Science and Policy: Nutrient Management Challenges for the Next Generation

This document contains the programme and abstracts of all presentations to the 30th Annual FLRC Workshop at Massey University on the 7th, 8th and 9th February 2017.

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 7th February

0915-1010 Registration and Morning Tea

1010–1015 **Professor Mike Hedley**
Director, Fertilizer & Lime Research Centre, Massey University
WELCOME

1015–1025 **Professor Ray Geor**
Pro Vice-Chancellor, College of Sciences, Massey University
INTRODUCTION

Session 1 : Wider Perspectives

Chairman: **Dr Ranvir Singh**
Fertilizer & Lime Research Centre, Massey University

1025-1055 **Brian Kronvang,** *Invited speaker*
G Blicher-Mathiesen and J Windolf
Department of Bioscience, Aarhus University, Denmark
30 YEARS OF NUTRIENT MANAGEMENT LEARNINGS FROM DENMARK: A SUCCESFUL TURNAROUND AND NOVEL IDEAS FOR THE NEXT GENERATION

1055-1100 **Questions**

1100-1115 **Stephen Lamb** *Invited speaker*
BOP Regional Council, Tauranga
UPDATE ON THE ROTORUA LAKES NUTRIENT MANAGEMENT PLAN IMPLEMENTATION

1115-1130 **Warwick Murray and M Freeman**
Chalice Consulting Ltd, Tauranga
EFFECTIVE USE OF OVERSEER IN REGULATION

1130-1145 **Leo Fietje, J Palmer, A MacCormick and N Peet**
Environment Canterbury, Christchurch
MANAGING DIFFUSELY SOURCED NUTRIENT LOSS – BUILDING ON LESSONS LEARNED

1145-1200 **Sarah McLaren, B Clothier and R Singh**
New Zealand Life Cycle Management Centre, Massey University
ENVIRONMENTAL CERTIFICATION: ADDING VALUE FOR NEW ZEALAND'S PRIMARY PRODUCERS OR A WASTE OF TIME AND MONEY?

1200-1215 **Discussion**

1215-1315 **Lunch**

Session 2 : Smart Tools and Technologies

Chairman: **Professor Ian Yule**
NZ Centre for Precision Agriculture, Massey University

1315-1330 **Simon Blackmore**
UK National Centre for Precision Farming, Harper Adams University, Newport, Shropshire, United Kingdom
ROBOTIC AGRICULTURE: FROM DREAM TO REALITY

1330-1345 **Jim Wilson**
Soil Essentials, Hilton of Fern, Scotland
CAN LOW COST, CONSUMER UAV'S MAP USEFUL AGRONOMIC CHARACTERISTICS?

1345-1355 **Suzanne Higgins and J S Bailey**
Agri Food and Biosciences Institute, Belfast, Northern Ireland
THE ROLE OF PRECISION AGRICULTURE IN OPTIMISING SOIL NUTRIENT STATUS AND GRASSLAND PRODUCTIVITY IN NORTHERN IRELAND, WHILE REDUCING NUTRIENT LOSSES TO AIR OR WATER

1355-1405 **Tommy Cushnahan, I Yule, R Pullanagari and M Grafton**
NZ Centre for Precision Agriculture, Massey University
THE CLASSIFICATION OF HILL COUNTRY VEGETATION FROM HYPERSPECTRAL IMAGERY

1405-1415 **Ina Draganova, L Burkitt, A Hoogenboom, R Hickson, M Bretherton, C Hedley, P Roudier and S Morris**
New Zealand Centre for Precision Agriculture, Massey University
MONITORING OF CATTLE IN STREAMS AND WET AREAS ON A HILL COUNTRY FARM

1415-1425 **Alistair Murdoch, N Koukiasas, P De La Warr, R A Pilgrim and S Sanford**
School of Agriculture, Policy and Development
The University of Reading, UK
ROBOTIC WEEDING OF FIELD VEGETABLES OFFERS POTENTIAL REDUCTION IN HERBICIDE INPUTS OF AT LEAST 90%

1425-1435 **Eva Schröer-Merker**
Centre of Excellence in Farm Business Management, Agri One
CAN SMART TOOLS AND TECHNOLOGIES HELP SOLVE THE CHALLENGES IN NUTRIENT MANAGEMENT?

