Nutrient Management for the Farm, Catchment and Community

This document contains the programme and abstracts of all presentations to the 27th Annual FLRC Workshop at Massey University on the 18th, 19th and 20th February 2014.

They are printed here in the programme order and may be of assistance to people who wish to search for keywords prior to accessing the individual manuscripts.

Individual manuscripts will be available after the event from the website at:

http://flrc.massey.ac.nz/publications.html

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Programme

Tuesday 18th February

0915-1015 Registration and Morning Tea

1015–1030 **Professor Mike Hedley**
Director, Fertilizer & Lime Research Centre, Massey University
WELCOME AND INTRODUCTION

Session 1 : Some Wider Perspectives

Chairman: **Professor Mike Hedley**
Fertilizer & Lime Research Centre, Massey University

1030-1050 **Cameron Gourley,** *Invited Speaker*
W Dougherty, S Aarons and K Kelly
Dept of Environment and Primary Industries, Victoria, Australia
IMPROVING NITROGEN USE EFFICIENCY
- FROM PLANET TO PADDOCK

1050-1100 **Alison Dewes**
Headlands, Te Awamutu
DAIRY FARMING FOR ECONOMIC RESILIENCE AND ENVIRONMENTAL PROTECTION

1100-1110 **Adrian Brocksopp, M Bramley, N McHaffie, D Burger and M Scarsbrook**
DairyNZ, Hamilton
ACCELERATING THE ADOPTION OF GOOD ENVIRONMENTAL PRACTICE ON DAIRY FARMS IN THE UPPER WAIKATO CATCHMENT

1110-1120 **Warren Webber and G Morgan**
LakesWater Quality Society, Rotorua
EVOLVING TO NDA ALLOCATIONS FOR THE LAKE ROTORUA CATCHMENT

1120-1130 **Bob Parker, B Longhurst and M Hawke**
Fruition Horticulture, Tauranga
A FARMER PREPARED CATCHMENT PLAN – HOW DID THEY DO IT?

1130-1140 **Mike Manning**
Ravensdown, Pukekohe
THE JOURNEY TO ACHIEVE 'NUTRIENT MANAGEMENT CERTIFICATION' AND THE ROLE OF THE FERTILISER INDUSTRY

1140-1155 Discussion

1155-1200 Poster Paper Presentations

Peter Lorentz, E L Meehan and S A Bowie
Analytical Research Laboratories Limited, Napier
FARM ENVIRONMENTAL IMPACT - A LABORATORY MODEL TO HELP FARMERS UNDERSTAND AND MITIGATE THEIR ENVIRONMENTAL FOOTPRINT

Natalie Watkins and M Shepherd
AgResearch, Hamilton
A COMPENDIUM OF NEW ZEALAND PASTURE FARMLET EXPERIMENTS MEASURING NITROGEN LEACHING

1200-1300 Lunch

Session 2 : Implementing Environmental Policies

Chairman: **Dr Lucy Burkitt**
Fertilizer & Lime Research Centre, Massey University

1300-1320 **Warwick J Dougherty and C J P Gourley** *Invited Speaker*
Dept of Primary Industries, New South Wales, Australia
IMPROVING PHOSPHORUS MANAGEMENT IN INTENSIVE AUSTRALIAN GRAZING SYSTEMS

1320-1335 **Roger Williams, H Brown, R Ford, L Lilburne, I Pinxterhuis, M Robson, V Snow, K Taylor and T von Pein**
The MGM Project Team
THE MATRIX OF GOOD MANAGEMENT: DEFINING GOOD MANAGEMENT PRACTICES AND ASSOCIATED NUTRIENT LOSSES ACROSS PRIMARY INDUSTRIES

1335-1350 **John Paterson, A Brocksoop and E van Reenen**
Bay of Plenty Regional Council
A JOINT INDUSTRY APPROACH TO MONITOR AND REPORT ON FARM CHANGE TO MEET CATCHMENT AGREED ENVIRONMENTAL TARGETS

1350-1400 **Simon Park, T Kingi, S Morrell, L Matheson and S Ledgard**
Headway Ltd, Tauranga
NITROGEN LOSSES FROM LAKE ROTORUA DAIRY FARMS - MODELLING, MEASURING AND ENGAGEMENT

1400-1410 **Bill Kaye-Blake, C Schilling, R Monaghan, R Vibart, S Dennis and E Post**
NZ Institute of Economic Research, Wellington
THE ECONOMIC IMPACTS OF NUTRIENT POLICY OPTIONS IN SOUTHLAND

1410-1420 **Lucy McKergow, S Elliott, A McKay, Mike Freeman and T Faulkner**
NIWA, Hamilton
LINKING FARM PLANS WITH CATCHMENT PRIORITIES AND OUTCOMES

1420-1435 Discussion

1435-1445 Poster Paper Presentations

Weiwen Qiu, D Curtin, M Beare, R Gillespie, T Harrison-Kirk and T Fraser
Plant & Food Research, Lincoln
LONG-TERM INFLUENCE OF MANAGEMENT PRACTICES ON NUTRIENT SUPPLY POTENTIAL OF A SILT LOAM SOIL

Tim Jenkins and K Jackson
Centre for Sustainable Agricultural Technologies Ltd, Christchurch
SIGNIFICANCE OF LOW CONTAMINANT LEVELS IN AN INDONESIAN GUANO PHOSPHATE FERTILISER

Sue Chok, M Grafton, T Mills and I Yule
NZ Centre for Precision Agriculture, Massey University
THE VARIABILITY IN NEW ZEALAND SINGLE SUPERPHOSPHATE GRANULE STRENGTH AND SIZE, AND IMPLICATIONS FOR ACCURATE FERTILISER APPLICATION

Thomas O R Macdonald, F G Scrimgeour and J S Rowarth
University of Waikato, Hamilton
COW HOUSING SYSTEMS – AN ECONOMIC ANALYSIS

1445-1515 Afternoon tea

Session 3 : Nutrient Loss

Chairman: **Mr James Sukias**
NIWA, Hamilton

1515-1525 **Keith Cameron, H J Di, A Roberts, N Beale, J Weir and N Borrie**
Centre for Soil & Environmental Research, Lincoln University
MONITORING EFFECTS OF SOUTHLAND DEMONSTRATION FARM ON STREAM WATER NITRATE

1525-1535 **Donna Giltrap, R Cichota, I Vogeler and M Shepherd**
Landcare Research, Palmerston North
COMPARISON OF APSIM AND NZ-DNDC MODELS WITH PLANT N UPTAKE AND WATER AND NITRATE LEACHING DATA

1535-1545 **Diana R. Selbie, K C Cameron, H J Di, J L Moir, G J Lanigan and K G Richards**
AgResearch, Hamilton
THE FATE OF URINE NITROGEN: A GRASSLAND LYSIMETER STUDY IN IRELAND

1545-1555 **Simon Woodward, R Stenger, A Shokri and R Hill**
Lincoln Agritech Ltd, Hamilton
N AND P CONCENTRATION-DISCHARGE RELATIONSHIPS ACROSS A RANGE OF WAIKATO CATCHMENTS

1555-1605 **George Ledgard**
Environment Southland, Invercargill
AN INVENTORY OF NITROGEN AND PHOSPHORUS LOSSES FROM RURAL LAND USES IN THE SOUTHLAND REGION

1605-1615 **Coby Hoogendoorn, C Lloyd-West and B Devantier**
AgResearch, Palmerston North
NITROGEN LEACHING FROM SHEEP GRAZED HILL COUNTRY: MEANS, MEDIANS OR BACK-TRANSFORMED MEANS?

1615-1625 **Sam Carrick, J Cavanagh, J Scott and M McLeod**
Landcare Research, Lincoln
UNDERSTANDING PHOSPHORUS, NITROGEN AND CADMIUM TRANSFER THROUGH A YOUNG STONY SOIL

1625-1640 Discussion

1640-1650 Poster Paper Presentations

Mike Manning, K C Cameron, H J Di and A Robinson
Ravensdown, Pukekohe
EFFECTIVENESS OF *ECO-N* IN REDUCING NITRATE LEACHING LOSSES AT HIGH RATES OF N FERTILISER WITH AND WITHOUT URINE ADDITION

Edith N Khaembah, P C Beukes, P Gregorini, A J Romera, S L Woodward and D F Chapman
DairyNZ, Hamilton
THE POTENTIAL OF DIVERSE PASTURES TO REDUCE NITROGEN LEACHING FROM NEW ZEALAND DAIRY FARMS

Qinhau Shen, M J Hedley and M Camps Arbestain
New Zealand Biochar Research Centre, Massey University
CAN BIOCHAR BE USED TO INCREASE THE BIOAVAILABILITY OF PHOSPHORUS IMMOBILIZED IN ANDISOLS?

1715-1815 **New Zealand Society of Soil Science 'Norman Taylor Lecture'**

Mike Hedley, Professor in Soil Science, Massey University

THE NEXT STEPS IN NUTRIENT MANAGEMENT OF GRAZED PASTURE SYSTEMS

Wednesday 19th February

Session 4 : Water Quantity, Quality & Soil Services

Chairman: **Associate Professor David Horne**
Fertilizer & Lime Research Centre, Massey University

0840-0900 **Steve Raine and A C McCarthy** *Invited Speaker*
University of Southern Queensland, Australia
ADVANCES IN INTELLIGENT AND AUTONOMOUS SYSTEMS TO IMPROVE IRRIGATION AND FERTILISER EFFICIENCY

0900-0915 **Carolyn Hedley, P Roudier and L Valette**
Landcare Research, Palmerston North
DIGITAL ELEVATION MAPS FOR SPATIAL MODELLING OF SOIL SERVICES

0915-0925 **Jay Howes, D Horne and N Shadbolt**
Fertilizer & Lime Research Centre, Massey University
A CALCULATOR FOR EVALUATING IRRIGATION ON DAIRY FARMS

0925-0935 **Roland Stenger, J Clague, S Woodward, B Moorhead, S Wilson, A Shokri, T Wöhling and H Canard**
Lincoln Agritech, Hamilton
ROOT ZONE LOSSES ARE JUST THE BEGINNING

0935-0945 **Ranvir Singh, A Rivas, P Espanto, A Elwan, D J Horne, J Roygard and A Matthews**
Fertilizer & Lime Research Centre, Massey University
MONITORING AND MODELLING TRANSPORT AND FATE OF NITROGEN IN UNSATURATED AND SATURATED (SHALLOW GROUNDWATER) ZONES IN MANAWATU RIVER CATCHMENT – WORK IN PROGRESS

0945-0955 **Karin Müller, M Deurer, M McLeod, I Young, J Scott and B Clothier**
Plant & Food Research, Hamilton
MACROPORE NETWORKS AFFECT THE FILTERING FUNCTION OF SOILS

0955-1005 **Linda Lilburne, T Webb, D Palmer, S McNeill, A Hewitt and S Fraser**
Landcare Research, Lincoln
PEDO-TRANSFER FUNCTIONS FROM S-MAP FOR MAPPING WATER HOLDING CAPACITY, SOIL-WATER DEMAND, NUTRIENT LEACHING VULNERABILITY AND SOIL SERVICES

1005-1020 Discussion

1020-1030 Poster Paper Presentations

James Sukias, C Tanner and A Hughes
NIWA, Hamilton
CONTROLLED DRAINAGE
– ASSESSING RELEVANCE TO NZ PASTORAL SITUATIONS

Andrew McMillan, M Duncan, MS Srinivasan, B Phillips, M Kirschbaum and J Laubach
Landcare Research, Palmerston North
MEASUREMENT OF WATER VAPOUR FLUXES WITH EDDY COVARIANCE TOWERS – HOW DIRECTLY MEASURING EVAPOTRANSPIRATION CAN HELP US MANAGE WATER

P (Jeya) Jeyakumar, C W N Anderson, A Holmes and S Miller
Institute of Agriculture & Environment, Massey University
OPTIMISING COPPER SPRAYS ON KIWIFRUIT: A REVIEW

1030-1100 Morning Tea

Session 5 : Managing Effluent

Chairman: **Dr Christine Christensen**
Fertilizer & Lime Research Centre, Massey University

1100-1110 **Dave Houlbrooke, B Longhurst, S Laurenson and T Wilson**
AgResearch, Hamilton
BENCHMARKING N AND P LOSS RISK FROM DAIRY EFFLUENT DERIVED NUTRIENT SOURCES

1110-1120 **Bob Longhurst, B Parker, B Nicholson and M Hawke**
AgResearch, Hamilton
FARM DAIRY EFFLUENT MANAGEMENT PRACTICES IN REREWHAKAAITU, ROTOMAHANA AND OKARO LAKES CATCHMENTS

1120-1130 **Stephan Heubeck, J Nagels and R Craggs**
NIWA, Hamilton
VARIABILITY OF EFFLUENT QUALITY AND QUANTITY ON DAIRY FARMS IN NEW ZEALAND

1130-1140 **Moira Dexter, J Luo, D Houlbrooke and M Kear**
AgResearch, Hamilton
EFFECTS OF ACIDIFICATION ON NITROGEN TRANSFORMATIONS IN STORED DAIRY EFFLUENT

1140-1150 **Tony van der Weerden, J Luo, M Dexter and A Rutherford**
AgResearch, Mosgiel
GREENHOUSE GAS EMISSIONS FROM SOLID DAIRY MANURE DURING STORAGE AND FOLLOWING LAND APPLICATION

1150-1200 **James Hanly, D J Horne, M J Hedley and C L Christensen**
Fertilizer & Lime Research Centre, Massey University
STRATEGIC CAPTURE OF EFFLUENT TO REDUCE N LEACHING ON DAIRY FARMS WITH FREE DRAINING SOILS: ASSESSING IMPLICATIONS FOR EFFLUENT MANAGEMENT AND COST

1200-1215 Discussion

1215-1230 Poster Paper Presentations

Rashad Syed, S Saggar, K Tate and B Rehm
Institute of Agriculture & Environment, Massey University
CHARACTERISING A FIELD METHANE OXIDATION BIOFILTER – TREATING FARM CH_4 EMISSIONS FROM MASSEY NO. 4 DAIRY POND

Tim Norris and L Schipper
University of Waikato, Hamilton
A METHOD FOR MEASURING THE EFFECT OF DAIRY AND DRYSTOCK GRAZED PASTURES ON SOIL CARBON STOCKS

Sam McNally, L Schipper, D Laughlin, S Rutledge, M Dodd and J Six
Department of Earth and Ocean Sciences, University of Waikato
COMPARATIVE ROOT C INPUTS UNDER A MIXED SWARD AND CONVENTIONAL RYEGRASS/CLOVER PASTURE

Stephan Heubeck, J Nagels and R Craggs
NIWA, Hamilton
TEMPERATURE INDEPENDENT ANAEROBIC DIGESTION IN NEW ZEALAND DAIRY FARM EFFLUENT PONDS

1230-1330 Lunch

Session 6 : Hill-Country Management

Chairman: **Dr James Hanly**
Fertilizer & Lime Research Centre, Massey University

1330-1340 **Estelle Dominati and A Mackay**
AgResearch, Palmerston North
USING AN ECOSYSTEM SERVICES APPROACH TO ASSESS THE COST OF SOIL EROSION AND HOLISTIC VALUE OF SOIL CONSERVATION IN HILL COUNTRY

1340-1350 **John Dymond, L Basher, C Phillips, M Marden, H Betts and A Herzig**
Landcare Research, Palmerston North
DEVELOPMENTS IN EROSION AND SEDIMENT MODELLING IN NEW ZEALAND

1350-1400 **Dave Horne, M R Bretherton, I Draganova, M J Hedley and S T Morris**
Fertilizer & Lime Research Centre, Massey University
WINTERING CATTLE IN HILL COUNTRY: MONITORING THE IMPACTS ON THE SOIL RESOURCE

1400-1410 **Lucy Burkitt, M Hedley, P Bishop, D Horne, M Bretherton, B Kusumo and R Calvelo-Pereira**
Fertilizer & Lime Research Centre, Massey University
PRELIMINARY FINDINGS ON THE EFFECT OF TREADING DAMAGE AND URINE APPLICATION ON N LOSSES IN MANAWATU HILL COUNTRY

1410-1425 Discussion

1425-1445 Poster Paper Presentations

Peter Bishop, B Kusumo, R Calvelo-Pereira, L Burkitt, C Hedley, M Hedley, S Saggar and M Camps
Fertilizer & Lime Research Centre, Massey University
ASSESSMENT OF DENITRIFICATION POTENTIALS OF GRAZED PASTURE SOILS

Aldrin Rivas, R Singh, P Bishop, D Horne, J Roygard and M J Hedley
Fertilizer and Lime Research Centre, Massey University
MEASURING DENITRIFICATION IN THE SUBSURFACE ENVIRONMENT OF MANAWATU RIVER CATCHMENT

Nicole Schon, A D Mackay and R A Gray
AgResearch, Christchurch
EARTHWORMS IN SHEEP-GRAZED PASTURES

P (Jeya) Jeyakumar, K Müller, J A Carter, C van den Dijssel, K Mason, R Blackburn and M Deurer
Institute of Agriculture and Environment, Massey University
OCCURRENCE OF SOIL WATER REPELLENCY IN NORTH AND SOUTH ISLAND UNDER PASTURE

Peter Bishop and B Quin
Advanced Agricultural Additives NZ Ltd, Palmerston North
EFFECT AND MITIGATION OF MICRO-VARIANCE IN SOIL pH ON PASTURE YIELDS USING ALPHA®

Tim A Jenkins and V Jenkins
Centre for Sustainable Agricultural Technologies Ltd, Christchurch
EFFECTS OF GYPSUM ON SOIL QUALITY: PRELIMINARY RESULTS

1445-1515 Afternoon Tea

Session 7 : Decision Support

Chairman: **Dr Dave Houlbrooke**
AgResearch, Hamilton

1515-1525 **Caroline Read**
Overseer Management Services Ltd, Wellington
OVERSEER®: TAKING IT FORWARD

1525-1535 **Ants Roberts and N Watkins**
Ravensdown, Pukekohe
ONE NUTRIENT BUDGET TO RULE THEM ALL – THE OVERSEER® BEST PRACTICE DATA INPUT STANDARDS

1535-1545 **David Wheeler, M Freeman and M Shepherd**
AgResearch, Hamilton
OVERSEER DATA INPUT TIMESCALES – USING ANNUAL AND AVERAGE DATA

1545-1555 **Sam Carrick, S Hainsworth, L Lilburne and S Fraser**
Landcare Research, Lincoln
S-MAP @ THE FARM SCALE? TOWARDS A NATIONAL PROTOCOL FOR SOIL MAPPING FOR FARM NUTRIENT BUDGETS

1555-1605 **Scott Fraser, H Jones, R Hill, S Hainsworth and B Tikkisetty**
Landcare Research, Hamilton
WAIKATO SOIL WINDOWS – TAKING S-MAP DOWN TO THE FARM

1605-1615 **Annette Semadeni-Davies, S Elliott and U Shankar**
NIWA, Hamilton
HOW CLUES CAN HELP IN MANAGING TO CATCHMENT NUTRIENT LIMITS

1615-1625 **Hamish Lowe and S Smith**
Lowe Environmental Impact Limited
OVERCOMING CHALLENGES IN MODELLING NUTRIENT LOSSES FROM A NON-TRADITIONAL INDOOR DAIRY PRODUCTION UNIT

1625-1635 **Matthew Keltie and P Jordan**
Landcorp Farming, Wellington
NUTRIENT MANAGEMENT PLANNING - A CORE STRATEGY FOR LANDCORP FARMING

1635-1650 Discussion

1650-1800 **Poster Papers on Display**
Informal Drinks In The Ag Hort Lecture Block

1815-**Workshop Dinner at Wharerata**

Thursday 20th February

Session 8 : Managing Cows

Chairman: Mr Alan Campbell
Waikato Regional Council

0900-0910 **Tom Pow, B Longhurst and Z Pow**
Wiremu Farms Ltd, Mata
THE FUTURE FOR NZ DAIRY FARMING SYSTEMS: SELF MANAGING COWS WITH ACCESS TO PARTIAL HOUSING

0910-0920 **Jean Margerison, J Lau, M J Hedley, D J Horne, J A Hanly, A Shilton and N Brown**
Institute of Agriculture & Environment, Massey University
EFFECT OF FREE STALL BED TYPE ON BED UPTAKE, LYING TIME AND DAILY BEHAVIOUR PATTERN OF DAIRY CATTLE COMPARED WITH CATTLE AT GRAZED PASTURE

0920-0930 **Seth Laurenson, D J Houlbrooke, R M Monaghan, D Dalley and D Stevens**
AgResearch, Mosgiel
RESTRICTED GRAZING OF WET SOILS - FROM CONCEPT TO SYSTEM

0930-0940 **Christine Christensen, D J Horne, M J Hedley and J A Hanly**
Fertilizer & Lime Research Centre, Massey University
DURATION-CONTROLLED GRAZING ON DAIRY FARMS: DECISION SUPPORT FOR TIMING OF SLURRY RE-APPLICATION

0940-0950 **Sean McCarthy, K Hutchinson and L Bowler**
DairyNZ, Palmerston North
IDENTIFYING OPPORTUNITIES TO REDUCE N LEACHING WHILE MAINTAINING FARM PROFITABILITY AND MILKSOLIDS PRODUCTION - A CASE STUDY ANALYSIS

