulphur compounds (e.g. pyrite) can fuel autotrophic denitrification.

Through a combination of hydrochemical analyses, isotopic analyses, excess N_2 determinations and lab incubations it has been ascertained that denitrification occurs in the groundwater systems of the Toenepi Stream and Lake Taupo catchments. Particulate organic matter residing in the groundwater zone has been identified as the main electron donor, but additional contributions from reduced inorganic substrates cannot be excluded. While measurements allow denitrification to be detected locally, quantifying its effect on nitrate fluxes through a sub-catchment or catchment requires modelling based on a sound understanding of the biogeochemical and hydrological conditions.

COULD MODIFYING THE PAKIHI SOILS OF THE AORERE VALLEY IMPROVE PRODUCTIVITY AND REDUCE P LOSS?

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In the Golden Bay area some 5300ha of gley podzol (pakihi) soils are farmed. Pakihi soils are characterised by being poorly drained and of low natural fertility, but nevertheless have been farmed successfully once modified by drainage, pasture renewal and fertiliser use. The Aorere valley has high rainfall (2200-5000mm) and the Pakihi soils here are characterised with very low anion storage capacity (ASC) values. Farmers and fertiliser company staff in this area have noted that it is very difficult to raise the Olsen P status of the topsoils to optimise pasture productivity. Coupled with this, the Burton Ale Creek which drains a small catchment area of the Aorere Valley has dissolved reactive P (DRP) levels five times the ANZECC limit, measured by the Tasman District Council and is of some concern to the community. This paper is an exploration of the issues associated with the management of phosphorus in these soils and suggests some potential strategies for improving the agronomic effectiveness of P use and perhaps reduce loss to water.

FACTORS THAT INFLUENCE PHOSPHORUS LOSS WITH THE DEVELOPMENT OF ORGANIC SOILS

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Organic soils (OM conc. > 30%) cover 400,000 ha in New Zealand, of which around 67,000 ha have been converted for intensive land use (viz. dairy). High pasture production on these soils has been partly achieved with high P fertiliser application rates. However, organic soils typically have a number of properties that can exacerbate P losses including: high porosity and hydraulic conductivities which allow the transportation of P; a high soil moisture content with cyclic wetting and rewetting processes; and poor P retention, otherwise known as anion storage capacity (ASC). Studies have indicated that ASC increases in organic soils over time due to factors like cultivation and mineralisation: however, the rate at which ASC and therefore the influence on P loss changes is not well established. The hypothesis of this project is that ASC is low immediately following initial soil development, but increases, with age at a rate influenced by management thereby buffering P losses.

In this study, 93 paddocks in the southern Waituna catchment (46° 34'S/168° 36'E) containing peat, gley and podzol soils were sampled at 0-7.5 cm and below the plough layer (30-37.5 cm depth). Due to little or no stratification, the deeper depth of these organic soils was deemed to represent a sample that was less impacted by management decisions. A wide range of chemical and physical tests were done and information about the age and management histories of each paddock collected from land owners. Samples were clustered by soil type and depth, and relationships between soil physiochemical parameters and management variables examined via multiple regression, principal components and discriminant analysis techniques. Results are presented of those factors controlling the state and change of ASC and water soluble P, and to identify the potential mix of land management strategies that may minimise P losses while maintaining production.

SEASONAL CHANGES IN SOIL STRUCTURE UNDER WINTER GRAZING IN SOUTHLAND

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Land use change and intensification of New Zealand farming practices has occurred at a rapid rate in recent years and is largely recognised as an important contributor to a range of environmental problems. A decline in soil physical quality due to livestock grazing has been reported in a number of studies particularly those relating to winter grazing. High stock densities during winter result in considerable soil physical damage usually because soil moisture content during this time is high. Soil physical properties (porosity and bulk density) of poorly drained gley and pallic soils were assessed on two dairy farms in South Otago and Southland, New Zealand, both under an annual winter crop grazing strategy and annual cultivation. Pore size distribution and bulk density were determined at three depths in late autumn (pre grazing) and late winter (post grazing) across two years. Soil structure was significantly affected by winter grazing, with macroporosity significantly declining between grazing events. These values are considerably below those required for maximum pasture production.