1435-1450 **Discussion**

1450-1500 **Poster Papers**

Therese Kaul, M C E Grafton and I J Yule
NZ Centre for Precision Agriculture, Massey University
GEOSTATISTICAL DETERMINATION OF SOIL NOISE AND SOIL PHOSPHORUS SPATIAL VARIABILITY

Istvan Hajdu, I Yule, M Bretherton, R Singh and C Hedley
Institute of Agriculture & Environment, Massey University
USE OF WIRELESS SENSOR NETWORK TECHNOLOGY FOR THE INVESTIGATION OF ROOT ZONE SOIL MOISTURE DYNAMICS IN NEW ZEALAND'S HILL COUNTRY

Ahmed El-Naggar, C Hedley, D Horne, P Roudier and B Clothier
Institute of Agriculture & Environment, Massey University
USING ELECTRICAL CONDUCTIVITY IMAGING TO ESTIMATE SOIL WATER CONTENT

Angela Lane, C Hedley and S McColl
Lowe Environmental Impact, Palmerston North
GROUND PENETRATING RADAR – THE PROS AND CONS OF IDENTIFYING PHYSICAL FEATURES IN ALLUVIAL SOILS

1500-1530 **Afternoon Tea**

Session 3 : Farm Systems

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

1530-1545 **Tommy Dalgaard**
Department of Agroecology, Aarhus University, Denmark
NUTRIENT BUDGETING FOR FARM AND ENVIRONMENTAL MANAGEMENT IN DENMARK
– EXAMPLES FROM CONTRASTING FARM TYPES

1545-1555 **Carla Muller**
DairyNZ, Hamilton
MODELLING DAIRY FARM SYSTEMS:
- PROCESSES, PREDICAMENTS AND POSSIBILITIES

1555-1605 **Iris Vogeler, R Cichota, B Paton, J Trethewey and A Werner**
AgResearch, Hamilton
BALANCING OPTIMUM N FERTILISATION AND N LOSSES IN DAIRY SYSTEMS

1605-1615 **Kit Rutherford**
NIWA, Napier
SENSITIVITY ANALYSIS OF THE SEEPAGE WETLAND MODULE IN OVERSEER

1615-1625 **Warwick Catto and J Blennerhassett**
Ballance Agri-Nutrients, Tauranga
MITAGATOR – THE POWER OF USING SPATIAL VISUALISATION TO IMPROVE THE UPTAKE AND ADOPTION OF NUTRIENT MANAGEMENT TOOLS

1625-1635 **Alice Melland, J Eberhard and R Kelly**
University of Southern Queensland, Australia
A STOCKTAKE OF NUTRIENT LOSS RISK IN THE AUSTRALIAN DAIRY INDUSTRY

1635-1650 **Discussion**

1650-1705 **Poster Papers**

Donna Giltrap, A Manderson, S Saggar and R Davison
Landcare Research, Palmerston North
DEVELOPING A FARM SCALE GREENHOUSE GAS CALCULATOR FOR SHEEP AND BEEF FARMS

Danilo Guinto and W Catto
Ballance Agri-Nutrients, Tauranga
FERTILITY STATUS OF DRYSTOCK PASTURE SOILS IN NEW ZEALAND, 2009-2015

Dan Copland, H Venter, M Reed and P James
Ravensdown, Napier
ZONAL DIFFERENCES IN SOIL FERTILITY ON CANTERBURY DAIRY FARMS

Stewart Spilsbury and B F C Quin
FOO Technologies, Newry, Victoria, Australia
GIBBERELLIC ACID APPLICATION IN SUMMER (IN CONJUNCTION WITH WETTED, NBPT-TREATED PRILLED UREA) SUBSTANTIALLY INCREASES IRRIGATED PASTURE PRODUCTION ON FIVE DAIRY FARMS IN VICTORIA, AUSTRALIA