0950-1005 Discussion

1005-1035 Morning Tea

Session 9 : Carbon, Nitrogen & Reducing Losses

Chairman: **Professor Surinder Saggar**
Landcare Research, Palmerston North

1035-1045 **Chris Glassey, K Mashlan and S McCarthy**
DairyNZ, Hamilton
A FARM SYSTEMS PERSPECTIVE ON SENSIBLE OPTIONS FOR REDUCING NITROGEN (N) LOSS FROM DAIRY FARMS USING INDICATORS RELATED TO N SURPLUS AND N CONVERSION EFFICIENCY

1045-1055 **Peter Carey**
Land Research Services, Lincoln
EFFECT OF URINE AND POTASSIUM APPLICATION ON PASTURE PRODUCTION FROM A DICYANDIAMIDE-TREATED FREE-DRAINING CANTERBURY DAIRY PASTURE SOIL

1055-1105 **Jimena Rodriguez, S Saggar, P Berben, T Palmada, N Lopez-Villalobos and P Pal**
Institute of Agriculture & Environment, Massey University
EFFECT OF APPLICATION TIMES OF UREASE INHIBITOR (AGROTAIN®) ON NH_3 EMISSIONS FROM URINE PATCHES

1105-1115 **Iris Vogeler, T van der Weerden, R Cichota and S Ganesh**
AgResearch, Grasslands Research Centre, Palmerston North
A BOUNDARY LINE APPROACH FOR ESTIMATING THE RISK OF N_2O EMISSIONS FROM SOIL PROPERTIES

1115-1125 **Andrew McMillan, R Phillips, P Berben, T Palmada, N Jha and S Saggar**
Landcare Research, Palmerston North
AUTOMATED N_2O/N_2 ANALYSIS – A NEW TOOL FOR STUDYING DENITRIFICATION DYNAMICS AND TESTING MITIGATION STRATEGIES

1125-1135 **Balaji Seshadri, N S Bolan and R Naidu**
CERAR, University of South Australia, Mawson Lakes, Australia
OPTIMISING ABATTOIR WASTEWATER IRRIGATED SOILS AS A SINK AND SOURCE OF PHOSPHORUS FOR PLANT BIOMASS PRODUCTION, AS AFFECTED BY FLYASH APPLICATION

1135-1145 **Tim A Jenkins and V Jenkins**
Centre for Sustainable Agricultural Technologies Ltd, Christchurch
USE OF GYPSUM TO REDUCE EFFLUENT AND FERTILISER NUTRIENT LOSSES TO WATERWAYS

1145-1200 Discussion

1200-1300 Lunch

Session 10 : Precision Agriculture and Fertiliser Matters

Chairman: **Dr Philip Mladenov**
Fertiliser Association of NZ, Wellington

1300-1320 **John Fulton** *Invited Speaker*
University of Auburn, Alabama, USA
UNITED STATES EXPERIENCE OF RESEARCH AND EXTENSION ASSOCIATED WITH IMPROVING GRANULAR FERTILISER APPLICATION ON-FARM

1320-1330 **Miles Grafton, I J Yule and G Robertson Briar**
NZ Centre for Precision Agriculture, Massey University
THE BALLISTICS OF SEPARATION OF FERTILISER BLENDS AT WIDE BOUT WIDTHS

1330-1340 **Susan Evans and J Verhoek**
Ag Hub, Ballance Agri-Nutrients, Tauranga
AG-HUB: AUTOMATED NUTRIENT RECORDING AND PLACEMENT FOR FERTILISER & EFFLUENT

1340-1350 **Pip McVeagh, R Pullanagari, K Hutchinson, I Yule and J Beautrais**
NZ Centre for Precision Agriculture, Massey University
MEASUREMENT METHODS TO HELP IMPROVE PASTURE MANAGEMENT IN HILL COUNTRY

1350-1400 **Lindsay C Campbell and G D Batten**
Faculty of Agriculture and Environment, University of Sydney
FRIENDS, FOES AND FORESIGHTS IN THE NUTRIENT SUPPLY CHAIN

1400-1410 **Aaron Stafford, J Cavanagh and A Roberts**
Ballance Agri-Nutrients, Tauranga
SOIL CADMIUM – REVIEW OF RECENT DATA IN RELATION TO THE TIERED FERTILISER MANAGEMENT SYSTEM

1410-1420 **Ian Yule and B Wood**
NZ Centre for Precision Agriculture, Massey University
HOW DO WE TRANSFORM OUR INDUSTRY TO ACHIEVE A MODERN VISION FOR NEW ZEALAND AGRICULTURE?

1420-1435 Discussion

1435-1450 Closing Remarks

1450 Afternoon Tea and depart

IMPROVING NITROGEN USE EFFICIENCY

- FROM PLANET TO DAIRY PADDOCK

Cameron J P Gourley*, Warwick Dougherty, Sharon Aarons and Kevin Kelly

**Senior Research Scientist, Soils and Land Management*
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This paper provides an overview of changes in the global nitrogen cycle, presents some national nitrogen use efficiency (NUE) data for Australian grazed dairy production systems, discusses nitrogen loss pathways, suggests on-farm management practices and highlights the differences in international policies that encourage improved nitrogen use.

Human activity has increased the global flux of nitrogen two-fold (Vitousek *et al*. 1997), principally driven by large scale fertiliser manufacturing (Fowler *et al*. 2013). Additionally, the ability to transport inputs and outputs cheaply and extensively has led to substantial growth in agricultural production over the past 50 years with an accompanying 40% increase in world population. This has also led to a spatial disconnection between nitrogen flows required for agricultural production systems and the need to capture and recycle nitrogen at the farm scale.

Moreover, agricultural production systems are inherently inefficient at capturing nitrogen. The excess nitrogen can be dissipated into the broader environment as gaseous emissions of ammonia, nitrous oxide, di-nitrogen and other oxides of nitrogen, as well as surface runoff and the leaching of nitrate, with various transformations causing a cascade of potential environmental problems (Galloway et al 2008).

In the past decade, understanding losses of nitrous oxide and ammonia and the effectiveness of mitigation strategies have received considerable attention due to an international policy focus on greenhouse gas emissions. At the same time, grazing based dairy farms in Australia and New Zealand have been encouraged to increase milk production to supply a growing demand most notably in Asia. These intensifying systems have a greater reliance on imported feed and fertiliser (Wales et al. 2013), strategies likely to result in greater nitrogen losses per ha.

Growing societal expectations for air and water quality, stricter standards from international markets, and increasing costs for purchased nitrogen will mean that improving NUE and reducing nitrogen losses will be an increasingly necessary part of dairy production systems. While there are substantial and realistic options to improve NUE in Australian dairy systems, this is likely to require trade-offs in relation to productivity and environmental goals.

DAIRY FARMING FOR ECONOMIC RESILIENCE AND ENVIRONMENTAL PROTECTION

Alison Dewes

Headlands, Te Awamutu

This study has been undertaken on 25 Upper Waikato Dairy farms over a three year period. The aim of the study was to ascertain management factors or system configurations common to the farms achieving economic resilience with a lower environmental risk. Environmental risk has been determined using an environmental scorecard approach. Economic resilience was determined using Return on Total Capital (ROC) at a range of milk prices and climatic conditions.

This study of low footprint, profitable dairy farms is as significant and pertinent for the whole of NZ as it is for Waikato, Canterbury, Otago, Horizons, and Hawkes Bay. As regions throughout New Zealand undertake and implement plan changes for land and water policy, studies that ascertain what innovative farmers are doing will increasingly provide essential intelligence to decision makers.

Anecdotal evidence from farm performance data reflected that some dairy farms in the Upper Waikato were well below the average for the region in terms of N loss while having sound economic performance. This warranted further analysis in order to ascertain what farm management characteristics led to greater profitability and resilience. Using the economic and environmental data of 25 Upper Waikato farms, the 'Tomorrows Farms Today' study set out to test what management criteria contributes to a lower environmental footprint and a more economically resilient business under volatile commodity and climatic conditions. Over the three year period, climatic volatility resulted in a 30% change in pasture harvest on some farms, and fluctuations in the milk price of 20%.

The strengths and weaknesses of the lowest risk and highest returning businesses have been analysed as well as determining what the common characteristics of these businesses are. The study aimed to determine whether the successful farm systems can provide a relevant model for other dairy businesses in the Upper Waikato catchment.

ACCELERATING THE ADOPTION OF GOOD ENVIRONMENTAL PRACTICE ON DAIRY FARMS IN THE UPPER WAIKATO CATCHMENT

Adrian Brocksopp, Mike Bramley, Nicola McHaffie, David Burger, Mike Scarsbrook

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Private Bag 3221, Hamilton. 3240 New Zealand
Email: Adrian.brocksopp@dairynz.co.nz

The Upper Waikato Sustainable Milk Project is the largest environmental good-practice catchment project ever undertaken by the New Zealand dairy industry. Co-funded by the Waikato River Authority and DairyNZ, the project aims to accelerate the adoption of good environmental practice on farm to ultimately improve the health of the Waikato River. Over a three-year period from June 2012, all 700 dairy farms in the Upper Waikato Catchment are being offered one-on-one advice and support via the development of a farm-specific DairyNZ Sustainable Milk Plan (SMP). The SMP process involves consultants working with farmers individually to assess the current status of their farming system and identify risks in the key areas of nutrient, effluent, waterways and land management, as well as water use efficiency. From this assessment, an action plan to improve environmental practices and meet agreed project environmental targets, sustainable dairy water accord commitments and regional compliance rules is being developed and implemented for each farm. Follow-up support is also provided by the consultant during the implementation phase.

All individual actions implemented are being documented to enable estimation of potential changes in nitrogen, phosphorus, sediments and *E. coli* losses off-farm before and after plan implementation. Catchment modelling tools will be applied to estimate the total reduction in loads from all farms at a catchment scale. Success of the project will be measured by the collective actions of 700 farmers demonstrably reducing dairy farm-sourced nutrients, sediments and faecal contaminants going to the Waikato River, and an improvement in water use efficiency on farms. The project also aims to increase the capability of farmers and their advisors, contribute information to regional policy making processes and ensure that farmers are better prepared for the future of ‘farming with limits’.

This talk will present the SMP program and process, and share the initial results obtained from the 330 farms already involved in the program so far.

EVOLVING TO NDA ALLOCATIONS FOR THE LAKE ROTORUA CATCHMENT

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The Lake Rotorua catchment benefits from significant scientific research and modelling. The May 2011 NIWA 'ROTAN' report provides information on nutrient sources and mitigation potentials; and benchmarking by the Bay of Plenty Regional Council (BoPRC) establishes assessed nitrogen (N) discharge levels for each farm property during 2001-2004.

The new partially operative Bay of Plenty Regional Policy Statement (2010) provides for 435t/annum sustainable N load to Lake Rotorua by 2032, with 70% of the required reduction to be achieved by 2022. This represents a 270tN (51%) reduction by 2032 from the ROTAN estimate of current pastoral load (526tN), equivalent to a per hectare pastoral reduction from 25kgN/ha to 12kgN/ha, averaged across all pastoral land. On a sector basis with a 51% reduction, dairy would need to reduce from 54kgN/ha to 28kgN/ha, and drystock (including dairy support) would need to reduce from 16kgN/ha to 8kgN/ha, both with potential incentive support.

A collaborative Stakeholder Advisory Group (StAG) was established in late 2012 to advise on policy to achieve the required nutrient reductions. This group includes representatives from the Lake Rotorua Primary Producers Collective, Federated Farmers, Dairy NZ, Iwi landowners, LakesWater Quality Society, and other stakeholder entities.

This paper traces the assessment of nitrogen discharge allowances (NDA) allocation options considered by StAG to December 2013, including reductions based on pastoral averaging, land use capability, grand-parenting, sector averaging, and input/output bases. Sector averaging was the preferred basis throughout much of 2013. A desire to recognise geophysical and farm systems variance has prompted development of a hybrid model which uses discounted benchmarking values between maximum and minimum NDA limits. This latter approach does not appear to be a close proxy for geophysical attributes but does seem to be a pragmatic policy option.

Significant progress was made following a Farmer Collective proposal for a sharing of N reduction responsibilities. The current draft N reduction framework is for 140tN to be achieved by farmers via land management change (Rules Programme), 100tN to be achieved by significant land use change (Incentives Programme), and a further 30tN to be achieved by an incentivised gorse re-vegetation programme.

A FARMER PREPARED CATCHMENT PLAN

- HOW DID THEY DO IT?

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Rerewhakaaitu farmers were concerned about their ability to keep farming in the future based on the increasing attention being given to water quality and the likelihood of increasing regulation of nutrient use and increased rules around nutrient loss off farms and the need to improve the water quality in Lake Rerewhakaaitu.

Between 2002 and 2009 two projects were carried out in the catchment of Lake Rerewhakaaitu, focusing on N and P in particular. Over this time information was gained on where nutrients came from how they moved into the water system and where they went. The work also highlighted a range of practical mitigations that could be implemented on farm to reduce nutrient loss to waterways and the lake. By the end of the projects most farmers had implemented some mitigations to reduce nutrient loss off their farms.

At the last project meeting in June 2009 the then CEO of Bay of Plenty Regional Council offered the farmers the opportunity to write the catchment plan. The Council offered a clean sheet of paper without any requirements, only that there must be “action on the ground”. Farmers accepted the offer and developed the plan over the following years.

This paper summarizes how the farmers went about developing the catchment plan. Progress was based on some key principles which outlined how farmers would work with council staff and research providers. The use of farm Nutrient Management Plans based on OVERSEER were central to the catchment plan along with farmers making commitments to complete agreed mitigations, personalized to their farm, according to priorities identified for their farm. All mitigations are to be completed by June 2015. The process to develop the mitigations, essentially add up to the Catchment Plan once coupled with catchment-wide information.

THE JOURNEY TO ACHIEVE "NUTRIENT MANAGEMENT CERTIFICATION" AND THE ROLE OF THE FERTILISER INDUSTRY

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The Fertiliser Industry has been active since its inception in 1947, but particularly so since 1992, to have processes, capability and capacity to meet a recognised growing requirement for its farmer shareholders to improve nutrient use efficiency and lower their environmental footprint.

This has seen very significant investments by the Fertiliser Industry in research and capacity. This journey has thus far culminated in the successful introduction of the Nutrient Manager Adviser Certification programme for New Zealand, which commenced in November 2013.

The purpose of the Certification programme is: '*To build and uphold a transparent set of industry standards for nutrient management advisers to meet so they provide nationally consistent advice of the highest standard to farmers".*

FARM ENVIRONMENTAL IMPACT
- A LABORATORY MODEL TO HELP FARMERS UNDERSTAND AND MITIGATE THEIR ENVIRONMENTAL FOOTPRINT

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The introduction of nutrient and environmental management plans for farming systems has the potential to mitigate nutrient losses and nutrient enrichment of surface waters at the farm and catchment scale. The more recent interest by individual farmers in measuring the positive effects of their own farm plans has prompted ARL to introduce a Farm Environmental Impact suite of water tests. The principle of the model is the periodical assessment of surface water quality both entering and exiting the property. Assessment is against established threshold levels for measurands (pH, NH_4-N, NO_3/NO_2-N, DRP, Turbidity, Total Coliforms and E.Coli) and their likely impact on periphyton proliferation and other aesthetic values of rivers and streams.

A COMPENDIUM OF NEW ZEALAND PASTURE FARMLET EXPERIMENTS MEASURING NITROGEN LEACHING

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Farmlet experiments aim to mimic a farm system but at a smaller, experimental scale, and are generally used for testing hypotheses relating to the effects of management practices on productivity, profitability and, when incorporating environmental measurements, sustainability. They are also valuable for developing and testing farm system models. This paper provides a summary of New Zealand pasture farmlet experiments that have involved measurements of nitrogen (N) leaching losses and which could be used for comparing those measured losses with OVERSEER® Nutrient Budgets' (*Overseer)* modelled losses.

The majority of New Zealand farmlet experiments have been undertaken in the Waikato, Manawatu and Southland regions, with a small number undertaken in the Bay of Plenty, Canterbury and Otago regions. Within these farmlet experiments, the method of measurement of N leaching has generally been a function of the soil-type; porous ceramic cups/lysimeters on free draining soils (e.g., Waikato, Canterbury) or hydrologically isolated plots on drained clay soils (e.g., Manawatu, Southland). It is important to understand the implications of methodology for assessment of measurement error.

The typical duration of the experiments is 2 - 5 years. However, significantly longer trials have occurred, for example, Tussock Creek (Southland), where N leaching measurements have been undertaken for 13 years. The range of management factors tested on these farmlet sites include stocking rate, N fertiliser application rate, grazing management practices, use of nitrification inhibitors and effluent management. The majority of farmlet experiments have been undertaken on dairy farm systems, with fewer on sheep/beef farm systems.

Farmlet experimental data can be considered as representing the farm block scale within *Overseer*, not the total farm. There are practical and theoretical challenges of comparing data from farmlet experiments with whole farm system modelled data. Nitrogen leaching losses from a farm system are a result of many complex interrelated processes; therefore it is important to ensure that relevant supplementary farm system data are available (e.g., feed intake and drainage) to add robustness when comparing modelled with measured outputs.

The uncertainties associated with model outputs are generally accepted as increasing as the differences between a modelled site and calibration and validation sites increase. More sites with different environments/soils would decrease uncertainties and increase the reliability of N leaching estimates for such locations. However, this benefit has to be balanced against the cost of running complex long-term experiments.

IMPROVING PHOSPHORUS MANAGEMENT IN INTENSIVE AUSTRALIAN GRAZING SYSTEMS

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Phosphorus has been an essential input into pasture based grazing systems in Australia in order to optimise production. However, intensive grazing systems such as dairying now often have soil P reserves far in excess of those required for optimum pasture production and in some circumstances have been identified as contributing to water quality problems. In this paper we will consider P flows, accumulation and loss both at a paddock and farm scale. We will subsequently discuss options for managing P to optimise production, minimise P wastage and reduce environmental losses.

Surveys of soil P reveal that typically >20% of paddocks have 3 or more times the optimum soil P whilst 50% have at least twice the required available phosphorus. Some of this phosphorus comes onto dairy farms via imported feed adding to that imported in fertilisers. Phosphorus not only accumulates in soils, but in areas such as laneways and feed-pads. The accumulation of phosphorus in soils typically occurs such that only a relatively small proportion is in available forms. The amount of total P accumulating may be several times greater than that reflected in available soil P measures. On high P soils, further additions of P are clearly unwarranted. However, farmers are frequently reluctant to reduce or eliminate P additions for fear of potential impacts on production. Recent research by Coad *et al*. (in press) shows that declines in available soil P are slow and that farmers run little short term risk of impacting on production by withholding fertiliser P and instead relying on soil P reserves.

Withholding P or reducing whole farm P inputs also presents an opportunity to reduce potential environmental problems whilst more efficiently utilising an expensive resource in the form of P. In addition there is a need to identify from where within farms the major losses of P are occurring and thus prioritise future investments. Recent research in New South Wales, Australia (Dougherty unpublished), using a combination of measurement and modelling examined the relative P generation rates in surface runoff from laneways, effluent and manure re-use areas and grazing paddocks. Despite the high losses of P from laneways on a per hectare basis, their small size in relation to grazing areas means that they are relatively minor source of P loss. However, there are substantial practical challenges to reducing P loss from paddocks. The slow decline in soil P whilst reassuring for farmers, means that reducing losses of P in runoff from paddocks can be slow. Improved laneway, feedpad and other hotspot runoff management might provide short term reductions in nutrient loss, albeit relatively small ones. This improved management may involve a combination of engineering and farm system management solutions.

THE MATRIX OF GOOD MANAGEMENT: DEFINING GOOD MANAGEMENT PRACTICES AND ASSOCIATED NUTRIENT LOSSES ACROSS PRIMARY INDUSTRIES

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Across New Zealand, regional authorities are taking steps to maintain or improve the quality of freshwater. Although regional differences exist in the approaches being taken, the need to define agricultural good management practices (GMP) and understand the impacts of GMP on freshwater quality is a recurring theme. However, there are no commonly agreed definitions of GMP and there has been no systematic attempt to estimate nitrate and phosphorus losses associated with farms operating at GMP.

Environment Canterbury aims to address this through a collaborative project with agricultural industries (dairy, sheep and beef, horticulture, arable, deer and pork) and research agencies.

The main output from the project will be industry defined GMP and a table of nitrate and phosphorus loss benchmarks for a range of farming systems operating at GMP across Canterbury's soils and climates: the 'Matrix of Good Management'. Results are expected by July 2015.

In Canterbury, this will inform community deliberations regarding freshwater quality targets by setting out nitrate and phosphorus losses that are achievable by farmers operating at GMP; enable improved estimates of total catchment loads of nitrogen and phosphorus associated with diffuse losses from agriculture by quantifying these for current farm systems and provide clarity to farmers regarding industry agreed benchmarks for nutrient losses.

Nationally, the project will demonstrate a collaborative approach to defining agricultural GMP and a robust process for quantifying the associated nitrate and phosphorus losses. These aspects of the project will have applicability beyond Canterbury.