When grazed annually, cultivation increased soil porosity values, thereby rejuvenating, and to some extent moderating, the on-going effect of winter grazing on soil structure. However, it was evident that soils rapidly reverted back to a pre-cultivation state when subsequently grazed the following winter. Importantly, the period between annual winter grazing events, during which time the constraints associated with low macroporosity have been alleviated, was likely to be more favourable for crop growth relative to non-cultivated soils.

Two key factors important for post winter soil management are alleviation of poor aeration/drainage and the subsequent restriction of stock grazing during periods when soil moisture contents are high. This research indicates routine soil cultivation and annual grazing may be an important tool to alleviate the impact on severely damaged soils i.e. those with macroporosities < 6-10%v/v. While cultivation is important for rejuvenating soil structure following winter grazing, it is unlikely to significantly improve soil strength over time if on-going winter grazing occurs. On-going monitoring will help define how quickly this soil strength will return when paddocks return to pasture.

TRACE ELEMENT STATUS OF SELECTED KIWIFRUIT ORCHARD TOPSOILS IN THE BAY OF PLENTY

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With growing concerns on potential accumulation of soil trace elements in the Bay of Plenty under kiwifruit land use, 20 topsoils (0-10 cm deep) from kiwifruit orchards in Western Bay of Plenty, Whakatane and Opotiki were sampled by the Bay of Plenty Regional Council in 2012 and were analysed for total recoverable arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn). For Western Bay of Plenty, 12 archived topsoil samples collected by GroPlus in 2009 were retrieved and analysed for comparison with the 2012 samples in order to assess if any significant increase can be detected. The results indicate that for all trace elements, the mean values of the 2012 samples were below the environmental guideline values based on the 2003 NZ Biosolids Guidelines. However, for Cd, 3 out of 20 orchards (15%) exceeded the 1 mg/kg environmental guideline value. One-tailed paired t-tests on the Western Bay of Plenty samples (2009 vs. 2012 samplings) showed no significant increases in the concentrations of As, Cd, Cr, Ni and Pb. However, paired t-tests on the log-transformed values of Cu and Zn indicated significant increases in the concentration of these two trace elements over the 3-year period (one-tailed *P* values of 0.034 for Cu and 0.026 for Zn).

PRECISION AGRICULTURE ASSOCIATION OF NEW ZEALAND

Peter Barrowclough

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Following a growing awareness of the benefits of Precision Agriculture (PA) in NZ, on-going research by a number of organisations into PA over a number of years, and in response to feedback gained from two forums in 2011, the Precision Agriculture Association of NZ Inc. (PAANZ), has been established.

The primary goal of PAANZ will be to advance PA in New Zealand. A working committee was formed in 2012 to undertake a number of tasks to establish a Precision Agriculture Association as a formalised entity in New Zealand. Activities to date have included:

- Drafting a Constitution which meets the requirements of the Incorporated Societies Act.
- Registering the organisation.
- Developing a website.
- Developing a brand.
- Establishing a sponsorship policy and corporate engagement strategy.
- Drafting a strategic plan.
- Defining categories for membership and subscription requirements.

New technologies, like PA, that can assist the efficiency, productivity, profitability and sustainability of land-based production systems, are going to be crucial for New Zealand to achieve our growth objectives, maintain our international competitiveness and retain our global reputation for innovation and environmentally-sound production systems.

PAANZ will connect participants in the PA value chain to one common organisation – land users, researchers, commercial companies, Regional Councils, primary industry organisations, rural professionals and students.

Its focus will be on increasing the uptake of PA technologies in land-based primary production systems, accessing funding for research and the development of PA technologies, building capability within the sector and promoting adoption of PA through industry events, symposiums and field days.

Shortly we will be seeking members to join the association. Events such as a launch function, membership drive and AGM for the Association where committee members can be elected, are scheduled to occur throughout the early part of 2013 and dates will be advised as the various activities are planned.