Bert Quin, G Bates and P Bishop
Quin Environmentals, Auckland
THE COMMERCIALISATION OF THE SPIKEY® TECHNOLOGY FOR THE DETECTION AND TREATMENT OF FRESH URINE PATCHES

Coby Hoogendoorn, S Saggar, N Jha, D Giltrap, P Bishop, J Luo, P Berben, T Palmada, S Lindsey, G Bates, B Quin and M Hedley
Landcare Research, Palmerston North
EFFICACY OF SPIKEY®-APPLIED NITROGEN TRANSFORMATION PROCESS INHIBITORS FOR REDUCING NITROGEN LOSSES FROM URINE APPLIED TO WELL-DRAINED DAIRY SOILS IN AUTUMN–WINTER

Wednesday 8th February

Session 4 : Fertiliser Use

Chairman: **Dr Jamie Blennerhassett**
Ballance Agri-Nutrients, Tauranga

0840-0850 **Mike White, A Metherell and A H C Roberts**
Ravensdown, Napier
THE USE OF VARIABLE RATE FERTILISER APPLICATIONS IN NEW ZEALAND HILL COUNTRY

0850-0900 **Jeff Morton, A H C Roberts and A D Stafford**
Morton Ag, Napier
POTASSIUM REQUIREMENTS OF NEW ZEALAND HILL PASTURES

0900-0910 **Paddy Shannon**
Shannon Agricultural Consulting, Te Awamutu
A COMPARISON OF THE EFFECTIVENESS AS PASTORAL FERTILISERS OF TWO PROPRIETARY PHOSPHATE PRODUCTS COMPARED TO SUPERPHOSPHATE

0910-0920 **Phillip Schofield and S Heng**
Abron, Matamata
REDUCTION OF NITROGEN AND PHOSPHATE FERTILISER INPUTS WHILE INCREASING PASTURE PRODUCTION.

0920-0930 **Bert Quin, S Harold, S Spilsbury and G Bates**
Quin Environmentals, Auckland
COMMERCIALISATION OF THE ONESYSTEM® WETTED, NBPT-SPRAYED PRILLED UREA TECHNOLOGY IN NEW ZEALAND AND VICTORIA, AUSTRALIA

0930-0945 **Discussion**

0945-1000 **Poster Papers**

Aaron Stafford and D Guinto
Ballance Agri-Nutrients, Tauranga
TRIALS AND TRIBULATIONS WITH USE OF GA_3 ON PASTURES – WHAT DO LONGER TERM TRIALS TELL US?

Hendrik Venter
Ravensdown, Napier
SOIL ACIDITY IN THE KAKANUI RANGES

Bob Longhurst, G Rajendram, B Miller and M Dexter
AgResearch, Hamilton
NUTRIENT CONTENT OF LIQUID AND SOLID EFFLUENTS ON NZ DAIRY COW FARMS

Bridgit Hawkins
Regen Ltd, Wellington
GETTING DAILY WATER IRRIGATION RECOMMENDATIONS DIRECT TO FARMERS ..

Wafa Al Yamani, S Green, R Pangilinan, S Shahid, S Dixon, P Kemp and B Clothier
Environment Agency, Abu Dhabi
THE IMPACT OF USING TREATED SEWAGE EFFLUENT TO IRRIGATE ARID FORESTS IN THE HYPER-ARID DESERTS OF ABU DHABI

1000-1030 **Morning Tea**

Session 5 : Nutrient Loss and Attenuation

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

1030-1040 **Ranvir Singh, A Elwan, D Horne, A Manderson, M Patterson and J Roygard**
Fertilizer & Lime Research Centre, Massey University
PREDICTING LAND-BASED NITROGEN LOADS AND ATTENUATION IN THE RANGITIKEI RIVER CATCHMENT – THE MODEL DEVELOPMENT

1040-1050 **Dave Horne, A Elwan, R Singh, A Manderson, M Patterson and J Roygard**
Fertilizer & Lime Research Centre, Massey University
PREDICTING LAND-BASED NITROGEN LOADS AND ATTENUATION IN THE RANGITIKEI RIVER CATCHMENT – THE IMPLICATIONS FOR LAND USE