A JOINT INDUSTRY APPROACH TO MONITOR AND REPORT ON FARM CHANGE TO MEET CATCHMENT AGREED ENVIRONMENTAL TARGETS

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Farming in the Lake Rotorua catchment has been constrained since 2005 by 'bench marking' regulation (Rule 11) that caps nutrient loss to 2001-2004 levels. New regulations and incentives are being developed to bring about nutrient loss reductions that will collectively reduce nitrogen loss from farms in the catchment lake by 270 tonnes to satisfy the nutrient reduction targets needed for sustained water quality improvement in Lake Rotorua. Draft policy indicates that Lake Rotorua catchment farms will need a resource consent to control nitrogen loss by December 2017 and show progressive reductions through to 2032 when the farm's nutrient discharge allowance will need to be fully achieved.

Various agriculture sectors and some companies have their own forms of Environment Management System (EMS) templates that farmers can adopt to monitor and demonstrate improvement in environmental performance. For example Beef + Lamb New Zealand has the Land and Environment Planning toolkit (LEP) and DairyNZ has the Sustainable Milk Plan (SMP). These documents are non-regulatory mechanisms that encourage progressive improvement and they cannot be directly accessed by regulators and used to enforce nutrient reduction targets.

At Rotorua, a collaboration of industry and sustainable farming advisor representatives has initiated the concept of the 'EMS Dashboard'. This is a new approach to monitoring and reporting nutrient-loss mitigations using the existing sector owned environment management system (EMS) tools. The proposed EMS Dashboard will enable the Lake Rotorua catchment collective of farmers to demonstrate continuous improvement and excellence in environmental performance. It will also report their progress towards eventually meeting the 2032 nutrient-loss targets.

The EMS Dashboard will serve the monitoring and reporting needs of the resource consent by linking with the existing farming industry owned environment management systems to report key performance indicators (KPIs). It contains farm identity and location details together with KPIs that are scored and displayed in simple graphics that will track improvements over time.

Increased reporting and monitoring requirements for the Lake Rotorua catchment farmers are inevitable. Utilising the existing industry tools to help meet these pending accountability requirements will ensure that more farmers are proactively achieving excellence and are operating above compliance levels.

NITROGEN LOSSES FROM LAKE ROTORUA DAIRY FARMS - MODELLING, MEASURING AND ENGAGEMENT

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Dairy and drystock farmers in the Lake Rotorua catchment need to make large reductions in farm nitrogen (N) loss to meet the annual catchment target of 435 tN by 2032. Dairy farmers initiated a Sustainable Farming Fund Project in 2011 to promote adoption of N mitigation methods using three approaches: (i) differential N rate fertiliser trials on-farm; (ii) farm system modelling; and (iii) farmer engagement. These three strands of work were led respectively by AgResearch, Perrin Ag Ltd and DairyNZ.

Farm trials: Interim results from the N-rate plot trials on the Parekarangi Trust farm have indicated smaller pasture production differences than expected between the standard, strategic and nil N fertiliser treatments, with indicative fertiliser N response rates of 5.7-7.6 kg DM / kg N applied. Pasture composition is relatively consistent across treatments, with little indication yet of reversion to low productivity grasses in the strategic and nil N treatments. In contrast, a separate farm system trial at Parekarangi has shown that changing from regular to nil N fertiliser use has more than halved the nitrate-N leachate concentration.

Farm modelling: Three dairy farms were modelled in Overseer and Farmax for status quo and future mitigated scenarios, based on each farmer's perspective on what mitigation practices they could adopt. This analysis was expanded to nine dairy farms (plus three drystock farms) with additional BoPRC support, and extrapolated across all pastoral land in the catchment. Potential changes to land management were generally much more cost effective than land use change options, with average respective costs (capitalised) of $171 and $559 per kg N mitigated. Surveyed farmers also had a clear preference for management changes, compared with land use change. Based on farmer preferences, the overall cost of achieving the assumed pastoral share of catchment N reduction (270 tN/yr) was estimated at $88.1 million with additional capital value losses accruing to drystock farms.

Farmer engagement: A series of farm discussion groups and field days have been run throughout the project. Farmer participation has varied during the project and it is too early to determine what level of practice change has occurred on-farm. Rural professionals have been regular attendees. Recurring messages from Rotorua dairy farmers include: practical, local and long-term farm trials and modelling are both important to understand N mitigation options; policy proposals need to be accompanied by explicit costings that are relevant to their farm situation.

THE ECONOMIC IMPACTS OF NUTRIENT POLICY OPTIONS IN SOUTHLAND

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We investigate impacts of nutrient caps and mandated farm practices in the Southland region on its economy and environment. We use the multi-agent simulation model RF-MAS to evaluate explicitly how individual farmers respond to the caps and mandates. The model uses data on farm parcels to estimate pasture productivity, links productivity to the options available for each farm, and uses behavioural rules to simulate farmers’ choice of activities on their farms. We model a baseline out to 2037, and then compare 16 model scenarios that are combinations of caps on nitrate leaching (15 – 60 kg/ha) and phosphorus (0.5 – 2 kg/ha) loss applied uniformly across the region. We also analyse four scenarios that include non-uniform nutrient caps, grandparenting of dairy farms and mandated mitigation practices.

In the baseline, dairying is expected to increase in Southland, and sheep and beef is expected to decrease. These changes would increase the N discharges by 16% to 19,039 tonnes in 2037; P losses would increase 28% to 539 tonnes in 2037. The baseline projection is for total value of agricultural production to increase in real terms to $4.6 billion per annum.

We find a range of results, depending on how low the caps are set and other features of the policies. The economic costs arise from either land-use change from the baseline (lower amounts of dairying) or farm practice change – the use of techniques and technologies to reduce nutrient loss. Further, we find that the N cap is predominantly the binding cap, while the P cap is only binding in two scenarios.

Key points of comparison for the model scenarios are presented in this paper.

LINKING FARM PLANS WITH CATCHMENT PRIORITIES AND OUTCOMES

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The traditional route of water quality management often puts considerable resources into understanding the problem from all angles and exploring a large range of causes. However, a detailed understanding of the problem doesn't always translate into a solution. In this toolkit we move the timing of the solutions phase up front which focuses subsequent analysis. The toolkit is a process that uses manyexisting tools (databases, plans, toolkits, models, e.g. CLUES, OVERSEER®, Beef+Lamb LEPs, DairyNZ tools, NZeem®, LRI/LUC, Restoration Indicator Toolkit, etc.) to link resource management issues identified at catchment scale with good management practices that may be applied at farm scale. The tool will help identify where nutrient loss attenuation measures (implemented via farm planning) should be targeted in a catchment, while providing a method whereby the cumulative effect of farm plans on catchment-scale outcomes can be quantified. The toolkit is being designed with and tested by land management officers (LMO). It contains four modules (within catchment prioritisation, farmer lead solutions, LMO training, and catchment outcomes), can be used for up to four contaminants: sediment, nitrogen, phosphorus and faecal microbial indicators AND is simple (this doesn't mean it's easy!).

LONG TERM INFLUENCE OF MANAGEMENT PRACTICES ON NUTRIENT SUPPLY POTENTIAL OF A SILT LOAM SOIL

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Land management practices can influence soil fertility in several important ways. The amounts of nutrient applied in fertiliser and removed in harvested products differ depending on land use. Land use may also affect soil organic matter content (SOM) which, in turn, can alter the soil's potential to supply nutrients (particularly N) via mineralisation. The retention and leaching of nutrient cations (Ca, K, Na) may also change if SOM changes. Changes in soil fertility may occur relatively slowly and, often, long term data are needed to quantify fertility trends. The objective of this work was to evaluate long-term effects of land use (sheep-grazed pasture vs arable cropping) and tillage practices on biological and chemical components of soil fertility. In 2013, soil samples were collected (0-7.5, 7.5-15, 15-25 cm depths) from five treatments in a long term tillage trial at Lincoln, Canterbury. The trial, which is on a Wakanui silt loam, was established in 2000 to quantify the effects of management (tillage type; summer and winter crops) on soil quality following the conversion of long term pasture to arable cropping. The sampled treatments were: long-term ryegrass-clover pasture; an arable cropping rotation, managed using either intensive, minimum, or no-tillage cultivation practice; and a continuous chemical fallow (plots maintained plant-free since 2000 using herbicides; not cultivated). The pasture treatment, which represents the pre-trial land use, was maintained within the trial as a control. Nitrogen (and C) mineralisation potential were determined by incubating samples for 98 d (25^{o}C, -60 kPa water potential). The effects of the treatments on chemical fertility were evaluated by using standard soil tests (Olsen P, pH, available cations, cation exchange capacity (CEC)). Under arable cropping, N mineralisation potential declined by 22 to 28% compared with long-term pasture. Tillage type had little effect on total N mineralised in the top 25 cm, but it did affect the vertical distribution of mineralisation (more concentrated near soil surface under no-tillage; uniform depth distribution in intensively tilled plots). Mineralisation was least in the long-term fallow (67% less than in pasture), which had negligible inputs of fresh organic matter in the 2000-2013 period. As a result of a decline in soil organic matter under arable cropping and long-term fallow, there was a decrease in CEC (pH 7) up to 22% at 0-7.5 cm depth. There was substantial decrease in available cations under arable cropping, with K decreasing by 46 to 73% and Mg by 36 to 52%. Although most indicators of nutrient availability were low in the fallow treatment, it had highest levels of Olsen P, presumably due to accumulation of mineralised P. The implications of these findings for soil fertility management under continuous arable cropping will be discussed.

SIGNIFICANCE OF LOW CONTAMINANT LEVELS IN AN INDONESIAN GUANO PHOSPHATE FERTILISER

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Phosphorus is a major element required for pasture and crop production and phosphate fertiliser has been applied in New Zealand for over a century. Undesirable elements including cadmium (Cd), uranium (U) and fluorine (F), are associated with most phosphate sources and can either be directly toxic or have accumulated detrimentally in agricultural soils.

The Javanese guano phosphates described here were formed by relatively unique biogeochemical processes resulting in distinctly lower contaminant levels and suitability for direct fertiliser application. Levels of Cd are typically around 45 $mg(kg\ P)^{-1}$, U 60 $mg\ kg^{-1}$ and F 0.065% compared to general sedimentary phosphate rock levels of Cd 27 to 641 $mg(kg\ P)^{-1}$, U 50 to 200 $mg\ kg^{-1}$, and F around 2.2 to 4.1%. This guano resource expands options for sustainably addressing phosphate requirements.

THE VARIABILITY IN NEW ZEALAND SINGLE SUPERPHOSPHATE GRANULE STRENGTH AND SIZE, AND IMPLICATIONS FOR ACCURATE FERTILISER APPLICATION

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Tension exists between single superphosphate (SSP) manufacturers and ground spreaders on the physical quality of SSP in New Zealand. Spreaders have criticised that, for the past several years, SSP has increased in variability and contains a high percentage of fine SSP particulates. This may cause uneven spreading, because small particles are influenced by wind drift and have poor ballistic properties, which could lead to striping. The purpose of this study was to determine the level of variability in SSP particle size distribution and what effect this variability has on spreading.

Nineteen SSP samples were taken from Ravensdown Co-operative and Ballance Agri-Nutrient sites throughout the North Island. They were sieve tested and strength tested to determine the variability in their particle distribution and granule strength. Single superphosphate was found to have a high degree of variability in particle distribution that was independent of manufacturer and location. Percentage of fines ranged from 0.3% to 44%, with an average of 19%.

An explanation for the increase in small particles is the exclusion of Christmas Island rock phosphate from SSP. Christmas Island rock phosphate (CIRP) is known to have a high level of iron oxide, which acts as a binding agent, increasing granule strength. However, CIRP has not been included in SSP since 2011, due to a high Australian dollar and logistical costs. A decrease in strength was observed in SSP without CIRP, which increases the probability of granules breaking apart due to attrition, during manufacturing and transportation. Improvements could be made to the manufacturing process to increase SSP granule quality. However, the investment required to do this would increase the price of SSP making it uneconomical for farmers.

Analysis of historical Spreadmark test patterns was done to determine if there was any difference in test patterns before and after 2011. No significant difference in bout widths was observed, which indicates variability in SSP particle size distribution does not impact even spreading. Bulk truck spreading trials of a well distributed and poorly distributed SSP sample was done to confirm the relationship found in the Spreadmark test patterns.

COW HOUSING SYSTEMS – AN ECONOMIC ANALYSIS

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Farming within limits is the new reality for New Zealand's dairy industry. Dairy farmers in New Zealand are challenged with lifting the overall environmental performance and compliance of their farm systems. At the same time, there is a need to maintain or increase productivity and profitability. This paper identifies that changing farm systems through additional infrastructure investment is a compliant yet profitable approach to farming with the limits of regulation. Cow housing systems using woodchip bedding and slatted concrete flooring are identified as compliant farm system infrastructure investments. Both housing systems incorporate duration controlled grazing, supplementary feeding systems and nutrient management ability.

Financial analysis of these farm systems has been performed using data provided by case farmers, academic publications and industry sources. The analysis showed per cow cost of installing housing infrastructure ranging between $900 for the woodchip system and $1750 for a Concrete slatted system. Analysis of the financial benefits indicates the annual benefit ranges between $200 and $400 per cow subject to on-farm management decisions.

Ten Year Financial modelling within the parameters of 300 cows each fed 500kg of maize silage and a $6.50 proxy farm gate milk price was used to calculate the net present value of investment in cow housing infrastructure with a 6% discount rate. The net present value of a woodchip bedding system excluding financing cost was $236,346. The concrete slatted flooring had a net present value excluding financing cost of $239,572. End of year cash flows modelled under the same parameters show the woodchip floor to return $32,112 annually and the concrete slatted floor to return $32,551 annually. Return on invested capital was 11.34% for the woodchip bedding and 7.20% for the concrete slatted floor. Overall net present value of ten-year revenues increased by 5.00% and 4.91% for the woodchip bedding and concrete slatted systems respectively when compared to the status quo farm system. This report recommends the use of cow housing options as cash positive farm systems capable of generating both increased production and environmental performance under regulation.

MONITORING EFFECTS OF SOUTHLAND DEMONSTRATION FARM ON STREAM WATER NITRATE

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The objective of this research work was to monitor the effects of the Southland Demonstration Farm on the concentration and amount of nitrate in the Tomoporakau Creek. The creek runs through the central area of the farm and drainage outfalls discharge directly into this stream.

A detailed GPS topographical survey was conducted to confirm the drainage catchment area and hydrology of the site. Groundwater piezometers were established adjacent to the stream in order to monitor groundwater levels and compare those to stream water levels. Detailed surveys of the stream bed, stream surface, groundwater levels, and stream bank geometry were also conducted. Stream flow rate measurements are continuously monitored using "Sontek" Doppler flow equipment installed in concrete box culverts at 'up-stream' and 'down-stream' monitoring sites. Stream water is pumped continuously from the monitoring sites using submerged samplers that send water to an instrument base-station at the dairy shed. The water nitrate concentration from each site was monitored in real-time using flow-through UV absorption spectrometer sensors. This system does not require any reagents as it measures the water nitrate concentration by detecting the UV light absorption by nitrate**.** These sensors also measure a full spectrum adsorption in order to automatically 'correct' for light absorption due to particulate material and/or other chemicals in the water.

COMPARISON OF APSIM AND NZ-DNDC MODELS WITH PLANT N UPTAKE AND WATER AND NITRATE LEACHING DATA

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Two process-based models, APSIM and NZ-DNDC, were compared with measurements over 3 years of drainage, NO_3-leaching and plant N-uptake. The data came from experiments with urine depositions (1000kgN/ha) in lysimeters under pasture in the Waikato. Two irrigation schedules were applied: low irrigation (rainfall + irrigation ~1100mm/year), and high irrigation (rainfall + irrigation ~2200 mm/yr).

The NZ-DNDC model simulated the drainage and leaching to 50 cm depth while APSIM and the measured values were at 70 cm. While this could make some differences to the timing of drainage and leaching, the cumulative values over the year should be little affected. Total measured drainage ranged from 520±40 mm (2009 low irrigation) to 1580±40 mm (2010 high irrigation). Both models estimated total drainage well (r = 0.93 and 0.87 respectively), although with a slight tendency to underestimation (average relative error –1.1% and –4.3%).

APSIM over-estimated pasture N-uptake from early spring to summer, while NZ-DNDC under-estimated N-uptake over this period. Over the entire year this resulted in an average relative error of +16% for APSIM and (+75 kg N/ha) –33% in NZ-DNDC (-175 kgN/ha).

Both models simulated similar NO_3-leaching losses in 2008 (APSIM 573 and 689 kg N/ha; NZ-DNDC 527 and 697 kg N/ha for low and high irrigation respectively) compared with measured values of 540±70 kg N/ha (low irrigation) and 620±60 kg N/ha (high irrigation). However, both models over-estimated losses in 2009 and 2010. For NZ-DNDC, the over-estimation of NO_3-leaching losses could be partly explained by the under-estimation of plant N-uptake. It could also be that NO_3 adsorption by allophane reduced the amount of NO_3-leaching in the field. When NO_3 adsorption was considered in the APSIM model (also increasing the nitrification rate because of the high soil C), the average error changed from an over-estimate of 41% to an underestimate of 14%.

Although the two models had different methods for simulating soil water, both produced reasonable estimates of total drainage. However, estimation of NO_3-leaching was more challenging as it depends on appropriate representation of other aspects of the N-cycle. Modifications to improve NO_3-leaching simulation will be discussed further at the workshop.

THE FATE OF URINE NITROGEN:
A GRASSLAND LYSIMETER STUDY IN IRELAND

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In grazed pasture systems, the nitrogen (N) contained in a cattle urine patch may be up to 1200 kg N ha^{-1}. The majority of this N is in excess of plant requirements and is vulnerable to environmental loss. In this study, cattle urine was applied at five rates of nitrogen, 0, 300, 500, 700 and 1000 kg N ha^{-1} to soil monolith lysimeters in late autumn in Ireland. Measurements of gaseous N emissions, nitrate (NO_3^-) leaching and pasture N uptake were made for a calendar year following urine application in two consecutive experiments. Increasing the rate of urine N applied increased the cumulative nitrous oxide (N_2O) emissions, NO_3^- leaching and pasture N uptake in years one and two, but had little effect on the percentage of N recovered in each pathway. Furthermore, the total recovery of urine N in year one was low, only 63%, so in year two a detailed ^{15}N isotopic balance for the fate of urine patch N attempted to answer the question – where is the missing N? Of the 1000 kg N ha^{-1} urine applied in year two, 27% was recovered in gaseous emissions (predominantly inert N_2), 10% was recovered in the drainage water, 26% was taken up by the pasture, and 23% remained in the soil. The comparison of mass and ^{15}N balance methods suggest that urine may stimulate the release of native soil N.

N AND P CONCENTRATION-DISCHARGE RELATIONSHIPS ACROSS A RANGE OF WAIKATO CATCHMENTS

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Waikato Regional Council operates a river water quality monitoring programme where samples are taken monthly at 114 sites and analysed for concentrations (C) of a range of water quality parameters. Water flow (or discharge, D) is measured at or nearby 26 of these sites, which allows *nutrient concentration–river discharge relationships* (C-D relationships) to be established.

The patterns of the C-D relationships were surprisingly similar across the region in spite of substantial differences in natural conditions, land use and the potential effect of point source discharges. Statistically highly significant ($p \leq 0.005$) C-D relationships were found at nearly all sites (n=24–26) for total nitrogen (TN), nitrate nitrogen (NO_3-N) and total phosphorus (TP); all but two of them were positive. Ammonium nitrogen (NH_4-N) and dissolved reactive phosphorus (DRP) were less frequently correlated to discharge. While all significant correlations (n=18) were positive in the case of NH_4-N, 9 of the 14 significant correlations for DRP were negative. In spite of many C-D relationships being statistically highly significant, there is typically a wide spread in the data, resulting in substantial uncertainty if the equations are used for predictions.

To evaluate to what extent these relationships provide information on the transfer pathways from the land surface to river monitoring sites, we stratified all concentration data into those from sampling dates when baseflow (BF) dominated discharge versus those when quickflow (QF) was dominant. As the positive C-D relationships imply, average baseflow concentrations of TN, NO_3-N and NH_4-N were lower than quickflow concentration s at the same site, whereas negative C-D relationships for TP or DRP were associated with higher concentrations of these solutes in baseflow compared with quickflow.

As BF is largely due to discharge of (older) groundwater, while quickflow is predominantly due to (younger) near-surface flows, trends in these data reflect land management changes at different time scales. Deteriorating NO_3-N concentrations were predominantly the combined effect of BF and QF deteriorations, while TP trends, both positive and negative, were largely due to trends in BF. The prominent role of baseflow in determining these river concentration trends highlights the importance of understanding a nutrient's mean residence time in the groundwater system of a particular catchment when trying to link a concentration change to a land management change.

AN INVENTORY OF NITROGEN AND PHOSPHOROUS LOSSES FROM RURAL LAND USES IN THE SOUTHLAND REGION

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The Southland region has undergone a period of large scale land use change and intensification since the early 1990s. To understand the effects of rural land uses on nutrient losses and resulting water quality, an inventory of nutrient losses from rural land was undertaken for the region.

Loss estimates of N and P (kg/ha) were calculated under different productive land uses to produce regional inventories of total load estimates (t/yr). Total excretal N loads (Nex) were also calculated for the region using data derived from the National Greenhouse Gas Inventory (2011) and regional stock number data.