FERTILIZER APPLICATION: DRIVING THE FUTURE WITH INNOVATIONS

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Fertilizer application in agricultural production is a comparable young topic and a success story of innovation. In the early 20th century, agricultural production was at the crossroads: Urbanization and population increase resulted in the need for higher production of food thru less people. Justus von Liebig's discoveries in plant nutrition, resulting in the "Liebig law", laid the foundation, but fertilizer remained a limited commodity until the discovery of the Haber-Bosch principle allowed production of "artificial fertilizer" at industrial scale in 1910. With the new material at hand, agriculture changed dramatically.

Besides vast improvements in increasing yield quantity and quality, manual application of fertilizer remained a bottle-neck in production due to time and labor demand and the need for an even application. Consequently, fertilizer application proved to become a new field for agricultural equipment manufacturers. First success resulted in doubling the working rate to approx. 0.8 ha/h going along with major improvements in application quality. A breakthrough in technology was the series introduction of twin-disc spreaders with a working width of up to 10 m leading to 2 ha/h in the late 1950s.

With growing working width, the efforts towards application quality became crucial for further success. The material to be applied is rarely homogenous and subject to change in regard to physical properties. Disturbances during application, such as rough terrain, wind and other, have a great effect on the working result. Today, in-door test scenarios with computer-aided 3D-analysis are standard in spreader design. Modern spread-centers allow for more than 120 tests per day. With the knowledge gained, advances in implement design are driven – and new electronic innovations become possible allowing effective use of the large working width and application rates possible. While automatic rate-control is a standard and more and more units are also equipped with GPS-based section control helping to precisely engage and disengage dosage units, further advances helping to compensate wind, tilt or curves are on the edge.

Today, centrifugal twin-disc spreaders are responsible for about 75 % of mineral fertilizer application. Latest models feature working widths of over 50 m, covering 50 ha/h.

EUROPEAN EXPERIENCE WITH VARIABLE RATE FERTILIZER APPLICATION (VRA)

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Modern fertilization strategies handle the amount of applied fertilizer according to the demands of crops and paddocks. Besides agronomic and economic reasons increasingly also environmental sensitivities (soils, water-bodies, biotopes) have to be respected in fertilization. N-demand and sensitivities are not distributed uniformly over paddocks and within landscapes. The concepts and techniques of precision agriculture (based on sensors, GIS, GNSS) allow addressing these spatially varying requirements in different ways. Outcomes are fertilizer rates that vary over space (‘variable rate applications’, VRA). Different approaches support VRA for N, P, K, lime and manure.

Estimates vary between 0.1% and 3% of European arable farmers that use some type of VRA (only rare VRA on grassland). Systems can be based on soil maps, soil samples and/or yield maps. Such maps are prepared once within 10 to 25 years (soil assessment, ECa-mapping etc.), only in one of three to seven years (soil analysis) or almost every year (yields). Using these information three to five classes of yield performance or soil nutrient status of the very field are delineated and mapped e.g. as zones. Between these zones mainly P and K, sometimes nitrogen and rarely lime are applied differently with VRA-capable spreaders. Besides this mapping approach about 1.400 to 1.900 sensor-systems are probably used in Europe to apply nitrogen as VRA by optically detecting varying canopy characteristics (greenness, biomass) of cash crops. These sensors can also be used for VRA of fungicides or plant growth regulators. Surveys show that sensor-based nitrogen-VRA result in small (0% to 4%) yield increases, less applied N-fertilizer (-2% to -6%), more uniform product quality (e.g. protein), increased performance of combines (+10% to +25%) and reduced N-leaching (-5% to -20%).

Most VRA show sufficient economic benefit and especially lowered management load of production. Farmers that use VRA are technical innovators or have supportive consultants. Starting VRA often is linked to having implemented satellite based guidance systems and a quest to go beyond. European farms that use VRA often are above average in size and economic performance within their region.

Experiences and results of VRA-fertilization with sensors and mapping systems will be presented.