1050-1100 **Bethana Jackson, M I Trodahl, A K Metherell and K Miller**
Victoria University of Wellington
SPATIAL TARGETING OF MITIGATION STRATEGIES TO REDUCE NUTRIENT LEVELS IN WATERWAYS WHILE MINIMISING PRODUCTION LOSS

1100-1110 **Martha Trodahl, L Burkitt, M Bretherton, J Deslippe, B Jackson and A Metherell**
Victoria University of Wellington
DEVELOPING N & P EXPORT COEFFICIENTS FOR RURAL NEW ZEALAND LANDSCAPE MODELLING IN LUCI

1110-1120 **Simon Woodward and R Stenger**
Lincoln Agritech Ltd, Hamilton
USING MONTHLY STREAM WATER QUALITY DATA TO QUANTIFY NITRATE TRANSFER PATHWAYS IN THREE WAIKATO CATCHMENTS

1120-1130 **Greg Barkle, R Stenger, B Moorhead and T McKelvey**
Aqualinc Research Ltd, Hamilton
EXPORT OF NITROGEN AND PHOSPHORUS FROM ARTIFICIALLY DRAINED DAIRY PASTURES IN THE HAURAKI PLAINS

1130-1140 **Petra Fransen, L Burkitt, M Bretherton, D Horne, R Singh, R Hickson and S Morris**
Institute of Agriculture & Environment, Massey University
SELECTION OF CATTLE SUPPLEMENT FEEDING AREAS TO REDUCE NUTRIENT AND SEDIMENT LOSS IN SURFACE RUNOFF

1140-1155 **Discussion**

1155-1215 **Poster Papers**

Genevieve Smith, R Singh and A Matthews
Fertilizer and Lime Research Centre, Massey University
ASSESSING FARM-SCALE NUTRIENT FLOW PATHWAYS AND NITRATE ATTENUATION IN RANGITIKEI SAND COUNTRY

John Paterson, L Burkitt and B Levine
Phosphorus Mitigation Project, Rotorua
ADVANCING ON-FARM PHOSPHORUS LOSS MITIGATION IN CONJUNCTION WITH APPLIED RESEARCH ON A NEW MITIGATION TOOL - THE DETAINMENT BUND

Kamal P Adhikari, S Saggar, J A Hanly and D F Guinto
Institute of Agriculture & Environment, Massey University
UNDERSTANDING THE INEFFECTIVENESS OF CU AND ZN IN REDUCING UREA HYDROLYSIS LOSSES FROM GRAZED DAIRY PASTURE SOILS

Marya Hashmatt and H Kerckhoffs
Institute of Agriculture and Environment, Massey University
CURRENT CHALLENGES IN GOLD3 KIWIFRUIT NUTRIENT MANAGEMENT RESEARCH

Lokesh Padhye and Sumaraj
Department of Civil and Environmental Engineering, University of Auckland
NUTRIENT INTERACTIONS WITH ACTIVATED CARBON'S SURFACE CHEMISTRY

1215-1315 **Lunch**

Session 6 : Pastoral 21 - Increasing Productivity and Reducing Environmental Footprint

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

1315-1330 **David Chapman, G Edwards, D Dalley, K Cameron, H Di, R Bryant, A Clement, B Malcolm and J Curtis**
DairyNZ, Christchurch
NITROGEN LEACHING, PRODUCTIVITY AND PROFIT OF IRRIGATED DAIRY SYSTEMS USING EITHER LOW OR HIGH INPUTS OF N FERTILISER AND FEED:
- THE PASTORAL 21 EXPERIENCE IN CANTERBURY

1330-1345 **Ron Pellow**
South Island Dairying Development Centre, Christchurch
APPLYING PASTORAL 21 FARMLET RESEARCH TO A WHOLE FARM