This approach reveals that approximately 16,900 tons of N is currently lost per annum from productive land uses across the region. Of this, 50% of losses come from land used for sheep/beef/deer farming, 31% comes from dairying, and 16% from wintering activities with the remainder from forestry and arable (<3%). The total regional loss calculated for P was approximately 640 tons per annum, with 66% coming from sheep/beef/deer, 22% from dairying and 9% from winter fodder crops.

Natural state (ca. 1840) N and P losses were calculated at 11% and 40% of current day losses respectively. Nex loads in 2011 were calculated at 159,100 tons per annum, an order of magnitude higher than the amount of N lost for the region. Regional stock number data highlights that stock units in the region have plateaued since the early 1980s, however the regional Nex load has still increased; a product of dairy cows having a higher Nex load per stock unit equivalent.

Good agreement was found for N loss, and to a lesser extent P loss, with other recent Southland studies (NZIER 2013; Aqualinc 2013). The results have significantly helped council understand nutrient losses from leading rural land uses. The study has also provided a sound platform from which to undertake detailed catchment scale analyses of nutrient losses.

NITROGEN LEACHING FROM SHEEP GRAZED HILL COUNTRY: MEANS, MEDIANS OR BACK-TRANSFORMED MEANS?

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Nitrogen (N) leaching data obtained from grazed pastures rarely conform to a normal distribution. These data are likely to have a large number of very low values originating from areas with little N leaching (non-urine patch areas), and a smaller number of points with large values (urine patches, including patch overlap). Transformation of the data is often necessary before the appropriate statistical analyses can be performed. Whilst data transformation allows the appropriate testing of treatment effects on N leaching, estimates of the amount leached are of key interest.

For normally distributed data the raw mean is the appropriate estimate of the true population mean, with its standard error being a descriptor of the variability surrounding that mean. However, for non-normally distributed data the raw mean is no longer a valid estimate of the population mean. In this case the appropriate estimate of a population mean is the back-transformed mean and the 95% confidence intervals a measure of variability surrounding that mean. However, in published literature it is not uncommon to find raw means and standard errors presented to describe the results, even though the data was non-normally distributed. If the data distribution is not normal, the value of the raw means will be very different to the back-transformed means.

Nitrate-N leaching data from a recently completed 3 year study in hill country are used to illustrate the effect of using different ways of expressing population means when summarising non-normally distributed data. The study area had a slope class mix of 16, 56 and 28% low, medium and steep slopes (>25°), respectively, and was stocked with sheep at 11 SU ha^{-1}. For that dataset the raw mean, median and back-transformed mean values for nitrate-N leaching were 124, 58 and 29 kg nitrate-N ha^{-1}, respectively, for low slope (0-12°) areas and 16, 1 and 1 kg nitrate-N ha^{-1} respectively, for medium slope (13 – 25°) areas. If we make the assumption that nitrate-N leaching from steep slopes would be negligible, the estimated amount of nitrate-N leached per ha of hill country would be 29, 10 and 5 kg N ha^{-1} using the raw mean, median and back-transformed mean values, respectively. In this paper we discuss the validity of using the raw mean, median or back-transformed mean as estimates of population means and the implications this may have on interpreting N leaching results.

UNDERSTANDING PHOSPHORUS, NITROGEN AND CADMIUM TRANSFER THROUGH A YOUNG STONY SOIL

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In Canterbury land-use intensification, particularly irrigated dairy expansion, is occurring on stony soils, but concerns exist about the ability of these soils to sustain intensified land-use, whilst maintaining nutrient leaching within discharge limits. Environmental models consistently predict stony soils as having a high vulnerability to leaching under intensive land use, but it is recognised there is little experimental research to validate the model predictions. This paper presents scoping experiments to quantify the degree of leaching vulnerability of young stony sand soils, and to determine what are most likely to be the key drivers for leaching.

Barrel lysimeters (460 mm in diameter by 700 mm deep) of intact soil columns were collected of a young stony sand soil. Four lysimeters were used to study the preferential leaching of nitrogen (N), phosphorus (P), and cadmium (Cd) from a pulse (25 mm depth) of dairy shed effluent (DSE) followed by continuous artificial rainfall – both applied at 5 mm/h. A further two lysimeters were used to study the preferential leaching of N, P, Cd, and carbon (C) under simulated irrigation (12–18 mm depth applied every 3–4 days). Sequential treatments of superphosphate, cow urine, and DSE were applied, with intervals of at least one pore volume (>200 mm) of drainage between each treatment.

The constant-rate experiment demonstrated that these soils have the potential for rapid leaching of N, P and Cd from an application of DSE. In contrast, no unequivocal increase in P, N and Cd leaching occurred after the DSE treatment in the simulated irrigation experiment, indicating strong sensitivity of these soils to the management practice of DSE application.

The simulated irrigation experiments indicated that under irrigated dairy pasture, urine deposition will be the key driver of leaching. Both the superphosphate and DSE applications resulted in low leaching. In contrast the urine treatment showed increased leaching of N, P, C, and Cd starting within 20–90 mm of drainage following the urine application.

The results of this scoping study confirm predictions that young stony sand soils have high potential leaching risk, and we argue that these results urgently justify a larger-scale research programme given the intensification of agricultural development on these vulnerable soils.

EFFECTIVENESS OF *ECO-N* IN REDUCING NITRATE LEACHING LOSSES AT HIGH RATES OF N FERTILISER WITH AND WITHOUT URINE ADDITION

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There is increasing concern that nitrate (NO_3^-) leaching from intensive agriculture can degrade water bodies and may threaten human health. Nitrogen (N) inputs from fertilisers, effluents and the urine of grazing animals in particular can cause increased NO_3^- leaching from dairy farm systems. Questions have therefore been asked about the effect of high rates of N fertiliser application on leaching losses from grazed pastures and if these effects can be mitigated by using a nitrification inhibitor. This study used two N fertiliser rates (300 kg N/ha and 500 kg N/ha) with and without urine, and with and without the nitrification inhibitor DCD 'eco-n'. Results show that increasing the fertiliser application rate from 300 kg N/ha to 500 kg N/ha increased the peak concentration of NO_3^- leached from 2.4 NO_3^--N/L to 11.2 NO_3^--N/L. However these values are significantly lower than those from N fertilisers plus urine, where peak the concentration of NO_3^- leached exceeded 220 NO_3^--N/L, 20 times that of fertiliser alone. Similarly, the total amount of NO_3^- leached was highest in the fertiliser plus urine treatments where the amount of NO_3^- leached was on average 45 times the loss from the N fertilisers alone. This confirms that urine addition is the main source of NO_3^- leaching in grazed pastures, even with the high N fertiliser application rates used in this study. The application of eco-n reduced the total NO_3^--N leaching losses by 42% in the fertiliser plus urine treatments. This indicates that eco-n has the potential to significantly reduce the environmental footprint of intensive dairy pastures even at high N fertiliser application rates.

THE POTENTIAL OF DIVERSE PASTURES TO REDUCE NITROGEN LEACHING FROM NEW ZEALAND DAIRY FARMS

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The DairyNZ Whole Farm Model was used to evaluate the effect of utilising diverse pastures on whole farm productivity and nitrogen (N) excretion. Two typical dairy farms; Scott Farm in the Waikato region (stocking rate = 3.2 cows/ha) and Lincoln University Dairy Farm in the Canterbury region (stocking rate = 3.9) with 2 - 7 year old Holstein-Friesian x Jersey crossbred cows, were modelled over the 2011 - 2012 season. The effect of feeding diverse pastures was assessed using three scenarios; the standard pasture (the traditional New Zealand perennial ryegrass – white clover pasture mix; control), and this pasture combined with diverse pasture sown on 20 or 50% (20 or 50% diverse) of the farm area, with the remainder sown in standard pasture. The diverse pasture mixture comprised of standard pasture in a mix with herbs (chicory and plantain), prairie grass and either lucerne in Waikato or red clover in Canterbury. Diverse pasture yield and quality in the model were parameterised using measured data for diverse pastures grown in both regions. Model outputs were farm-grown dry matter (DM) production, milksolids production and N excreted in urine. Relative to the control, the 20% diverse treatment reduced DM production by 2 and 1% in Waikato and Canterbury, respectively. The effect of the 50% diverse treatment was a 6% reduction (Waikato) and a 2% increase (Canterbury) in DM production. Milksolids production did not differ between the control and the diverse treatments in Waikato. In Canterbury, milksolids production for the control and the 20% diverse treatment were similar, but a 3% increase in production was predicted for the 50% treatment. In both regions, incorporating diverse pastures in 20 - 50% of the farm area has the potential to reduce urinary N excretion by 3 - 7%. This study suggests that, at a farm system level, lower urinary N excretion by dairy cows feeding diverse pastures can reduce N discharge onto pastures and ultimately, the risk nitrate leaching, without compromising milksolids production.

Key words: Diverse pastures, urinary nitrogen, dry matter production.

CAN BIOCHAR BE USED TO INCREASE THE BIOAVAILABILITY OF PHOSPHORUS IMMOBILIZED IN ANDISOLS?

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A large proportion of phosphorus (P) fertilizer applied to Andisols reacts with Al reactive surfaces and becomes unavailable for plant uptake. Up to 3 tonnes/ha of P have been locked away in intensively farmed soils. In this study we explore the possibility of mobilizing P retained in these soils through the use of biochar. The specific objectives of this study were to (i) investigate the effect of biochar application to Andisols on arbuscular mycorrhizal fungi (AMF) growth and P availability; and (ii) identify other biochar-associated mechanisms that may modify soil P availability (e.g., through changes in soil pH). For this, a root study container (RSC) technique that divided the soil into three components - root zone, rhizosphere and hyphae zone - was used. Three types of biochar were studied: two made from chipped pine (*Pinus radiata* D.Don) branches at 450°C and 550°C (BP450 and BP550) and a third one from chipped willow (*Salix matsudana* L.) branches at 550°C (BW550). Each biochar at a dose of 4.48% (w/w, which was equivalent to a field deep-banded rate of 10 t/ha) was mixed into samples of Egmont silt loam topsoil (Andisol) that contrasted in Olsen extractable P levels (4.3 and 33.3 mg P/kg referred to as LP and HP, respectively). The various combinations of LP ± biochar or HP± biochar were packed into either the upper root zone compartment, or the lower hyphae compartment of the RSC, or both. *Lotus pedunculatus* cv barsille seeds (inoculated with *Rhizobium)* were sown in the root zone soil. Abundant indigenous AMF were identified, and thus no external inoculum was introduced. The lotus shoots were harvested at regular intervals dry matter yield, P and N concentrations of plant shoots determined. Results obtained to present indicate that (i) the presence of BW550 in the root zone of the LP soil significantly ($p<0.05$) enhanced plant growth and P uptake; (ii) the presence of pine biochar (BP450 and BP550) in the hyphae zone of the HP soil substantially increased plant growth and P uptake ($p<0.05$). Once the experiment is finalized, AMF colonization on roots, hyphal length in the hyphae zone soil and P forms fractions in the rhizosphere soil will be determined. Information obtained from the present study will help reveal the mechanisms underlying the influence of biochar on P bioavailability in Andisols.

Keywords: Biochar, Andisols, Root container study, Arbuscular mycorrhizal fungi

ADVANCES IN INTELLIGENT AND AUTONOMOUS SYSTEMS TO IMPROVE IRRIGATION AND FERTILISER EFFICIENCY

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Water, nutrients, energy and labour are critical determinants of on-farm productivity and profitability. The National Centre for Engineering in Agriculture (NCEA) has a 20 year history of working with industry to improve the efficiency and productivity of irrigated farming systems. The NCEA has developed software tools and hardware technologies to improve the measurement, evaluation, optimisation and control of these key inputs for both manually operated and automated irrigation and fertiliser application systems. The tools are applicable to both uniform and spatially variable application systems. Spatial variability in crop water and nutrient requirements can occur as a result of spatial and temporal variations in soil structure, fertility and properties; or pests and diseases.

Two irrigation and fertiliser software frameworks that have been developed at the NCEA are 'KMSI' and 'VARIwise'. KMSI is a suite of online irrigation, nutrient and energy calculators and database tools which present sensed data, performance evaluations and recommendations for growers and consultants with manually operated irrigation and fertiliser application systems. Two tools in KMSI are IPART and NutriCalc, which provide performance auditing and reporting for irrigation and nutrient applications, respectively.

VARIwise steps toward autonomous irrigation and nutrient prescription and application by linking infield sensing, data processing and control actuation. 'VARIwise' is a software framework that implements and simulates control strategies on fields with sub-field-scale variations in all input parameters (including nutrients). Input parameters are measured using infield soil sensors and on-the-go crop monitoring cameras. The control systems can be implemented in VARIwise either in simulation through APSIM or in field implementations using irrigation and fertiliser actuators. Variants of the framework have been developed for centre pivots, lateral moves and surface irrigation systems. This presentation will provide an overview of the irrigation and nutrient management tools developed by the NCEA along with a focus on current research investigating automated nutrient and water management control strategies for irrigation systems.

DIGITAL ELEVATION MAPS FOR SPATIAL MODELLING OF SOIL SERVICES

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Valuable soil information can be obtained from digital elevation maps (DEMs) because the derived terrain attributes inform and improve spatial prediction of key soil attributes (e.g. moisture status and organic matter) that impact on soil function and the services that soils provide.

While the publically available national 25-m resolution DEM is well suited to catchment-scale studies, recent technological developments have been enabling the availability of DEMs at much higher resolutions (≤10m).

DEMs derived from electromagnetic (EM) and LiDAR surveys are suited to paddock- and farm-scale spatial prediction of topography-controlled soil properties. Soil EM surveys can provide DEMs at an approximate 10 m resolution, and airborne LiDAR surveys provide DEMs at ≤1 m resolution.

Quantitative analysis of DEMs to derive primary terrain attributes, such as slope and aspect, and secondary terrain attributes, such as flow accumulation pathways, is conducted in software packages using sophisticated algorithms. For example, a multiple flow direction algorithm assesses upslope area for any one pixel and allows this accumulated upslope flow to be distributed among all downslope directions.

The two case studies presented in this paper are:

An EM-derived DEM is used to investigate soil available water-holding capacity (AWC) and topsoil depth at a North Otago irrigated paddock on rolling downlands (90 ha). AWC varied between 10 and 19% (v/v) at 9 stratified sampling positions and showed some correlation to terrain attributes. Topsoil depths ranged between 0 and 76 cm, and a random forest model was used to produce a map of topsoil depth (r2 0.5; RMSE 9 cm).

A LiDAR-derived DEM is used to produce a soil organic carbon (SOC) map for Massey University Tuapaka hill country farm (476 ha). The map is a surrogate for soil quality, because organic matter provides essential AWC, structure, cation exchange capacity (CEC) and nitrogen (N) stores. It also provides the dissolved organic carbon (DOC) to drive N attenuation in surface and sub-surface soils to waterways. SOC ranged between 42 and 194 T/ha to 30 cm soil, being highest for the Ramiha soil series at the highest elevations, formed from a mixture of loess and volcanic ash, and lowest for the Tokomaru soil series at lowest elevations, formed predominantly from greywacke-derived loessial deposits.

A CALCULATOR FOR EVALUATING IRRIGATION ON DAIRY FARMS

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Few issues are as important, topical or problematic in New Zealand agriculture as irrigation. Central government is currently championing irrigation for its potential to dramatically increase dairy production or as a way of introducing dairy to previously marginal areas.

There is a general consensus that applying irrigation to pasture with significant soil water deficits over the summer will increase pasture production. However, there is much less agreement on the profitability of irrigating dairy pastures. Furthermore, there are concerns about the management of irrigation systems, the efficiency with which water is used and the likely impact of irrigation on the quantity and quality of drainage water.

A calculator has been developed to help dairy farmers explore issues associated with irrigation. Farms that have irrigation can benchmark their system against best management practise as predicted by the calculator. Farmers considering the adoption of irrigation can use the Calculator to predict the likely profitability of irrigation. Inputs to the Calculator are few and simple.

The calculator has been used to evaluate irrigation management on a South island dairy farm and a Manawatu sheep and beef farm. The use of the calculator to estimate the likely profitability of irrigation is demonstrated on three contrasting Manawatu dairy farms.

ROOT ZONE LOSSES ARE JUST THE BEGINNING

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Minimising root zone losses has rightly been the main focus in recent years of measures to reduce agricultural land use impacts on freshwater quality. However, root zone losses are just the beginning, as far as managing to water quality limits is concerned. To be able to fully explore all potentially available management options, the entire *'source → transport/transformation → impact'* chain needs to be understood.

Where, when, and to what extent the root zone losses impact on freshwater bodies depends on the transport and transformation processes occurring in the vadose zone – groundwater – surface water continuum. We will be demonstrating these processes using a combination of New Zealand and European examples.

Understanding the '*where*' requires investigating the relative importance of the various subsurface flow paths (e.g. artificial drainage, interflow, shallow and deeper groundwater). Modelling of the subsurface hydrological system also helps to define the groundwater catchments that contribute water (and the nitrate it carries) to a monitoring site. These groundwater catchments do not necessarily match the topographically defined surface water catchments.

Regarding the '*when*', it is essential to consider the lag times, both in the vadose zone and in the groundwater system. Depending on the relative importance of the various flow paths, not all nitrate lost from the root zone will reach a surface water body at the same time. The resulting distribution of transfer times further complicates establishing the link between an impact observed in a surface water body and the land use activity that has caused it.

As for the '*extent*' to which root zone nitrate losses impact on freshwater bodies, it is critical to account for attenuation processes occurring along the flow paths. The two key nitrate attenuation processes are mixing/dilution and denitrification (occurring below the root zone).

While groundwater denitrification has to date received relatively little attention in New Zealand, its potentially substantial role is recognised by many European drinking water supply companies and regulatory authorities. Accordingly, new policy initiatives in Europe have started taking account of the spatially variable nitrate reduction along the flow paths from the *source* to the *impact* zones.

MONITORING AND MODELLING TRANSPORT AND FATE OF NITROGEN IN UNSATURATED AND SATURATED (SHALLOW GROUNDWATER) ZONES IN MANAWATU RIVER CATCHMENT – WORK IN PROGRESS

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A sound understanding of the transport and fate of farm nutrients is a key component of managing and mitigating the likely impacts of these nutrients on freshwater quality and ecosystem health. While the cycling and leaching of nitrogen in the soil profile (rootzone) is reasonably well understood, there is limited information available about its transport (time lag) and fate (transformation) in the subsurface environment (below the rootzone), particularly in the Manawatu River catchment. To address this, Massey University's Institute of Agriculture and Environment (IAE) and Horizons Regional Council has established a collaborative research study to monitor and model the transport and fate of nitrate-nitrogen from farms to river via groundwater in the Manawatu River catchment.

Field measurements and laboratory experiments are being conducted to develop methods to assess and characterise the transport and transformation of nitrate-nitrogen in alluvial unsaturated and saturated (shallow groundwater) zones. Ceramic suction cups have been installed at Massey University's No 1 Dairy Farm to monitor soil water at multiple depths in the rootzone (from 0 to 60 cm) and the unsaturated zone (from 0.6 to 4.5 m). Shallow groundwater is monitored in four PVC piezometers installed from 4.5 to 8.7 m below ground level in the saturated zone. The collected soil water and shallow groundwater samples are being analysed for; nitrate-nitrogen, ammonium, dissolved oxygen, and dissolved organic carbon. Preliminary measurements indicate a significant reduction in nitrate-nitrogen concentrations, particularly in the saturated (shallow groundwater) zone at this site.

The observational and experimental learnings from this test site at Massey Dairy No. 1 farm will be used to assess and characterise the transport and transformation of nitrate-nitrogen in the subsurface environment at other selected sites in the catchment. The collected information will be used to develop a nitrogen flow model including transport and denitrification of nitrate-nitrogen in unsaturated and saturated zones in the Manawatu river catchment, with a focus on the Mangatainoka subcatchment. This research will bridge a gap in current knowledge between rootzone and river based processes and help in the management of nitrogen movement from farms to rivers in the Horizons region.

MACROPORE NETWORKS AFFECT THE FILTERING FUNCTION OF SOILS

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Soils can deliver the ecosystem service of filtering. But filtering capacities differ between soils such that the quick transport of agrichemicals into aquifers cannot be excluded. We hypothesized that a soil's filtering capacity depends on its macropore structure, which is linked to soil texture. Tension disc infiltrometry can be used to measure hydraulic properties near saturation. The differentiation between hydrologically active and non-active pores at a given tension is an indirect method to characterize macropore continuity. Water flow through macropores is a function of the macropore size distribution, tortuosity and the connectivity of macropores. These characteristics can directly be derived by 3D X-ray computer tomography (CT). Our objective was to analyze the macropore network and to characterize the resulting filtering performance of soils with contrasting structures. For this purpose, two soils under pasture with known filtering behaviour for microbes were selected. The soils were an Allophanic Soil (excellent filter) and a Gley Soil (poor filter). Each soil was separated into three horizons assuming that each horizon had a specific macropore structure. In March 2011, infiltration near saturation was measured in the field; hydraulic conductivity K_0 and flow-weighted mean macropore diameter α for each soil horizon were derived. We extracted intact soil cores from the centre of the infiltration areas and determined the macropore architecture by X-ray CT. The results were validated with bromide leaching experiments through intact soil cores. Dye tracer experiments visualized flow patterns in situ. Our results confirmed the better filtering capacity of the Allophanic Soil. The soil's comparatively low macroporosity was coupled with a high connectivity of the smaller macropores which led to a more homogeneous matrix flux. Similarly, all measurements confirmed the poorer filtering capacity of the Gley Soil, which had a bi-modal pore system with a few very large, but well connected macropores. This resulted in preferential flows. We identified the macroporosity, mean pore diameter and connectivity as the relevant 'form' parameters to describe the 'function' of agrichemical transport.