NEW SPREADING TECHNOLOGIES FOR IMPROVED ACCURACY AND ENVIRONMENTAL COMPLIANCE

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There has been considerable focus on the need for accurate spreading and attempts have been made to quantify the factors responsible for creating inaccuracy. Further technological improvements in Geographical Information Systems (GIS) have made it possible to measure and model what happens in the field. The term "Field CV" was used and it was clear that factors which were not previously considered had an important impact of spreading accuracy.

Developments in spreader testing facilities have allowed some manufacturers to identify many of these factors and rapidly test equipment. This had led to an acceleration in technical development, affording farmers greater choice with the potential to improve accuracy of spread and achieve better utilisation of fertiliser. GPS guidance and autosteer systems have been around for some years now but these are now being linked to machinery control to further improve in-field accuracy.

The factors affecting spreading accuracy are identified, explained and quantified in order to give a realistic perspective of what is presently being achieved. These factors are described within three groups: Machine factors and design, there are differences and refinements in design that do make a difference to the spreaders ability to spread accurately in the field. Materials being spread and their effect on spread pattern, (blended materials for example). Environmental and field factors, field shape and slope.

The impact of new technologies such as boundary spreading and variable width spreading are investigated and a range of new machine developments and improvements are described. The competing demands for large machine capacity for higher work rate and achieving environmental compliance especially in the dairy sector where smaller paddock size leads to increased Field CV is also discussed.

Key words: Precision Agriculture**,** coefficient of variation of spread, CV, centrifugal fertiliser spreaders, border spreading, headland spreading, fertiliser spreading accuracy.

UTILISING VARIABLE RATE FERTILISER APPLICATION TO IMPROVE FARM PROFIT

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Profitability from using fertiliser starts with calculating what we actually need. This is done through measurement, and grid soil sampling on our dairy farm has resulted in a 45% saving of our base fertiliser and lime in the 2011/2012 season. This was done through testing in zones where the effluent had been spread under our centre pivot.

Further testing of the same area this year in a grid format will result in the application of only 23 tonnes of lime over a 70 ha area instead of the advised 100 Tonnes. This variability was mostly due to having merged multiple fields with different histories.

EM Mapping has been used to identify different soil zones on both our cropping and dairy farms. One field of interest on the cropping farm which was to be planted in autumn wheat which would traditionally had 350 kg/ha of 30% Potash Sulphur Super but by assessing the potential yields of the different zones with realistic expectations of 8,10,12 and 14 tonnes per ha. We applied 200,250, 300 and 350 kg of product in the different zones which resulted in a $48.50/ha saving in base fertiliser which was enough to cover the cost of EM mapping of the field and has resulted in an increased profit from the crop.

Application maps are made for all fertiliser applications and proof of placement maps are sent wirelessly back from the spreader to the office which gives us total accountability for our fertiliser placement. Use of automated headland management control results in the elimination of any overlap giving up to 10% savings in fertiliser use. We are also building exclusion zones in gateways, water troughs, water ways, roadsides and the like.

The same EM zones are also currently being used for variable rate irrigation with savings of between 30 and 50% of the water being applied compared to what would have traditionally been applied to this area.

These examples help show that significant savings can be made by taking soil variability into account when considering crop or pasture needs and providing the correct technology to apply inputs.