PEDO-TRANSFER FUNCTIONS FROM S-MAP FOR MAPPING WATER HOLDING CAPACITY, SOIL-WATER DEMAND, NUTRIENT LEACHING VULNERABILITY AND SOIL SERVICES

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Recent modelling developments within S-map (New Zealand's soil survey data information system) have been designed to support nutrient management at multiple scales. A chain of models has been developed, implemented and tested. Firstly, statistical analysis of water content data held in the National Soils Database has resulted in a set of pedo-transfer functions (ptfs) that estimate key points on the water retention curve for each soil sibling in S-map. With this information, the profile available water can be derived. This in turn is a key parameter in a soil-only model (or ptf) of vulnerability to nitrate leaching – one of a set of models that spatially describe risks related to other mechanisms of nutrient loss (e.g. runoff, by-pass flow). The nitrate leaching model can be recast in terms of ecosystem soil services, in this case as the 'regulation of N filtering' service. These soil-based models can be extended to account for spatial variation in rainfall and potential evapotranspiration, by running a daily water balance for each soil to estimate annual accumulated drainage; thus creating a spatial layer of leaching vulnerability based on soil and climate. Another output of this stage of the modelling is 'water demand', which can assist in the development of new irrigation schemes. Finally, information about land management (i.e. nutrient inputs) can be added into the vulnerability ptfs to estimate nitrate leached.

This suite of ptfs or models within S-map has a range of uses in farm nutrient management. The water content and other pedological information from S-map can be entered into nutrient budget models (e.g. OVERSEER), mechanistic nutrient leaching models (e.g. Apsim, Spasmo), irrigation models (e.g. IrriCalc), effluent management systems (e.g. FDE), all for use at the farm scale.

The soil- and soil–climate-based vulnerability models are useful for district- and regional-scale analyses where education or even regulation is needed to limit the potential for significant nutrient losses, or conversely to support the design of new irrigation schemes to maximise water and nutrient use efficiency. The soil–climate–land management models are used to predict catchment nutrient loads – an essential step in setting water quality objectives. These models have been used to help communities understand the likely impacts of possible land use changes, irrigation developments, or policy constraints on water quality.

CONTROLLED DRAINAGE

– ASSESSING RELEVANCE TO NZ PASTORAL SITUATIONS

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Farm drainage systems are used to prevent excessive soil water levels during wet periods, thus protecting soil quality and enhancing plant productivity. Although beneficial, drainage systems are also known to be a significant loss route for dissolved nutrients as they by-pass nutrient attenuation areas such as wetlands and riparian zones. A potential way of reducing nutrient loss through drainage systems is to use to strategically placed weirs in drainage channels to control water movement out of the soil profile by restricting drainage to only the excess water that will damage crops, or limit grazing or farm equipment access to paddocks. Such systems are used in cropping areas of Europe, Canada and the USA (where it is designated as a "beneficial management practice") with significant benefits for water quality, agricultural productivity and nutrient- and water-use efficiency. Improvement to water quality arise by decreasing total drainage outflows, promoting higher nutrient use efficiency and increased N retention and NO_3-N attenuation. Crops have the potential to utilise nutrients held in the root-zone and reduce plant moisture stress during drier periods. Raising the water table may also promote in-situ denitrification. The practicality of using controlled drainage under New Zealand farming conditions however is less clear, with only 2 studies having been undertaken that we are aware of.

In order to locate suitable sites for a controlled drainage study, review of controlled drainage literature was used to inform a GIS pre-screening process to identify areas with appropriate soils (loam or clay loam) and slope (<1.5 degrees).

In selecting specific sites, additional factors that needed to be considered were sites needed accessible drainage systems where control weirs could be installed, and sites needed to have two near-identical paddocks to set up as paired monitoring sites to allow a valid comparison between a paddock where controlled drainage was undertaken and an adjacent paddock where normal drainage was allowed to occur. Two dairy farms were identified as suitable sites- one at Tatuanui (3 km east of Morrinsville) and the other near Waharoa in the Waikato region.

Site set-up and control structures include individually designed and constructed weir/flume arrangement due to the low gradients present at the sites.

Soil moisture sensors will be placed at two depths at different locations of each experimental paddock to assess the effectiveness of the weirs in controlling soil moisture levels within the paddocks. Outflows from each paddock will be measured for flow volume, and be sampled for water quality (particularly nitrogen species). Pasture productivity and nutritional value will also be assessed.

MEASUREMENT OF WATER VAPOUR FLUXES WITH EDDY COVARIANCE TOWERS – HOW DIRECTLY MEASURING EVAPOTRANSPIRATION CAN HELP US MANAGE WATER

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The continued expansion of irrigated areas in New Zealand places greater pressure on our freshwater resources and underscores the need for better water-use efficiency. The two principal fates of irrigation water and natural rainfall are drainage and evapotranspiration, and therefore these are key terms in the agricultural water budget. Evapotranspiration has generally been estimated using a variety of models based on commonly measured meteorological variables. Eddy covariance is a technique that measures the vertical flux of water vapour and therefore provides a means to directly measure evapotranspiration. The method also quantifies carbon dioxide fluxes, which allows not only a validation of evapotranspiration models, but also provides new insights into the relationship between photosynthesis and plant water use. Options also exist for partitioning evapotranspiration into its components: soil evaporation and plant transpiration. In the last few years several eddy covariance towers have been established in agricultural fields in New Zealand. The measurements are frequent (every 30 minutes), continuous and integrate over a large spatial area (>1 ha). Some of the towers are collocated with lysimeters where drainage is also quantified. We discuss how these measurements can provide information that can be used to help farmers and water managers make efficient water management decisions.

OPTIMISING COPPER SPRAYS ON KIWIFRUIT: A REVIEW

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Psa in New Zealand has caused a major decline in the kiwifruit supply chain. Today there are many ongoing research activities being conducted by various research organizations to adapt efficient kiwifruit management for a Psa-affected environment. This includes the effective control of Psa without compromising the quality of kiwifruit orchards, potentially growing resistant kiwifruit varieties, and understanding how climate factors affect vine susceptibility.

No curative treatment has yet been identified that can control Psa; all present treatments are preventative-based mechanisms. Copper sprays have been used on kiwifruit vines as a bactericide since the outbreak of Psa in 2010. At present, kiwifruit growers are using a variety of Cu-based chemicals at various rates and times.

The spraying of copper-based bactericides is one of the most effective practices in protecting against Psa. Although their use has yet to be optimised, copper-based bactericides play a major role in reducing the production of spores from the cankers. In New Zealand, copper compounds have been recommended for spraying immediately after winter pruning, at bud break, two and four weeks after bud break, and in high risk situations like after a major wind, rain or hail event. Some studies have reported that the application of Cu-based bactericides significantly affects the kiwifruit yield. However, studies on the most effective system for application of these Cu-based agrichemicals have been limited. In addition, there have been no studies published on the occurrence of Cu resistant Psa in Kiwifruit vines.

Our review of literature has identified the following key points;

- High level research activities have been conducted on Psa strains and their resistance to Cu in both New Zealand and overseas, covering all major kiwifruit growing countries.
- Studies into the resistance of Psa to Cu have mainly focused on the micro or molecular biological aspects of the pathogen. The link between the mechanism for resistant gene development and the role of bioavailable Cu (Cu^{2+} ions) present on the plant surfaces is currently a major research gap that needs to be addressed.
- There is a lack of research findings in literature associated with the bioavailability of Cu^{2+} ions on the surface of kiwifruit vines, their efficacy in controlling Psa, and their phytotoxic effects on kiwifruit vinery.

BENCHMARKING N AND P LOSS RISK FROM DAIRY EFFLUENT DERIVED NUTRIENT SOURCES

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Farm dairy effluent (FDE) is generated in a number of locations around a dairy farm including the milking shed, off-paddock animal confinement facilities, stock laneways and silage stacks. The storage and management of this effluent, with respect to the specific attributes of the farm (e.g. soil type, proximity to water, topography and climate) has a huge bearing on the proportion of the nutrients (and other potential contaminants) that are lost. However, the relative contribution of nutrients that are lost from the various points of FDE generation, storage, distribution and land application are not widely documented.

This study assessed the risk of nutrient loss that is associated with a given management decision or defect in the design and/or maintenance of the effluent infrastructure on a typical or average Waikato farm. We have distinguished between the 'at risk' components, i.e., the total quantity of nutrient that could potentially be lost (worst case scenario), and, an 'attenuated loss', which is the quantity that is actually lost given best case soil attenuation potential. The 'at risk' and 'attenuated losses' of nutrients from a number of individual contributing factors have been reported. This approach highlights the potential non-compliance magnitude and enables farmers to prioritise management efforts toward the most influential factor contributing to overall farm losses. We suggest the greatest gains in reducing nutrient loss from effluent sources on dairy farms can be achieved by preventing pond discharges, ensuring adequate capture of effluent from off-grazing systems and employing sound irrigation practices when land applying effluent.

FARM DAIRY EFFLUENT MANAGEMENT PRACTICES IN REREWHAKAAITU, ROTOMAHANA AND OKARO LAKES CATCHMENTS

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Improving the water quality in sensitive lake catchments is an on-going challenge for the New Zealand dairy industry. In three catchments in the Rotorua Lakes region, dairy farmers have taken a proactive stance in understanding nutrient flows from their farms. Over the past five years individual farm nutrient management plans have been implemented along with on-farm mitigations to reduce losses of nitrogen, phosphorus and sediment. An outstanding issue remained concerning the lack of qualitative data relating to farm dairy effluent management. During spring 2013 a majority of catchment farmers (> 90%) took the opportunity to have land application depths measured and nutrient loadings quantified.

This paper summarises the findings of land application of effluent from either dairy sumps or storage ponds through five different application delivery systems. These measurements provide data on effluent spreading distribution, application depth, nutrient concentrations of major nutrients and nutrient loadings.

The main form of effluent delivery system encountered was the travelling irrigator. The mean application depths of travelling irrigators at fast, medium and slow settings were 11, 14, and 21mm respectively with corresponding nitrogen loadings of 33, 51 and 90 kg N/ha. Chemical analysis of effluents sourced from dairy sumps had concentrations of 4.0, 0.5 and 4.1g/m^3 for N, P and K respectively, compared to 3.5, 0.6 and 3.9 g/m^3 respectively for pond effluent. Over application of nutrients (>150 kg N/ha per irrigation) could occur when a thicker effluent (~ 1% DM) was applied at a slower rate. During the course of the study other issues related to effluent application were also identified and are discussed.

VARIABILITY OF EFFLUENT QUALITY AND QUANTITY ON DAIRY FARMS IN NEW ZEALAND

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Better management of dairy farm effluent is a key priority for the New Zealand dairy industry, regulatory bodies and the public. Farmers spend millions of dollars annually to improve effluent treatment systems, effluent storage systems and effluent land irrigation systems. This is in part driven by the economic imperative to realize the maximum value represented by effluent fertilizer nutrients, and in part by the increasing need to reduce nutrient losses to ground and surface water, driven by increasing environmental awareness of the NZ public and ever tightening effluent management regulation enforced by regional councils. In this regard the use of effluent storage ponds for deferred effluent irrigation will become a near universal practice in the near future. At the same time farming practices are changing rapidly, with the use of feed and stand-off pads, imported feed supplements and higher stocking rates becoming widespread. These changes will present additional challenges for proper effluent management and most likely rapidly outdate “standard industry figures” for effluent characteristics, volumes, concentrations and related parameters.

As part of a dairy farm effluent pond monitoring program, effluent volume and quality was measured at 3 farms in Northland, Waikato and Southland. The results indicate a very large variability in effluent flow and quality, both between farms and at each individual farm between different sampling periods. On a per cow basis effluent volumes, nutrient concentrations, and as a consequence secondary environmental parameters such as effluent management methane GHG emissions per cow, varied several-fold. It is indicated that different on-farm management techniques have a greater influence on overall effluent volume, quality and environmental impact than cow numbers. As dairy farming in NZ continues to intensify, it is inferred that parameters like cow numbers and stocking density are increasingly becoming imprecise inputs for planning effluent management and assessing potential environmental issues associated with dairy farm effluent. Wherever possible actually metered data of effluent volume, solids and nutrient concentration and volumes should be used for planning improved effluent management systems.

EFFECTS OF ACIDIFICATION ON NITROGEN TRANSFORMATIONS IN STORED DAIRY EFFLUENT

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Good practice management typically requires storage of farm dairy effluent (FDE) during periods when conditions are not conducive for land application. This strategy is effective for decreasing runoff and drainage losses of FDE nutrients; however, a compromise is that ammonia (NH_3) can be volatilised from the stored FDE. Lowering of the pH of FDE increases the ratio of ammonium (NH_4^+) to NH_3; further lowering of the pH can also impair microbial and enzyme (e.g. urease) activity which decrease the quantity of NH_3 available for volatilisation

In a trial commissioned by MPI and Ballance Agri-Nutrients, the effectiveness of adding sulphuric acid to fresh dairy effluent for preserving nitrogen (N) during storage was determined. Acidified (pH 2.5, 5.0, 5.5 and 6.0) and control effluent (pH 7.8) were placed in open containers, outdoors, undercover, in early autumn. At regular intervals during the 81 day trial period, the effluents were stirred and samples collected and analysed for pH and N fractions.

During the trial the effluent total N decreased in all treatments, the largest loss was observed from the control treatment (62%) at day 81, as the effluent pH lowered, the magnitude of N losses decreased, the statistically different losses ranged from 14 to 59% in acidified effluents in comparison.

The trial showed that the pH of the effluents adjusted to 5.0, 5.5 and 6.0, rapidly increased to that observed in the control. Frequent addition of acid to maintain a lower pH may be more effective for controlling N loss.

However, the effluent acidified to pH 2.5 behaved differently. It appeared to adsorb NH_3 lost from the other treatments giving an increase in measured total N over the first 40 days. Also urea, which was hydrolysed almost immediately in other treatments, remained until day 56; this led to a slower rise in pH and NH_4^+ levels and greatly reduced overall NH_3 volatilisation. These factors combined to make effluent adjusted to pH 2.5 retain much more N than the other rates.

GREENHOUSE GAS EMISSIONS FROM SOLID DAIRY MANURE DURING STORAGE AND FOLLOWING LAND APPLICATION

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Wintering dairy cows in animal shelters is becoming more common. This is particularly apparent in southern New Zealand where the main alternative is winter foraging of brassica crops, a practice associated with high N leaching loss and soil structural damage.

Information on greenhouse gas (GHG) emissions associated with manure storage and land application in New Zealand is extremely limited. Therefore, we conducted a study to quantify greenhouse gas (GHG) emissions (nitrous oxide, N_2O; methane, CH_4) and ammonia, NH_3, an indirect source of N_2O emissions, from storage and land application of dairy manures collected during winter housing in southern New Zealand.

Following the end of the wintering period (generally mid-late August), manure is typically stored on-farm for *ca* 2 months prior to being applied to land in late October. However, a small proportion of farmers will store manures for up to 5 months. We collected manures from three storage facilities on commercial dairy farms and measured gaseous emissions over 1, 2 and 5 months' storage. Storage facilities included (i) the bunker of a wintering barn with slatted-floor (bunker), floor of a deep litter barn (deep litter), and the solid fraction of a weeping wall system (weeping wall). We also quantified GHG emissions from two manure types (bunker and weeping wall) following its application to pasture at three rates (1.5, 3.0 and 4.5 t dry weight/ha).

STRATEGIC CAPTURE OF EFFLUENT TO REDUCE N LEACHING ON DAIRY FARMS WITH FREE DRAINING SOILS: ASSESSING IMPLICATIONS FOR EFFLUENT MANAGEMENT AND COST

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Standing cows off pasture is a practice dairy farmers use, particularly on poorly drained soils, to reduce treading damage to pastures and/or reduce losses of nutrients and contaminants in surface runoff and drainage. Wet soil conditions prone to treading damage mostly occur in winter and spring, whereas, summer and autumn are the most effective seasons to stand cows off pasture to reduce nitrogen (N) leaching. Adopting greater standoff increases the cost (capital and maintenance) of standoff facilities and creates new management challenges, particularly in effluent management.

In catchments with N leaching limits, farms on free draining soils have the same imperative to reduce N leaching as those on poorly drained soils, but treading damage is not nearly as critical. The requirement to stand cows off will, therefore, be mostly confined to the summer/autumn period. This raises the interesting question as to whether relatively low cost modifications could be made to an existing feedpad to allow greater standoff of cows later in the lactation season to adequately mitigate N leaching. To evaluate the feasibility of such a change, it will be important to assess the implications for effluent management and cost, particularly capital cost.

This paper explores the potential to retro-fit free-stalls to a dairy farm's existing uncovered feedpad, to allow cows to be stood off pasture for longer periods in summer and autumn. A farm in an Upper Manawatu River catchment within the Tararua District was selected for this assessment. OVERSEER® was used to estimate the likely reduction in N leaching as a result of standing cows off. With the increased time cows spend on the modified feedpad, more effluent will be captured. A number of tools (Effluent Storage Calculator, Effluent System Comparison Framework) were used to investigate the options and issues associated with the management of the extra effluent generated. Finally, the costs of this initiative are considered.

CHARACTERISING A FIELD METHANE OXIDATION BIOFILTER – TREATING FARM CH_4 EMISSIONS FROM MASSEY NO. 4 DAIRY POND

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The potent greenhouse gas, methane (CH_4) is produced by the anaerobic decomposition of manure when stored in anaerobic lagoons, liquid systems or pits. When left untreated, methane emissions from New Zealand dairy effluent ponds escape to the atmosphere, contributing to the greenhouse gas effect. Soil biofilters seeded with CH_4 eating bacteria (methanotrophs) are one of the biotechnologies studied worldwide to mitigate CH_4 emissions from various land-based sources, viz. landfill, coalmines, wetlands, rice fields, and anaerobic ponds. This study builds on the findings of Pratt *et al.* (2012), demonstrating the high CH_4 removal efficiency of the field soil biofilter operating at Massey No. 4 dairy farm pond, Palmerston North. As CH_4 removal is a biological process, methanotroph abundance and diversity in the biofilter and at different stages of its operation were studied for 3 months using the molecular biology technique – quantitative polymerase chain reaction (qPCR). Biofilter parameters like moisture content, pH, microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) were also studied. Results reveal that both type I and type II methanotrophs are present across the biofilter, but type I methanotrophs were dominant, along with the type X subgroup – methylocapsa. Other subgroups – methylococcus and the methylobacter / methylomonas / methylomicrobium / methylosarcina group – were least dominant, as indicated by the gene copy number. The acidic environment of the biofilter tends to influence the operation of the biofilter by changing the dynamics of the methanotroph population. The maximum CH_4 removal rate achieved at the end of 11 weeks of study was 24.9 g/m^3 h, which is 35% more than earlier reported by Pratt *et al.* (2012). This experimental study is ongoing and the final results will be presented at the FLRC workshop. This study has characterised the methanotroph population dynamics in the biofilter by demonstrating 1) how CH_4 and O_2 affect the methanotroph abundance across the length of the biofilter, and 2) the effect of the acidic environment on active and inactive populations of methanotrophs. These results will facilitate effective biofiltration of CH_4 emissions from dairy effluent ponds with minimum maintenance and at low cost.

A METHOD FOR MEASURING THE EFFECT OF DAIRY AND DRYSTOCK GRAZED PASTURES ON SOIL CARBON STOCKS

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Soil is the largest terrestrial store of carbon (C) with some 2000 Pg to a depth of 1 m compared to 500 Pg in the atmosphere. The Intergovernmental Panel on Climate Change recommends that C stocks be measured using the depth based approach where the C stock (tC. ha^{-1}) is the product of sample depth (m), bulk density (t.m^{-3}) and percent C. However, soil properties such as bulk density may vary spatially and temporally in response to land use change and management practices. For greater accuracy in determining the effects of land use change on soil C, a mass based coring approach coupled to equivalent soil mass calculations (ESM) of soil C stocks may be more accurate as it accounts for differences in bulk density.

Barnett et al. (2014, Agriculture, Ecosystems & Environment 185, 34-40) used a paired pit approach to sample 25 adjacent dairy and drystock pastures to a fixed depth of 0.6 m and showed that drystock grazed soils had about 8.6 t.ha^{-1} more C in the top soil than adjacent dairy sites ($P<0.05$). However, there was no significant difference between land uses when C was accumulated to 0.6 m.

Our objective was to test a more accurate method for estimating C stocks between dairy and drystock grazed pastures. We resampled the paired dairy and drystock sites to a depth of 0.6 m by taking 5 soil cores from each of two plots (5x5 m) within a paddock of each land use. Soil C was measured using an Elementar (Isoprime 100 analyser) on bulked soil samples from each plot in depth intervals (0-10, 10-25, 25-40, 40-60 and 60-65 cm) and total C stocks were calculated using ESM. Such an approach takes into account the inherent spatial variability in C stocks, thus giving a more accurate estimation of the field mean and increasing the power to detect small differences in C stocks between land uses. Furthermore, C stocks can be estimated efficiently and cost effectively which is important for C monitoring and accounting purposes.

COMPARATIVE ROOT C INPUTS UNDER A MIXED SWARD AND CONVENTIONAL RYEGRASS/CLOVER PASTURE

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There is significant interest in the potential for roots to increase soil carbon (C) under pastures. Roots are considered to contribute more to soil C and subsequent stabilisation than inputs of above-ground plant biomass. Therefore, increasing root biomass or depth distribution of roots in the soil profile are potential strategies for increasing soil C.

New Zealand agriculture is dominated by a ryegrass-clover based pasture, which is typically shallow rooting. Mixed sward pastures (including species such as chicory, lucerne and plantain) have more species than conventional ryegrass-clover swards. Increasing species richness may increase biomass and rooting depth, which could increase C inputs to soil. However, little is known about the rooting characteristics of these mixed swards in comparison to traditional ryegrass clover swards. Our objective was to determine whether mixed swards had greater root biomass, rooting depths, and annual inputs of C to soil than a conventional ryegrass-clover pasture.

We sampled root biomass (to 30 cm) in mixed sward and ryegrass-clover paddocks (n=6) at DairyNZ Scott farm four times through a year. There was greater root biomass under mixed pastures compared to ryegrass-clover for all seasons with an average difference of 980, 1700, 700, 3700 kg/ha root biomass (autumn, winter, spring, summer) to 30 cm depth. Root biomass in the 10-20 and 20-30 cm depth fractions was significantly greater (p<0.05) under mixed swards compared to ryegrass-clover swards with an annual difference of 650 kg/ha and 300 kg/ha root biomass respectively. The 0-10 cm depth was not significantly different, except for in summer when there was 2000 kg/ha more root biomass under the mixed sward.

In addition, using the observed seasonal root biomass changes, root turnover was predicted to be greater under the mixed sward pastures with a difference in inputs to soil of 2117 kg dry matter/ha root biomass (847 kg/ha C). However, ryegrass-clover swards had a greater root surface area, specific root length and lower mean root diameter than the mixed swards. These root parameters need to be considered along with total biomass when estimating C stabilisation in soil and are currently under investigation.

TEMPERATURE INDEPENDENT ANAEROBIC DIGESTION IN NEW ZEALAND DAIRY FARM EFFLUENT PONDS

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In the medium term effluent storage ponds for deferred effluent irrigation will become a near universal feature on New Zealand dairy farms. The adoption of these ponds is driven by increasingly tightening regulation, aimed at protecting ground and surface water resources by deferring the land application of dairy farm effluent to times of optimum soil and weather conditions that help to minimize issues such as run-off and leaching. In effluent storage ponds, as well as in more traditional treatment ponds, anaerobic conditions prevail, causing the production and release of biogas. Uncontrolled biogas release leads to secondary environmental problems such as local odour impact, while the biogas methane contributes to dairy farm GHG emissions. Past research has shown that low anaerobic digestion temperatures can to some extent be compensated for by longer hydraulic retention times and lower organic loading rates, to achieve near equal biogas methane yields compared to higher digestion temperatures. Data from 2 years of monitoring biogas production and pond temperatures in effluent storage and treatment ponds at 6 farms located in Northland, Waikato and Southland were analysed to determine if under typical New Zealand field conditions pond temperature has a limiting effect on biogas methane production. The results indicate that on an annual basis pond temperature does not appear to be limiting biogas methane production. This appears to be due to a combination of factors, including typical dairy farm ponds not being loaded with solids during the coldest months of the year (dry season), the ability of ponds to retain undigested solids and low loading rates that prevent excessive acidification (over loading) of ponds during the coldest time of the year. The conclusions that can be drawn from these observations are two-fold. Firstly, low temperatures do not appear to be limiting dairy farm manure management methane GHG emissions under typical NZ field conditions, including in the coldest dairy farming regions of the country. Secondly, the non-limiting nature of temperature for anaerobic digestion in dairy farm effluent ponds under New Zealand field conditions would allow for the widespread adoption of simple and low-tech biogas recovery and use technology in all regions of the country. This would not only mitigate issues of dairy farm effluent odour and GHG emission, but biogas technology could also make dairy farms more energy self-sufficient, provide energy security and help to contain increasing on-farm energy costs.

USING AN ECOSYSTEM SERVICES APPROACH TO ASSESS THE COST OF SOIL EROSION AND HOLISTIC VALUE OF SOIL CONSERVATION IN HILL COUNTRY

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Resource management in many countries is looking more closely at an ecosystem services approach to inform policy makers and the community.

This paper describes a methodology to operationalize a natural capital-ecosystem service framework to quantify and value the ecosystem services lost from a sheep and beef grazed pasture following a land slide; characterise the recovery of the provision of ecosystem services in the years following the land slide and to quantify and value the services from a grazed pasture following the introduction of wide-spaced trees as part of a soil conservation scheme to limit erosion.

This provides new information to inform benefit cost analysis of the wide-spaced tree soil conservation practice, as an ecological infrastructure investment.

The total value of the ecosystem services provided by a grazed sheep and beef pasture was for uneroded flat and rolling land $5,085/ha/yr and $3,717/ha/yr for uneroded steep land. Following an erosion event, the total value of the services provided by the steep land dropped by 64%. Recovery of ecosystems services after the erosion event was slow. After 50 years recovery was at approximately 61% (in dollar value) of the uneroded land. Planting conservation trees to reduce the risk of soil erosion increased the total value of the services of the resulting tree-pasture system by 23%, 20 years after planting.

A traditional cost benefit analysis of soil conservation shows planting trees isn't profitable unless the trees are harvested for timber, and low discount rate (<5%) is used. However, when considering the value of the extra provision of ecosystem services provided by the trees, in addition to the reduced risk of soil erosion, the Net Present Value of the investment is greatly positive regardless of the discount rate (0-10%).

This study addresses a real conservation issue and shows how an ecosystem services approach can be integrated to advance existing governance frameworks and to provide a more complete economic analysis for decision makers.

DEVELOPMENTS IN EROSION AND SEDIMENT MODELLING IN NEW ZEALAND

John Dymond, Les Basher, Chris Phillips, Mike Marden, Harley Betts, Alex Herzig

Landcare Research

New Zealand is characterised by erosion rates that are naturally high but are also exacerbated by land use. The sediment that is produced is often regarded as a key environmental stressor on freshwater and marine ecosystems. Models have been developed to assess erosion rates and to predict sediment yield. Many of these tools have limitations that limit their application for operational purposes and local to regional scale policy guidance.

SednetNZ is being developed to provide a model with better erosion process representation than a number of existing models such as SPARROW (Elliot et al. 2008), the Suspended Sediment Yield Estimator (Hicks et al. 2011), NZeem (Dymond et al. 2010), and the Highly Erodible Land Model (Dymond et al. 2008).

In this paper we compare a range of existing models, describe their limitations, outline where they have particular benefit, and update where development of SednetNZ is at with reference to some recent case studies.

WINTERING CATTLE IN HILL COUNTRY: MONITORING THE IMPACTS ON THE SOIL RESOURCE

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Cold and wet conditions in winter and spring are a challenge to winter management of beef cattle in hill country. In these landscapes, cattle are generally at liberty to roam across large paddocks when soils are wet. While the effect of treading damage by cattle on hill country soils and pasture has been studied at the small scale, there have been relatively few attempts to quantify the extent of soil and pasture damage at the paddock scale or to relate the extent of this damage to cattle movement and behaviour. In turn, cattle traffic patterns may be explained by reference to differences in micro-climate in hill country. A major research initiative has been established at Massey University's Tuapaka farm to the study effects of wintering cattle on soils, pasture and water quality.

Typical hill country paddocks are large and are comprised of a complex range of slopes, soil types and micro-climates. This scale and complexity makes it difficult to measure, monitor and record these variables, particularly with regard to their effect on cattle movement and the extent of treading damage. At Tuapaka, remote sensing technologies are being employed to provide spatial and temporal information to assist in the definition and characterisation of the variables associated with soil damage by cattle grazing in hill country. These include tracking cattle movement with GPS collars and the mapping of damaged areas using GPS units. Furthermore, LIDAR data for the study site has been procured. Information from these sources may be integrated to give a detailed picture of soil treading damage at the paddock and farm scale. Results for the first two years of the trial will be reported.

PRELIMINARY FINDINGS ON THE EFFECT OF TREADING DAMAGE AND URINE APPLICATION ON N LOSSES IN MANAWATU HILL COUNTRY

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Hill country represents an important pasture base for sheep and beef grazing in New Zealand. Due to steep terrain, exposed slopes and sometimes fragile soils, traditional beef breeding and bull beef production can create significant areas of tread damaged soils with reduced pasture cover. In 2012, the extent of animal treading damage at the study location was mapped as part of an associated study. On average, approximately 43% of the 2 paddocks mapped, had varying degrees of treading damage. Animal treading can impact on nutrient transformations within soil and little is known about the quantitative impact of animal treading on soil N transformations, N uptake by pasture and N leaching in this steep hill country.

Animal treading commonly reduces the macroporosity of soils, affecting a plant's ability to take up water and nutrients and reducing plant growth. Reduced plant growth is likely to lead to a build-up of soil nitrate and ammonium concentrations. However, denitrification and nitrous oxide emissions have been shown to increase following treading and compaction in New Zealand lowland soils (Menneer *et al.* 2005; Bhandral *et al.* 2007). Elevated soil nitrate and ammonium concentrations due to reduced N demand by pasture, decreases in soil aeration and elevated soil water content are the likely reasons for higher denitrification rates. In addition, the concentrated deposition of urine is likely to increase denitrification rates due to increased soil nitrate concentrations. These processes are important as enhanced denitrification rates may lead to a reduction in soil nitrate concentrations and a lower risk of nitrate leaching. The physical damage cause by treading is likely to reduce water infiltration rate and could also lead to decreased nitrate leaching. However, to our knowledge, the effect of treading damage on nitrate leaching has not been widely studied. This paper presents a preliminary examination of the effect of urine application and treading damage on denitrification and nitrate leaching on a hill country soil in the Manawatu region.

ASSESSMENT OF DENITRIFICATION POTENTIALS OF GRAZED PASTURE SOILS

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In pasture systems, grazed by dairy and beef cattle, large fluxes of both urine N and C occur in the soil associated with urine patches. Various field and lysimeter studies have shown that urine patches enriched in N, whilst covering only 30% of the grazing area per annum are estimated to create 50% of the pasture growth, 50% of the N leached and 68 % of the N lost to the atmosphere by volatilisation (55%) and denitrification (13%). Leaching losses of NO_3-N to water and incomplete denitrification releasing N_2O-N to atmosphere impact adversely on the environment. Complete denitrification under soil conditions where micro-organisms can create low redox potential has the potential to reduce both nitrate leaching to waterways and greenhouse gas emissions.

Our knowledge of the spatial distribution of highly denitrifying conditions in soils is limited, and would be improved by extensive field surveys. One limiting factor constraining the extent of field surveys is the lack of a rapid technique to assess denitrification activity and potential for a soil horizon.

This paper summarizes field work undertaken to evaluate whether soil Vis-NIR spectroscopy can be used to predict both denitrification activity and potential activity.

MEASURING DENITRIFICATION IN THE SUBSURFACE ENVIRONMENT OF MANAWATU RIVER CATCHMENT

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Denitrification is an important nitrate (NO_3^-) attenuation process in soil-water systems. A sound understanding of this process will aid in the management and mitigation of the impacts of NO_3^- on groundwater and surface water quality. Denitrification in surface soils has been widely studied, but there are relatively few studies of its occurrence and distribution in the subsurface environment, particularly in the Manawatu River catchment, New Zealand. Challenges around the measurement of denitrification in the subsurface environment is one of the reasons that there has been limited research in this important area. Acetylene inhibition (AI) is a commonly employed method to measure denitrification in soil-water systems. However, subsurface denitrification studies using the AI method vary in methodological details, and this variation has implications for the reliability and comparability of results.

An experimental site was established at Massey University's No. 1 Dairy Farm to determine appropriate procedures for measuring denitrifying enzyme activity (DEA) in the subsoil, and to examine the ability of the 'push-pull' method to quantify denitrification in shallow groundwater in the Manawatu River catchment. Two laboratory incubation techniques, flask and vacuum bag incubation, were evaluated for their ability to measure DEA in subsoil samples (depth: 0-200 cm bgl). A single-well, 'push-pull' test was conducted on a piezometer (depth: 6.5 m bgl) to measure denitrification rate in the shallow groundwater. Preliminary results suggest that the DEA measurements for subsoils may require more nitrate input than what is commonly added in incubations with surface soils. Initial results from the 'push-pull' experiment indicate the occurrence of denitrification in shallow groundwater at the test site. This is shown by a higher nitrate loss than can be attributed to dilution and dispersion, coupled with the increasing N_2O concentration, and existence of favourable environmental conditions in the saturated zone.

While it is apparent that DEA assays for subsurface soils require standardisation, this study demonstrates the usefulness of the AI method as a simple and economical method to measure denitrification in the subsurface environment. The methods developed here are being used to measure denitrification in the vadose and saturated zones at other selected sites in Manawatu River catchment. These measurements are being conducted as part of a wider research programme by Massey University Institute of Agriculture and Environment and Horizons Regional Council to investigate the transport and fate of nitrogen from farms to the waterways in the catchment.

EARTHWORMS IN SHEEP-GRAZED PASTURES

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Earthworms beneficial to New Zealand pasture agriculture are all exotic, having arrived accidentally with the first European settlers. Today the distribution of earthworms and their three functional groups (epigeic, endogeic and anecic) remains patchy and it is estimated that up to 6.5 million ha of pastures in New Zealand, may benefit from the introduction of the deep burrowing, anecic earthworms. The two types of surface active earthworms (epigeic and endogeic) are reasonably widespread and abundant. This study explores the distribution of all earthworm functional groups from existing studies in sheep-grazed pastures and looks at what soil functions they contribute to.

Earthworm functional diversity is found to be low in sampled sheep-grazed pastures, with anecic earthworms often absent. Pasture conditions in hill-country pastures are generally suitable for anecic earthworms and it is likely that the anecic earthworms are often absent from hill-country pastures because they have not yet reached these pastures. In pastures where the anecic earthworm, *A. longa*, has been introduced initial rates of spread are less than 4 m annually, with rates of spread reaching 12.5 m/year as the time since introduction increases.

The presence of all three earthworm functional groups present in a pasture improves the functioning of the soil. This is reflected in greater amounts of organic matter incorporated from the soil surface to depth in the soil, also increasing the availability of nitrogen to plants. The presence of anecic earthworms moderates the nitrous oxide emissions generated by the surface active epigeic earthworms, reflecting in part differences in pore structure. Anecic earthworms have more continuous and deeper burrows to aid preferential flow in comparison to endogeic earthworms, and a study found gas diffusion to be most efficient when both endogeic and anecic earthworms were present. All this would explain the increased pasture growth during autumn when anecic earthworms were introduced into pastures already containing surface active epigeic and endogeic earthworms. There is also evidence to suggest that with all three functional groups present, soils and pastures are more resilient to treading pressure and extremes of climate.

Anecic earthworms while absent from many sheep-grazed pastures are easy to establish. A fully functional soil should contain all three types of earthworms for sustained production throughout the year. To gain a better understanding of earthworm functional diversity a comprehensive nationwide survey is required, along with more research on their contribution to soil ecosystem services.

OCCURRENCE OF SOIL WATER REPELLENCY IN NORTH AND SOUTH ISLAND UNDER PASTURE

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Soil water repellency (SWR) has been reported worldwide in diverse soils and climatic conditions ranging from pastoral and cropping systems to natural forests. Several studies reported SWR in New Zealand, but its spatial extent in pastoral systems has not been studied. Therefore, we conducted a survey on the occurrence of SWR in the top 4 cm of soils under pasture across New Zealand. We hypothesised that SWR is influenced by soil order and climatic factors such as drought proneness of top-soils and summer rainfall. Our sampling sites represented a combination of eleven major soil orders of New Zealand, six classes of drought proneness and three summer rainfall classes resulting in a total of 76 sampling sites. We found at least a moderate persistence of SWR in 47 out of 76 sites (62%) at field moist conditions and a moderate potential persistence of SWR in 67 out of 76 sites (88%) after air drying the soils. Both the degree and persistence of SWR were greatest for the soil orders Podzol and Organic, followed by Recent and Pumice, and least for the soil orders Allophanic and Pallic. We also found that the summer rainfall significantly influenced the degree of SWR ($P=0.004$). However, we did not observe any relationship between SWR and drought proneness. The survey indicated that the degree of SWR was positively correlated with the soil organic carbon ($R=0.49$) and nitrogen ($R=0.47$) contents, and negatively ($R=-0.5$) with bulk density. The persistence of SWR for field-fresh samples was negatively correlated with the soil water content ($R=-0.55$). We found a significantly positive relationship between the degree and potential persistence of SWR ($R=0.88$, $P<0.0001$). Soil water repellency was at least moderately persistent in a soil with a contact angle larger than about 93.6°. Hence, we propose that the critical contact angle might serve as a relatively quick and cost-effective measure for the likelihood that SWR may occur in New Zealand pastoral soils.

EFFECT AND MITIGATION OF MICRO-VARIANCE IN SOIL pH ON PASTURE YIELDS USING ALPHA®

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Micro-variance in soil pH is observed in many grazed pastures with soil pH variations of 0.5 to 1 pH units, being common. Thus the reliance on an average pH at a paddock scale may underestimate the risk to production posed by areas with low pH and associated aluminium (Al), manganese (Mn) and iron (Fe) toxicity. Application of the carboxylate co-polymer AlpHa® to reduces phytotoxic levels of Al, Mn and Fe without the adverse effects of over liming, allowing treatment of the whole paddock to maximize productivity. The significance of soil pH variability on pasture dry matter yields and the effect of AlpHa® applied at 2l /ha are examined in a greenhouse trial over the pH range of 4.8 to 5.6 in 0.2 pH unite increments.

EFFECTS OF GYPSUM ON SOIL QUALITY: PRELIMINARY RESULTS

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Gypsum (CaSO4.2H_2O) was assessed for effect on soil physical quality and earthworm levels in field conditions. While gypsum has acknowledged benefits in certain soil types such as dispersive clays and sodic soils, its soil conditioning efficacy is less established on other soils common in New Zealand. Five sites were studied for soil response to annual gypsum application over 18 months with some experiments ongoing. Each site had silt loam soil of various types and were under either apple orchard (Nelson), dairy farm (South Canterbury), mixed cropping (Central Canterbury) or vineyard (Marlborough) management. Preliminary results are presented here for impact on bulk density, soil compaction, earthworm biomass and visual soil assessment (modified VSA) of aggregation, clods and structure. These measures will be repeated after a further year and laboratory measurements of macroporosity and aggregate stability will be undertaken.

At 18 months after application, gypsum treated areas had a mean soil bulk density of 1.20 Mg/m3 compared to in control areas (p=0.012). Gypsum treated areas visual soil assessment of structure, aggregation and clods mean scores were 3.4 (out of 4 maximum soil quality), 3.3 and 3.2 compared to control soil means of 3.3 (p=0.010), 3.1 (p=0.002) and 3.0 (p=0.001). Burrowing earthworms were slightly higher in number (0.5%) in gypsum treated samples and had higher biomass (by 19.2%) but this was not statistically significant. Penetrometer measures of soil compaction were not statistically significantly different at 18 months though this may have been affected by dry conditions in the Marlborough vineyard sites. There had been statistically significant differences at the 12 month monitoring period.

Gypsum treated areas showed significant improvement in physical qualities of the non-clay and non-sodic soils studied.

OVERSEER®: TAKING IT FORWARD

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The presentation *Overseer®: Taking it Forward* will look at the changing use of Overseer® as regional councils establish regulatory frameworks to better manage water resources; outline the strategic planning process for future development of Overseer®; and provide an update on the current work priorities.

New Zealand is in a period of significant change in the way freshwater resources are managed. While farming systems continue to evolve to improve performance and efficiency, land managers are also dealing with a changing regulatory environment that looks more closely at the effects of land use on freshwater.

If Overseer® was on *Wikipedia* it would be listed as an "E-system" or software that has been written to simulate some real-world activity. According to *Wiki*, the development and evolution of this type of software follows a set of behaviours known as *Lehman's Laws*. These behaviours, not surprisingly, focus around keeping up with a changing environment. The first Law (*Continuing Change)* holds that such software must continually adapt or their utility will progressively decline.

For Overseer®, "changing environment" means the software, including its user interface, keeping up with the Joneses (or rather the Jobs) and to be fit for purpose as a tool that supports on-farm nutrient management in a more accountable regulatory environment.

Since the Overseer Owners (The Fertiliser Association of New Zealand, the Ministry for Primary Industries and AgResearch) established a formal ownership model (2009) there has been a more directed effort to prioritise the development of Overseer in this rapidly changing environment.