A PRECISION FERTILISER PLAN:
REAL MEASUREMENTS, REAL COSTS, REAL RESULTS

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Precision agriculture often refers to the use of a new technology rather than the adoption of a precision farming philosophy. This paper demonstrates how using the precision farming philosophy of: Plan, Measure, Manage, Review has been used to create and implement a fertiliser plan and decision support system over the past four seasons on a 85ha South Taranaki dairy farm. The plan was to achieve a consistent range of soil test values for Olsen P (40-50), Quick Test K (10) and Sulphate S (10) at the paddock scale from land that has historically had both different levels of fertiliser input and land use. Ten geo-referenced soil samples were taken from every paddock, every year in order to obtain paddock scale results. Variation in results was managed using 6 different fertiliser mixes included nil application. Results have shown a reduction in farm average Olsen P from 62 to 49 (within target range), Quick test K from 10 to 8 (below target range), and Sulphate S from 11 to 7 (below target range) over the four year period. The latest reduction of Quick Test K levels has lead to 67% of the farm this season receiving capital K compared to 41% and 52% in the two previous seasons respectively. Sulphate S levels are now controlled in the autumn as a standalone program due to the number of mixes already present using the current decision support system. Dairy farm fertiliser expenditure on average in NZ equates to \$507/ha/yr, undertaking this program has had direct costs of between \$50/ha/yr and \$377/ha/yr (\$154/ha/yr avg) over the previous four seasons whilst pasture growth has increased from 14.54 T DM/ha to 18.68 T DM/ha indicating that the programs cost savings have had no negative impact on pasture production. This program demonstrates that a adopting a precision farming philosophy rather than just using a standalone precision tool will have a much greater positive impact for the use of fertiliser on New Zealand farms.

MEASURING PASTURE QUALITY IN THE FIELD: A CASE STUDY AT LIMESTONE DOWNS

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Good pasture utilisation and management are essential for optimal productivity on hill country farms. Achieving a highly productive pastoral system requires high quality feed; focusing simply on producing large quantities is not enough. For farmers, the ability to collect near real time information on pasture quality and build a picture of the spatial variation of pasture quality over their property would allow them to better manage their grazing system. Improved pasture utilisation through better allocation of pasture would enable higher productivity to be achieved.

Traditionally pasture quality has been assessed using destructive sampling and laboratory analysis of dried ground pasture samples. At $200 a sample for wet chemistry, a laboratory based pasture quality analysis is expensive. This process also takes some weeks for the results to be sent to the farmer. An infield, non-destructive, near real time and inexpensive method of measuring pasture quality would be of great benefit to farmers.

Hyperspectral analysis is potentially a valuable option. Optical sensors have been used on dairy pastures throughout New Zealand to measure in-situ pasture quality with success. Optical instruments which measure the reflectance of pasture within a range of wavelengths were used to estimate the pasture quality parameters: crude protein, metabolisable energy (ME) and in-vitro organic matter digestibility (OMD)

Fieldwork, supported by the C Alma Baker Trust, was carried out at Limestone Downs, a hill country property near Port Waikato. Hyperspectral technology used to measure pasture quality in near real time showed great potential. 105 pasture samples from seven sites were taken from the property. Wet chemistry analysis of these samples were compared against green pasture measured infield using an ASD Field Spec® Pro and a FieldSpec HandHeld 2™, dried and ground samples were also measured with the ASD Field Spec® Pro. Significant variation of pasture quality was found between the sites. High levels of explanation of crude protein (r^2 0.81), ME (r^2 0.83) and OMD (r^2 0.85) were achieved from measuring living pasture in-situ using the ASD Field Spec® Pro. The level of explanation achieved for the FieldSpec HandHeld 2™ was reduced but still useful.

PRECISION IRRIGATION AS A TOOL TO REDUCE NUTRIENT LEACHING AND RUNOFF

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Variable Rate Irrigation is a tool with many benefits, primarily known to save water and increase yields under centre-pivot and lateral-move irrigation systems. However, many VRI owners have found other spin-off benefits such as

- Improved animal health of cows not walking on wet tracks,
- Ability to keep areas around troughs dry,
- Ability to renovate pasture in individual paddocks
- Ability to keep irrigation off areas being harvested while still irrigating other areas,
- Ability to withhold irrigation from wet patches (e.g. compacted soils or low lying areas)
- Water consumption reduced enough to be able to extend irrigation season or run other irrigators without having to source more water.

Precision VRI works by controlling valves along the length of an irrigator, turning them on, off, or pulsing to achieve the desired depth of irrigation that is prescribed in the map based FieldMAP software.

By monitoring soil moisture levels, irrigation can be variably scheduled to apply only enough water to keep soil moisture optimal, and to be prepared for rain events that could lead to runoff or leaching. By controlling the soil moisture status spatially in this fashion, further water can be saved, and nutrients can be conserved in the root zone by reducing the risk of leaching and runoff compared with normal uniform irrigation scheduling.