The new management approach included setting up a management company (Overseer Management Services Limited) and installing a General Manager to deliver a business plan and hold forums to engage on where to take this world class piece of software.

In 2014 we will establish a Stakeholder Advisory Group to provide a forum for robust discussion across all sectors and advise Owners on the strategic direction for Overseer – initially making recommendations for the Strategic Plan. A Technical Advisory Group will also be established to advise the Owners on the multi-disciplinary science and software upgrades needed.

ONE NUTRIENT BUDGET TO RULE THEM ALL
– THE OVERSEER® BEST PRACTICE DATA INPUT STANDARDS

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As was demonstrated at this Conference last year for the Lincoln University dairy farm, user selection of the input parameters can have a major effect on the estimates of nutrient cycling for the described farm systems and hence the ultimate reported estimates for all outputs, including N losses and P loss risk. The purpose of providing OVERSEER® Best practice Data Input Standards (the Standards) is to reduce inconsistencies between different users when operating OVERSEER® to model individual farm systems. The Standards were not developed to teach users how to use OVERSEER®. For any one farm, the aim is to have one base nutrient budget which best describes the way nutrients cycle into, around and out of the farm.

The Standards were developed, at the request of the OVERSEER Owners, by a group of seven technical expert users, who drew on their personal knowledge and experience plus the DairyNZ Input Protocol, the AgResearch Expert User Group Guidelines and the Waikato Regional Council Protocol for Variation 5 (West Taupo catchment). The Standards are the consensus view of the seven technical expert users. A wider stakeholder advisory group, consisting of agricultural industry (dairy, sheep and beef, arable) representatives, regional councils, the Ministry for Primary Industries, the Ministry for the Environment and Irrigation New Zealand critiqued and endorsed the Standards.

OVERSEER DATA INPUT TIMESCALES
– USING ANNUAL AND AVERAGE DATA

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Overseer Nutrient Budgets (*Overseer*) farm management input data can be obtained for individual years, while the underpinning climate databases within *Overseer* are based on long-term averages. Since *Overseer* does not restrict users to any specific combination of timescales for climate and farm management data inputs, this paper reviews the various options available, specifically in the context of nitrogen (N) loss estimates.

Use of long-term (e.g., greater than 20 years) average climate data with average ('typical') farm management input data will provide an estimate of what N loss would be in the long-term with this management and level of productivity. It fits closest to how the N model has been developed and calibrated using average N loss from experimental sites, generally 2-5 years in duration, with the long-term climate distribution pattern. However, there is no current prescription for an appropriate period for averaging farm management data.

It would be consistent with *Overseer's* framework to average a minimum of three years' annual farm management data, provided that that is combined with commensurate climate data. One individual year's output data from *Overseer* should generally not be derived using long-term average climate data because the management and productivity for a particular year will frequently not be commensurate with the average climate. For example, inputting management data for a drought year such as 2013 with long-term climate data is an extreme but useful example of such a potential mismatch that would produce erroneous estimates of nitrogen leaching for that period.

When considering the use of annual climate data, it is important to note that *Overseer* currently does not have the capability to input individual climate year characteristics for a location. The long-term average inputs can be modified to some extent by entering annual rainfall, average temperature and further modifying rainfall distribution and potential evapotranspiration through advanced options.

The over-riding consideration for choice of timescale combination for farm management and climate inputs is that it must be consistent with a commensurate realistic farm system and be appropriate to the use of the model output. Further work is required to evaluate some of the implications of data input choices.

S-MAP @ THE FARM SCALE? TOWARDS A NATIONAL PROTOCOL FOR SOIL MAPPING FOR FARM NUTRIENT BUDGETS

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Data that characterise land resources are fundamental to improving both agricultural productivity and environmental quality. Increasing agricultural productivity whilst minimising the impacts of intensive land use on fresh water is a national priority, with central and regional government policies, as well as industry initiatives, demanding quality soil information. Soil survey information has long been a key component of resource management studies at regional and national scale, but new policies and upcoming consenting requirements indicate that in coming years there will be widespread implementation of Farm Nutrient Budgets and Farm Environment Management Plans (FEMP), which will greatly increase the need for accurate farm-scale soil information. Whilst these budgets and plans are targeted at individual farms, collectively they contribute to catchment and regional objectives. Within this context it clearly makes sense to ensure that accurate farm-scale soil information is provided in a consistent and auditable manner across a catchment.

Farm-scale soil information can be sourced from site observations, chemical and physical laboratory measurements of soil samples, electro-magnetic surveys, and detailed soil survey in addition to coarse-scale land-use capability (LUC) maps. We propose a national protocol for providing farm-scale soil information. We argue that establishment of a national protocol has great advantages, providing clarity and certainty to those investing in farm-scale soil information, ensuring equitable and consistent outcomes from Farm Nutrient Budgets and FEMP, as well as making it possible to scale up farm data to catchment-level modelling.

We suggest that the S-map data and informatics system, together with the National Soils Database (NSD), is ideally structured to support farm-scale mapping that follows a national protocol, and we highlight some key development initiatives to achieve this vision. We have characterised the various methods for obtaining soil information into four quality levels, along with a description of the minimum standard for each method. Policymakers can then determine the most appropriate level that is acceptable given the context in which the soil information will be used. Freely available S-map data may be suitable for most situations, whilst intensive land use in highly sensitive catchments may require a higher level of information, such as site-specific measurements of key soil attributes.

WAIKATO SOIL WINDOWS

– TAKING S-MAP DOWN TO THE FARM

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S-map is the new national soils database that aims to provide a seamless digital 1:50,000 scale soil map coverage for New Zealand. Mapping for S-map is underway across the Waikato Region. A concurrent project, Waikato Soil Windows, has been initiated with the aim of (1) formalising soil–landscape relationships developed and used by pedologists undertaking S-map soil mapping, and (2) increasing the accessibility and uptake of soil information by land managers for farm management decision making. This paper describes how S-map information can be used to help achieve these goals. During recent S-map soil surveys in the Waipa and Upper Waikato catchments, detailed soil–landscape models have been, or are currently being, developed. Pedologists develop soil–landscape models while undertaking soil surveys to help them understand the relationships that control and explain the soil pattern within a land region. However, the models are not always explicitly communicated to the end user or other pedologists. Capturing and articulating these relationships will document the ideas used to determine soils in the landscape and will assist pedologists with further soil mapping in the future. There is growing interest in making use of the soil information contained in S-map for farm management decision making. At a scale of 1:50,000, the resolution of the spatial information in S-map may be too coarse to be useful for farm- or paddock-scale management without additional, detailed soil data (sibling data) and an understanding of the soil-landscape relationships. A well-presented and communicated soil–landscape model can be thought of as a 'window' that provides land managers with an insight into the soil pattern within a particular area. Moreover, these models (or 'soil windows') could facilitate the development of farm-scale soil maps by suitable skilled professionals that could then be linked to sibling data in S-map. The soil information held in the sibling database, captured and linked to the online 1:50,000 soil polygons during the S-map survey process, can be used at multiple scales. Greater value could potentially be derived from the sibling data if it were made more accessible to land managers. These data have multiple uses in the management of nutrients, water, effluent, cultivation, and grazing.

HOW CLUES CAN HELP IN MANAGING TO CATCHMENT NUTRIENT LIMITS

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This paper aims to show how the Catchment Land Use Environmental Sustainability (CLUES) model can be used to aid the implementation of the National Policy Statement on Freshwater Management (NPSFM). The NPSFM heralds a shift to limits-based water management whereby catchment scale objectives are set, and limits to achieve those objectives are determined. Three action points are proposed by the proposed freshwater reforms to aid implementation of the NPSFM: planning as a community; establishment of water quality objectives; and managing within water quality and quantity limits.

CLUES is a spatial decision support system which couples a number of existing models within a GIS-platform and includes a front-end interface in ArcGIS. The model and documentation can be downloaded free of charge from NIWA ftp://ftp.niwa.co.nz/clues/. Its purpose is to assess the long-term effects of rural land use change on water quality and socio-economic factors at a minimum scale of sub-catchments within the NIWA River Environment Classification. CLUES allows users to create both land use change and farm practice scenarios using a range of interactive tools. For each river reach, CLUES returns the following key annual water quality indicators: nutrient (total nitrogen and total phosphorus) yields, loads and concentrations, suspended sediment yields and loads and *E.coli* loads.

Here we discuss ways that CLUES can be used in the reforms, such as:

- As an aid to communication: The GIS platform and in-built scenario sketch tools mean that CLUES could equally be used in a public setting for collaborative planning.
- Assessment of the current state of freshwater bodies at the sub-catchment scale, for regions or specific catchments.
- CLUES can be used to help set limits which requires an understanding of contaminant sources and loading. CLUES can be applied iteratively with multiple land use and farm practice scenarios to help determine the capacity for change possible with respect to the current state. Limits to contaminant loads can be set accordingly.
- Effects of mitigation measures can be investigated.

OVERCOMING CHALLENGES IN MODELLING NUTRIENT LOSSES FROM A NON-TRADITIONAL INDOOR DAIRY PRODUCTION UNIT

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A non-traditional indoor dairy production unit is being developed in South Canterbury. The farm was previously a dryland farm. A barn will be constructed, to accommodate cows 24 hours/day (no pasture grazing during milking). For most of the year, cows will be housed within the barn and milked using a robotic-based milking platform. The cows will be fed within the barn, from crops grown on-farm (pasture, maize, lucerne) with additional feeding of imported supplementary feed.

The excreta from the barn will be scraped off floors (using automated scrapers) into a slurry storage facility and applied to land using a slurry tanker. Combined washdown water and milking area excreta will be applied to other parts of the farm using a travelling irrigator. The farm will not be irrigated with clean water.

Consents for various farm activities have been applied for. The regional council requires an Overseer based nutrient model to be produced for land use intensification. Modelling of the proposed farming operation highlighted several issues which were inconsistent with the assumptions and calculated outputs of Overseer®.

Despite having a model output that produced a 'realistic' leaching number for the total farm, it was considered the components within the modelled farm were not realistic. The solution was to develop an Overseer® model which treats the farm as a cropping farm receiving external organic fertiliser, keeping the barn operation separate to the land area used to generate the feed for the barn. The revised model examined just the paddocks, with excreta from the sheds calculated separately and applied to the cropped areas as an organic fertiliser. This strategy is consistent with that of other housed animal enterprises (poultry, piggery operations). Development of the fertiliser inputs was the key to this revised assessment.

This revised approach produced a nitrogen leaching rate which was very low when compared to typical Overseer® model outputs. When the nitrogen dynamics and flows within the proposed farming system are considered, the Overseer® output achieved appears reasonable and realistic. Utilising a very basic and conservative mass balance approach also supports the view that nitrogen leaching will be limited.

Keywords: Nitrogen, leaching, modelling, consenting.

NUTRIENT MANAGEMENT PLANNING

- A CORE STRATEGY FOR LANDCORP FARMING

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Landcorp Farming Ltd. (Landcorp) is a leading New Zealand agribusiness. Our extensive sheep and beef, deer and dairy operations are striving for best practice. Landcorp operates 137 farms encompassing 376,000 ha from Northland to Southland. We endeavour for continuous improvement in the productivity, profitability and sustainability of farming.

The reputation of New Zealand agriculture both locally and increasingly internationally is headlined by our ability to demonstrate that we can farm in our environment sustainably. The application of existing and new science are the tools to achieve sustainability.

Landcorp has developed internal process that allows us to benchmark our nutrient usage and identify nutrient inefficiencies and opportunities. The process involves both internal and external contacts including fertiliser technical field consultants, regional councils and at times external consultants.

The core of this process revolves around an annual soil testing program, followed by an annual Overseer nutrient budget completed using Landcorp internal input protocols. All farms currently have nutrient management plans which are revised every three years or when a significant farm system change occurs. These documents are supplementary components of a land and environment plan which more specifically details the land use capability and regional council requirements.

The land and environment plans are a key consideration of the business plan (revised annually) for each Landcorp farm and is deliberated at the annual fertiliser planning meeting. At the annual fertiliser planning meeting, the fertiliser company representative is present in a specialist capacity to provide further background on key points from the land and environment plan. They also ensure the nutrient policy is optimised and give overall reference to the nutrient footprint and environmental sustainability of the farm. Through this on farm process Landcorp also encourages farm managers and staff to be aware of the on farm drivers of nutrient inputs, flows and fate.

Landcorp believes that the ability of farm managers and staff to understand the concepts of farming environmentally sustainably is the key to maintaining and building our local and international reputation. A renewed focus on our environmental stewardship is a key point of our new strategic plan. We want to link the best people, science and technology to our customers.

THE FUTURE OF NZ DAIRY FARMING SYSTEMS:
SELF MANAGING COWS WITH ACCESS TO PARTIAL HOUSING

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The changes in New Zealand dairy farming systems are advancing at a great rate as farmers react from environmental and public pressure. This fundamental shift in dairying systems is being driven by leading farmers lifting milk solids (MS) production while exceeding animal welfare and environmental standards through the use of partial housing systems.

Newly designed off-paddock shelters are giving farmers far greater options in carrying capacity, grazing and effluent management.

With New Zealand's temperate climate and knowledge of pasture based grazing systems, an unique hybrid dairying system is emerging. The farming shift is related to partial housing or a 'hybrid grazing' (HG) system which combines an animal shelter with a pasture based grazing system, as opposed to the historical 'European' style barn (fully enclosed housing). A hybrid partial housing system eliminates many of the historical issues faced in the European barns which use a total mixed ration (TMR), minimal grazing system. This type of management leads to potential animal welfare issues and often comes with less profitability.

Farmers can benefit from adopting a hybrid system through pastoral, animal welfare, environmental and production improvements. Dairy farmers have begun to realise that stock will seek shelter if given a choice. Allowing cows to do so, reduces lameness, lessons animal maintenance energy requirements (from temperature stress), decreases soil damage and lowers environmental impacts.

The public is becoming more and more aware of where food is coming from. As New Zealand's primary industry, dairying standards need to be superior. Export markets and the urban population will continue to demand improvements on farm systems. Consumers expect a high quality products from an environmentally and animal friendly agricultural industry. These HG systems are already exceeding standards in this area.

EFFECT OF FREE STALL BED TYPE ON BED UPTAKE, LYING TIME AND DAILY BEHAVIOUR PATTERN OF DAIRY CATTLE COMPARED WITH CATTLE AT GRAZED PASTURE

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This research aimed to compare the effects of differing types of free stall beds on the acceptance and lying time of dairy cattle and compare these with animals grazed at pasture. Three groups of 12 adult, dry dairy cattle, which were of similar age, live weight and condition score were used in the study. One group (G) were grazed at pasture, except for two periods (each 2h) per day when they were placed on a concrete pad to simulate milking. Two groups were grazed at pasture for 4 h / d, stood on concrete pad for two periods (each 2h) per day to simulate milking and housed in freestalls (13 each) for 16 h overnight. Initially, all the stalls were fitted with sand beds to acclimatise the cows to lying in stalls. Then all the stalls were fitted with partially covered sand beds (S), followed by dual chamber water beds (W) and finally mattresses (M). The initial period of sand stalls was followed by each bed type in a Latin changeover design. Cows were housed on each bed type for 7 days followed by 5 d rest period on pasture. During the training period all cows quickly adapted to lying in deep litter sand beds despite not having used freestalls or housing previously (0.61 (0.05) days). All bed types were acceptable to cows resulting in similar lying times, with the exception of water beds, on which cows lay for significantly less time.. Cows housed on sand beds lay for similar periods as grazed cows (Lying: 11.1; S: 11.1; W: 9.9 (0.71) h/d). Cows housed on water beds lay for significantly less time and spent more time lying and standing in the ally, and often stood half in the beds. More cows housed on water beds chose to lie in the alley (3) compared with cows housed on sand beds (0).

RESTRICTED GRAZING OF WET SOILS:
FROM CONCEPT TO SYSTEM

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Intensive grazing by cattle on wet soil can have a negative effect on soil physical quality and pasture production. Damage generally occurs when soils are wet, due to the lowered bearing strength. Soil pugging usually causes direct damage to the pasture sward, while soil compaction impacts on several soil functions, including transportation and storage of air, water and nutrients, which in turn may lead to reductions in pasture production.

The Proctor compaction test has been used to identify a critical soil moisture content (CMC) beyond which soil structure will be damaged in response to a known force, such as a cow hoof. At 2 sites we assessed whether implementation of a farm management approach, termed 'restricted grazing', in which dairy cattle grazing was restricted when soil moisture content exceeded the CMC, improved pasture production and soil structure. At the North Otago study site, experimental plots (10 m x 25 m) were monitored for three years to assess the direct effect of a restricted grazing regime on soil structure and pasture production. A similar management strategy was employed on a dairy farm in South Otago to assess the implications of a restricted grazing management regime on the whole farm system, i.e. including effluent management, feed supply and general practicality. Although the two study sites have a similar soil type, the climate and landscape varies considerably. Here we critically assess the benefits and challenges of such management practices using results and practical considerations obtained from both sites.

DURATION-CONTROLLED GRAZING ON DAIRY FARMS: DECISION SUPPORT FOR TIMING OF SLURRY RE-APPLICATION

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Duration-controlled (*DC*) grazing management, which involves standing cows off pasture to ruminate and rest rather than allowing them to remain in the paddock after grazing, is able to decrease the amount of nitrate-nitrogen leached from grazed dairy pastures by more than 50%. The standoff facility employed by the *DC* system will accumulate on average 167 kg N/ha/yr in dung and urine, which requires uniform reapplication to the farm as slurry. The nutrient content of the slurry varies with the nature of the standoff facility (roofed or un-roofed), the cows diet, and whether standoff slurry and farm dairy effluent are combined, or stored separately. The variables interacting to influence slurry volume, nutrient concentration and the rate and timing of reapplication are complex. Decision support software is required to plan and implement the most cost effective slurry treatment systems. In addition, the software should assist timing of slurry reapplication to maximise its fertiliser value and minimise any adverse effects, such as runoff. In this paper, we model the rate of accumulation and nutrient concentration of slurry generated in a freestall barn. The requirements for slurry storage are also modelled based on rates of slurry generation and the timing of soil moisture-limited, slurry re-application. Secondly, the growth response caused by slurry reapplication to *DC* managed pastures is reviewed by examining 5 years of plot trial data.

IDENTIFYING OPPORTUNITIES TO REDUCE N LEACHING WHILE MAINTAINING FARM PROFITABILITY AND MILKSOLIDS PRODUCTION - A CASE STUDY ANALYSIS

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Current environmental objectives in some catchments in New Zealand require a reduction in nitrogen leaching per hectare (kgN/ha). Ideally this would be achieved with minimal impact on profitability or milk solids production so that farm businesses and regional communities can be sustained. A recent Nimmo Bell report undertaken for the horizons catchment suggested that an 18% reduction in N leaching/ha through optimising the use of existing resources (within-system focus) would best align environmental, farm and community objectives.

The analysis reported here was undertaken to identify opportunities to reduce N leaching/ha while maintaining current levels of milksolids production and farm profitability. Three case study farms in the Lower North Island were simulated using Overseer v6 and Farmax models. Mitigation options assessed included reducing the amount of imported feed and/or N fertiliser use, increasing effluent application areas, removing winter forage crops, grazing cow's off-farm in winter, and standing cows off in the autumn. Current management practices along with the farm production system, infrastructure, stocking rate and farmer goals had a large impact on the most suitable approach to achieving a reduction in N leached for individual farms.

Predicted reductions in N leaching/ha were 16%, 25% and 21% for farms A, B and C, respectively, without negative impacts on existing levels of farm profitability or milksolids production. Options varied between farms and were selected to meet farmer and environmental objectives for each property. The option selected for farm A was to reduce N fertiliser and supplement use and reduce cow numbers slightly to offset the change in feed supply. For farm B, a reduction in cow numbers with an increase in milksolids/cow was considered the best approach. For farm C the exclusion of a winter oats crop, increase in the number of cows wintered off and a slight increase in cow numbers was considered the best option to meet the objectives.

Moderate reductions in N leached are possible without large negative impacts on current levels of milksolids production and financial performance if the use of existing resources on farms is optimised. Larger system changes such as large reductions in stocking rate, eliminating N fertiliser use and substantial infrastructural changes have a detrimental impact on the financial indicators of farm businesses and introduce additional risk. The environmental and financial impact of different mitigation options varied between farms highlighting the requirement for individual farm analysis. It also emphasised the benefit of a detailed discussion on mitigation options with farmers to identify wider management considerations of implementing changes.

A FARM SYSTEMS PERSPECTIVE ON SENSIBLE OPTIONS FOR REDUCING NITROGEN (N) LOSS FROM DAIRY FARMS USING INDICATORS RELATED TO N SURPLUS AND N CONVERSION EFFICIENCY

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Recommendations for dairy farms aimed at reducing nitrogen (N) loss require thorough analysis of their impact on the whole farm system, and not just their likely impact on single Overseer indicators. By not considering the impact of a change on other aspects of the system, there is a risk of recommendations leading to reduced profit, and increased financial risk for farmers with no reduction of N leaching. A common example is a simple recommendation to lower the protein (N content) of a herd's diet by increased feeding of maize silage to improve a farm's N conversion efficiency (or reduce milk urea). Scenarios will be provided where increased maize silage feeding, could have the undesirable effect of increasing a farm's N surplus and N leaching. An important consideration for the impact of any recommendation is whether it involves significant change to the farm system (e.g. increased total feed supply, herd size or additional infrastructure), as opposed to improved efficiency within the existing system.

The concept of efficiency, such as the N Conversion Efficiency (NCE) measure reported in Overseer is useful for determining how all external N inputs (fertiliser and supplements) are used to produce milksolids, but NCE is not always well correlated with N leaching. For example, a farm producing 1500 kg MS/ha, using 5 t DM/ha of maize silage, increases its MS/ha to 2900 kg MS/ha by increasing maize silage use to 20 t DM/ha. NCE improves from 34 to 37 % , an apparently desirable result. The reality is that the farm N surplus /ha has increased from 212 to 351 kg N/ha and N leaching from 48 to 113 kg N/ha. This change will have required significant investment in livestock and infrastructure, as well as increased the farms risk to costs associated with feeding, and fluctuations in milk price.

In this paper a process and useful measures are outlined by which farmers and their advisors can assess recommendations for reduced N leaching against overall farm performance and efficiency and tailor these to meet goals of continued business viability and improved water quality in their region.

EFFECT OF URINE AND POTASSIUM APPLICATION ON PASTURE PRODUCTION FROM A DICYANDIAMIDE-TREATED FREE-DRAINING CANTERBURY DAIRY PASTURE SOIL

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A cut-and-carry trial was conducted on a low quick-test-potassium (QTK ≤4) Lismore soil during 2012-13 in Springston, Canterbury to test the responsiveness of a dairy pasture to urine, dicyandiamide (DCD) and potassium (K) applications. Over the full year, the applications of urine-only, urine+K, urine+DCD, and urine+DCD+K increased pasture production significantly over the non-urine control treatment by 23%, 29%, 36% and 42%, respectively. Applications of K, DCD and DCD+K significantly increased production over the urine-only treatments by 5%, 10% and 15%, respectively, for both spring and full-year totals. There was only one significant interaction for total DM overall (urine x DCD) with no significant increases to K or DCD applications for non-urine treatments.

The pasture responses to K and DCD applications were attributable to maintaining better balanced plant nutrition, rather than to soil K deficiency per se, as urine application maintained QTK levels to recommended values for the duration of the trial. Whilst these differences were considered to have their roots, at least partly, in K nutrition, it may also reflect differences that are particular to cut-and-carry trial management and measurement where large off-takes of nutrients in harvests can indirectly influence treatment responses. A relative absence of clover meant that this pasture fraction was not a major contributor to the response. The findings of this trial show that regular K application increased pasture DM responses to the N retained in soil by the use of a nitrification inhibitor (DCD) even when soil K levels were considered adequate.

EFFECT OF APPLICATION TIMES OF UREASE INHIBITOR (AGROTAIN®) ON NH_3 EMISSIONS FROM URINE PATCHES

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In grazed pastures about 80% of urine N in the form of urea is rapidly hydrolysed and is subjected to ammonia (NH_3) losses. The use of urease inhibitors (UI) has been used as a mitigation tool to decrease the rate of NH_3 volatilization from fertilizer urea and animal urine. In previous New Zealand trials the UI effect in reducing NH_3 emission from urine has been measured by applying urine mixed with the UI to the pasture soil thus increasing the chance to better inhibit the urease enzyme. However, these trials do not represent a realistic grazing scenario where only urine is deposited on to the soil.

Therefore, to determine the effect of UI Agrotain® in reducing NH_3 losses from urine deposition by grazing animals, a field experiment was carried out at Massey University dairy farm # 4 by spraying UI before or after urine application. The data on changes in NH_3 emission, soil pH and mineral-N from this experiment is processed and the results will be presented and discussed at the Workshop.

A BOUNDARY LINE APPROACH FOR ESTIMATING THE RISK OF N_2O EMISSIONS FROM SOIL PROPERTIES

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Agricultural greenhouse gas (GHG) emissions are the largest contributor to New Zealand's (NZ's) total GHG emissions. Nitrous oxide (N_2O) emissions represent approximately one-third of agricultural GHG, with animal excreta being its main source. For inventory purposes N_2O are currently estimated based on a Tier 2 methodology that employs disaggregated emissions factors (EF's) for dung and urine, with emissions from urine being greatest due to N being deposited in a readily available form. However, such EF's are insensitive to soil and climate factors that influence emissions. To reduce N_2O emissions, a better understanding of the factors driving emissions and an evaluation of mitigation strategies is required. While deterministic models can be used to evaluate how heterogeneity in climate and soil affect these emissions and identify mitigation options, site specific validation and parameterisation of such models is often lacking, limiting the accuracy of the models. An alternative is to consider empirical models, which are based on more easily available input data, as the one developed by Conen et al. (2000) for estimation of N_2O emissions. Their approach is based on a boundary line and using the soils' water filled pore space (WFPS), temperature SoilT and mineral nitrogen content (nitrate and ammonium). Following this approach, we determined boundary lines (or limits) for low, medium, and high N_2O emissions for two regions of NZ (Waikato and Otago), and four different soil types (Horotiu, Te Kowhai, Wingatui, and Otokia). The analysis was based on measured N_2O emissions, and modelled values of WFPS, SoilT, and soil nitrate and ammonium content using the Agricultural Production Systems Simulator (APSIM). These boundary lines were then used to estimate the likely risk of N_2O emissions throughout the year for the two different regions and four soils based on long-term modelling over a period of 20 years.

AUTOMATED N_2O/N_2 ANALYSIS – A NEW TOOL FOR STUDYING DENITRIFICATION DYNAMICS AND TESTING MITIGATION STRATEGIES

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The bulk of nitrous oxide (N_2O) from New Zealand agriculture is produced from denitrification – the four step process by which nitrate is progressively reduced to atmospheric N2 ($NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$). N_2O diffuses from the soil to the atmosphere when denitrification is incomplete and the last step of this process [$N_2O \rightarrow N_2$ (known as N_2O consumption)] does not occur. To properly understand the dynamics of N_2O emission from soil denitrification, we must not only know the rate of N_2O emission but also the rate of N_2O conversion to N_2. However, quantification of this final step is challenging due to the high background level of atmospheric N_2. We present an analytical system (unique in New Zealand and based on a Norwegian design), which quantifies N_2O consumption by directly measuring microbial production of both N_2O and N_2 using soil initially incubated in an N_2-free headspace. We simultaneously quantify the overall rate of nitrate removal together with rates N_2 to N_2O emissions to identify factors influencing the shift from N_2O production to N_2O consumption. We describe the system, which we call the Denitrification Dynamics Gas Chromatograph (DDGC), present initial results and discuss how the tool can be applied to test mitigation strategies.

OPTIMISING ABATTOIR WASTEWATER IRRIGATED SOILS AS A SINK AND SOURCE OF PHOSPHORUS FOR PLANT BIOMASS PRODUCTION, AS AFFECTED BY FLYASH APPLICATION

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Long-term discharge of abattoir wastewater can increase phosphorus (P) in soil, which may lead to loss of P and other nutrients under saturated conditions. Although some soils can retain P, the capacity of P sorption in most soils to adsorb and release P is low because of pH, since P availability to most crops requires a soil pH range of 6 to 7.5. Therefore, specific soil amendments based on pH of the native soil, such as addition of lime for acidic soils is required. Since lime application to soil involves high costs, an alternative alkaline material such as flyash (FA) is being used to improve the soil pH.

In this experiment, the biomass production of selected grass species such as napier grass (*Penisettum purpureum*), wallaby grass (*Themeda triandra*) and silky-blue grass (*Dicanthium sericeum*) were determined in abattoir wastewater irrigated soil (pH-5.25), both in presence and absence of FA. The plants were grown in plastic pots using tap water under controlled environment in a greenhouse and harvested after 60 days. Before the commencement of plant growth experiment, the abattoir wastewater irrigated soil was incubated (21 days under 80% water holding capacity) separately in the presence and absence of FA (15 % wt/wt), for each plant species. The entire experiment was conducted in triplicate.

The incubated soil was measured for changes in pH and Olsen P; the biomass was recorded from the plant growth experiment and compared between the crops in presence and absence of FA. The initial soil incubation showed that soil pH increased from 5.25 to 6.87 and the Olsen P improved from 29.12 to 94.66 mg P/kg soil. The plant growth was higher in FA amended soil compared to unamended soils. In FA amended soil, napier grass (6.14 g/pot) showed high biomass production followed by wallaby grass (4.64 g/pot) and silky-blue grass (4.59 g/pot). Hence, P in abattoir wastewater irrigated soils can be managed effectively using appropriate alkaline amendments for better soil productivity and higher biomass production.

USE OF GYPSUM TO REDUCE EFFLUENT AND FERTILISER NUTRIENT LOSSES TO WATERWAYS

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Agricultural systems are leaky and losses of phosphorus, nitrogen, organic matter and suspended solids can impact on water quality. While direct contamination of surface water can be prevented by avoiding livestock access and effluent discharge, it is less straightforward to prevent losses over and through soil that can eventually reach waterways. This is due to the complexity of hydrological and chemical factors involved.

Gypsum has long been used as a soil conditioner and fertiliser but it is comparatively recently that gypsum's potential for reducing agricultural emissions to waterways has been researched and modes of action elucidated. Gypsum ($CaSO_4.2H_2O$) can improve soil aggregation through calcium induced flocculation of particles and sulfate induced leaching of excess sodium. Such effects can reduce surface runoff volume by improving water infiltration into soil. Improved stability of aggregates reduces the potential loss of soil particles to waterways both over and through soil. The calcium ions can also increase precipitation of phosphate ions either directly as calcium phosphate or indirectly by increasing availability of aluminium ions. Increased ionic strength of soil solutions due to dissolution of gypsum may also increase adsorption of phosphate ions and organic matter to soil particles. These multiple modes of action can thus partially address both hydrological and chemical factors influencing nutrient loss.

Gypsum application has been reported to reduce phosphorus losses by at least half in some conditions. Surface runoff of nitrogen, organic matter and soil particulates can also be reduced with gypsum as can drainage losses of nutrients in organic form. New Zealand research into the best use and conditions affecting gypsum efficacy would appear worthwhile to help mitigate agricultural impacts on waterways.

UNITED STATES EXPERIENCE OF RESEARCH AND EXTENSION ASSOCIATED WITH IMPROVING GRANULAR FERTILISER APPLICATION ON-FARM

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Environmental concerns in conjunction sustainable agricultural production in the US are requiring farmers to better manage fertilizers. In response to the environmental and sustainable movements, the fertilizer industry is promoting the 4Rs to nutrient stewardship which encompasses using the right fertilizer source, right rate, at the right time, in the right place. This concept focuses on sound fertilizer management at the farm level while providing a platform to better educate the public and government agencies. This presentation will provide a current state of nutrient management in the US, technologies providing a means to address the 4Rs, how modern application equipment can create field performance concerns, and illustrating extension or education activities helping advance farm operations. Site-specific fertility management has expanded in the US in an effort to improve nutrient use-efficiency and to address soil fertility variability. Precision agriculture technology has shown to more accurately place and ensures the right rate applied. Technologies include GNSS-based guidance, rate control and automatic section control; all affording the ability to improve application of fertilizers while minimizing or eliminating over-application (2X or 3X rate areas). However, while research has outlined the benefits of these technologies, adoption of some has been low. Crops sensors are a prime example of how research has reported advantages for management of nitrogen in corn and wheat indicting a tool for farmers to capitalize on within their operations. Costs and inexperience using precision ag technology have created hurdles for crop sensor usage in the US. Concurrent to technology adoption, size of application equipment and in-field ground speeds have both increased in the US in order to meet required timing of nutrients. While these larger equipment provide the needed field capacity (ha/hr), issues such as product segregation and limitations of rate control systems have generated off-rate errors and uneven distribution having negative consequence to crop yields. Inefficient use and inaccurate placement becomes a concern for farmers today seeking to maintain profitability and build their site-specific management programs. Therefore, extension programming is providing engagement and education activities to ensure proper implementation of nutrient practices at the farm.

THE BALLISTICS OF SEPARATION OF FERTILISER BLENDS AT WIDE BOUT WIDTHS

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In recent years some New Zealand arable farmers have experienced crop striping when spreading blended fertilisers. These farmers have not experienced the phenomenon prior to upgrading spreading equipment, capable of spreading to tram lines spaced at 30m plus. Fertiliser companies have been criticised as the blends used are no different to those used previously and in some cases have been recommended by the fertiliser companies' representatives.

Tram line spreading is generally very accurate. Spreaders are pattern type tested by manufacturers based on particle size, uniformity of particle size and bulk density, to achieve a pattern overlap which delivers the minimum spread variation possible, given the fertiliser particle parameters.

Spreading to a 30m tramline requires fertiliser particles to spread to at least 22.5m from each disc to allow for the require spread overlap, as spread overlaps of around 50% are common. To propel particles 22.5m from a height of 1.5m requires them to be despatched at around 60ms^{-1}. At these speeds blended fertilisers split as their rate of deceleration through drag force is based on particle density, size and shape in order of importance. This paper quantifies the impact of drag force on typical fertilisers and demonstrates the relationship between increasing bout widths and greater separation of blends.

In addition a twin disk arable spreader was spread-pattern tested using the New Zealand Spreadmark test with typical high analysis fertilisers. Fertiliser particles discharging from the disks were filmed using high speed photometry and ballistic modelling compared to the pattern test.

Keywords: Drag force, Ballistics, Blended fertilisers, Blend separation, in-field coefficient of variation, high speed photometry

AG HUB: AUTOMATED NUTRIENT RECORDING AND PLACEMENT FOR FERTILISER & EFFLUENT

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Ag Hub is a modular online farm management system that collects and displays automated data. Ag Hub is owned by Ballance Agri-Nutrients.

The focus of this paper are the Ag Hub Fertiliser and Effluent modules, the data that they can collect automatically and discussing the benefits of having visibility of overall macro-nutrients applied.

AgHub Fertiliser allows orders to be placed directly to spreaders. GPS proof of placement files are automatically matched back to the order in Ag Hub, and the applied date set. Nutrients applied are recorded by paddock.

AgHub Effluent receives GPS placement and pump operating times. The nutrient concentration, spreader's swathe and pump flow rates are used calculate volume and depth of applied effluent and nutrients applied. Visual proof of placement maps show the distribution of nutrients applied for season to date and the last 12 months.

AgHub Nutrient Management combines information from the effluent and fertiliser modules.

Two case studies have been used to illustrate benefits. Stated benefits include improved compliance recording, pro-active decision making and KPI monitoring. Another stated benefit is the cost saving on conventional fertiliser associated with knowing the exact nutrient value of each effluent application.

In Conclusion Ag Hub is a smart precision agriculture tool that automatically records the application of nutrients from both effluent and fertiliser. Users have found Ag Hub simple to use and to be a valuable farm management tool.

MEASUREMENT METHODS TO HELP IMPROVE PASTURE MANAGEMENT IN HILL COUNTRY

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Hill country farmers generally have less opportunity to measure and manage their pastures than their dairying counterparts. The larger areas involved make measurement a time consuming activity, less labour availability and more variable grazing conditions under set stocking make accurate measurement difficult. The work described in this paper is part of a project under P21 sponsored by Beef and Lamb to examine methods to improve the effectiveness of grazing management through pasture measurement. Both pasture mass and pasture quality are examined. The work is being carried out by AgResearch and Massey University.

The productivity of most farms is governed by a number of factors, including climate, terrain (slope aspect, soil type, soil depth etc), fertiliser history and other management practices. A GIS can be used to represent the terrain as these factors do not change but are known to effect productivity. The GIS can then be used to categorise the farm and calculate the areas under these categories. A sampling strategy can then be worked out that is representative of the farm but minimizing the amount of measurement taken. In this way it is intended to come to a compromise between time spent measuring and accuracy of information. This approach can be used to not only measure actual feed on offer but farmers could use it to record trends and validate the information against their own practical experience.

Pasture quality is also of clear importance and there is evidence that variation in quality is perhaps greater than farmers and researchers account for in making grazing and management decisions. Previously pasture quality had to be sent to a laboratory for analysis, if wet chemistry was used then the process was very time consuming which meant the measurements were of limited value because of the delay in getting the information. Laboratory based Near Infrared Spectroscopy (NIRS) techniques have been proven to be reliable and these can be completed with a faster turn over and lower cost. Within this project an NIRS system was taken out into the field to test if pasture quality could be estimated in-situ and results are reported.

FRIENDS, FOES AND FORESIGHTS IN THE NUTRIENT SUPPLY CHAIN

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In mid- 2008 the prices of urea and TSP rose by 2.6 and 3.7 times respectively while in January 2009, the price of KCl rose by 2.8 times above their respective price trend lines. These changes reflect perceived and actual confidence in the supply of these essential fertilizers.

The reliability of fertilizer supply is usually considered only in terms of the lag from production to delivery and unanticipated demands from farmers. In future, the supply of fertilizers may depend more on global events than in the past. Supply of nitrogenous fertilizers is increasing governed by the supply of natural gas as a feedstock. The supply of natural gas for fertilizer production is affected by energy demands, offshore shipment to fulfil long-term contracts and price on the world market. Use of legumes has decreased due to relatively low cost of nitrogenous fertilizers and the high value of non-leguminous crops and pastures. Should nitrogenous fertilizers become less available, then legume-N will become more significant for food security. The technology for breeding Rhizobium and legume genotypes must be maintained with emphasis on stresses induced by changing climate.

There are abundant global reserves of potassium with very large deposits in Europe, Canada and the US. Furthermore, potassium can be recovered from seawater. On the other hand, phosphate resources are more limited, many of which are in more geopolitical unstable regions. Approximately 90% of the current phosphate reserves are located in these regions. A concerted effort to improve the yield of food per unit of fertilizer P must also be a priority area for research in Australia and New Zealand.

This paper examines the risks to fertilizer supplies, resource consumption on per capita basis and economic price spikes. Preparedness is paramount.

SOIL CADMIUM – REVIEW OF RECENT DATA IN RELATION TO THE TIERED FERTILISER MANAGEMENT SYSTEM

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Accumulation of cadmium (Cd) in New Zealand agricultural soils is a known long-term management issue. This accumulation is primarily driven through the incidental application of Cd contained in phosphorus fertilisers. Consequently, to manage soil Cd accumulation, the 'Tiered Fertiliser Management System' (TFMS) which imposes increasingly stringent fertiliser management practices as soil Cd concentrations increase, is an integral part of the national Cadmium Management Strategy.

The first step for implementing the TFMS is assessing on-farm soil Cd concentrations. Engaging with farmers to provide clear, sound information and advice is critical to the uptake of the programme. Many farmers have limited understanding of Cd and testing for it introduces a cost with few immediate benefits. Increasing regulation on soil contaminants has been signalled and voluntary uptake of responsible management of soil cadmium under the TFMS is encouraged and supported.

This paper provides a summary of national soil Cd concentrations from soil test data, including that collected on-farm under the first year of the TFMS, and perspectives from farmers and fertiliser industry staff as to the implications for managing soil Cd under the TFMS. Since 2007, around 3700 soil Cd samples have been analysed which form the basis of this update on our national soil Cd status. This includes approximately 1500 samples collected under the TFMS since its inception. Soil Cd concentrations reported over this time period range from <0.01 to 2.7 ppm, with large differences apparent between soil type and land use. The majority of soil samples that make up this database have been taken to 0-75 mm, or 0-100 mm soil depth, rather than the TFMS 'definitive' 0-150 mm soil sampling depth; hence results will be biased upward. The reason for this is that the TFMS allows for 'screening' to take place using conventional, routine soil fertility assessment so as to minimise initial additional labour and sampling costs. This increases the soil cadmium dataset while providing a precautionary approach for assessment of soil cadmium levels.

HOW DO WE TRANSFORM OUR INDUSTRY TO ACHIEVE A MODERN VISION FOR NEW ZEALAND AGRICULTURE?

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There has probably never been a time when the tensions between achieving higher food production, environmental sustainability and the need to reduce risk created through increased climatic variance have been more acutely felt. Possibly the biggest challenge is to have a balanced debate about a path forward especially in relation to the expansion of intensive agriculture and its effect on the environment. In our case the most recent focus has been fresh water and the health of our river systems versus dairy farming.

Some global commentators are already predicting that we are past peak food, and there is a good deal of evidence to suggest that global food production is not keeping up with population growth. There is also evidence from around the world that policies designed to assist environmental sustainability are reducing food output and quality. One of the major sources of risk for farmers is lack of water, many have made capital investments to reduce this risk but then the capital structure of their business usually leads to more intensive land use, which many argue is presently detrimental to sustainability.

Accelerated change is required, and the adoption of new methods and technologies encouraged. It will not necessarily be an orderly transition however and there will be a huge number of small incremental steps and individual solutions developed, “Rapid Incremental Improvement”. One of the major failings of technology adoption at the moment is that we perhaps have an idealised or normative view of farmers and their motives.

In this paper we argue that many improvements will come from land managers and farmers using improvisation to adapt enabling technologies to their farming systems. A concept called “Bricolage” is introduced which attempts to explain how this process might work, how solutions might be developed by this “brick by brick” approach, and what it means for technologists, researchers, regulators, government, service provider and farmers.