1345-1400 **Mike Hedley, D Horne, J Hanly, C Christensen, J Howes, I Tait, C Mitchell, N Kyamanawa, Q Mai, M Bretherton, J Margerison, N Butcher, B Toes and H Doohan**
Fertilizer & Lime Research Centre, Massey University
USING DURATION CONTROLLED GRAZING AND DIET TO MANIPULATE N LEACHING LOSSES

1400-1415 **Diana Selbie, M Shepherd, M Hedley, K Macdonald, D Chapman, R Monaghan, G Lucci, P Shorten, B Welten, M Pirie, C Roach, C Glassey and P Beukes**
AgResearch, Hamilton
FOLLOWING THE NITROGEN: EXPLAINING THE REASONS FOR DECREASED N LEACHING IN THE WAIKATO PASTORAL 21 FARMLETS

1415-1430 **Mark Shepherd, M Hedley, K Macdonald, D Chapman, R Monaghan, G Cosgrove, D Houlbrooke and P Beukes**
AgResearch, Hamilton
A SUMMARY OF KEY MESSAGES ARISING FROM THE PASTORAL 21 PROGRAMME

1430-1445 **John Rendel and A D Mackay**
AgResearch, Mosgiel
OPTIMISE USE OF RESOURCES: CURRENT & FUTURE APPROACHES...

1445-1500 **Discussion**

1500-1515 **Poster Papers**

James Hanly, S Kamikazi, C Christensen, M Hedley and D Horne
Fertilizer & Lime Research Centre, Massey University
EFFECTS OF GRAZING MANAGEMENT ON NUTRIENT ANION AND CATION LOSSES IN DRAINAGE WATERS FROM DAIRY PASTURES

Khadija Malik, P Bishop, S Saggar and M Hedley
Institute of Agriculture & Environment, Massey University
A LONGITUDINAL STUDY TO ESTIMATE NH_3-N LOSSES ASSOCIATED WITH TEMPORARY HOUSING OF DAIRY COWS AND MANURE MANAGEMENT

Rashad Syed, T Palmada, S Saggar, K Tate and P Berben
Institute of Agriculture & Environment, Massey University
DAIRY HOUSING METHANE MITIGATION USING GRAZED PASTURE SOILS

Jeff Brown
Fonterra, Palmerston North
MISCANTHUS (ELEPHANT GRASS) EXHIBITS VERY LOW NITROGEN LEACHING – ANOTHER OPTION FOR THE MITIGATION TOOLBOX?

Charlotte Drury, J Reid, D J Horne and N Heath
Institute of Agriculture and Environment, Massey University
WHAT DRIVES CHANGE IN FARMERS' MANAGEMENT PRACTICES?

Shelley Bowie and H Venter
Analytical Research Laboratories, Napier
WHOLE FARM TESTING: A FURTHER REVIEW OF DATA

1515-1545 **Afternoon Tea**

Session 7 : Contaminants and Soil Quality

Chairman: **Dr Ants Roberts**
Ravensdown, Pukekohe

1545-1555 **Jo-Anne E Cavanagh, Y Yi, N Lehto, B Robinson, C Gray, G Geretheran, J Jeyakumar, H Thompson and C Anderson**
Landcare Research, Christchurch
UNDERSTANDING THE INFLUENCE OF SOIL PROPERTIES ON PLANT UPTAKE OF CADMIUM IN NEW ZEALAND AGRICULTURAL SOILS

1555-1605 **Aaron Stafford, J Jeyakumar, C Anderson and M Hedley**
Ballance Agri-Nutrients, Tauranga
INFLUENCE OF FLUCTUATING SOIL MOISTURE ON CADMIUM PHYTOAVAILABILITY AND ACCUMULATION IN PLANTAIN

1605-1615 **Chris Anderson and S Smith**
Fertilizer & Lime Research Centre, Massey University
WHAT DOES CADMIUM IN OUR FORAGE CROPS MEAN OR OUR LIVESTOCK?

1615-1625 **John Drewry, R Parkes and M Taylor**
Greater Wellington Regional Council, Masterton
SOIL QUALITY AND TRACE ELEMENTS FOR LAND USES IN THE WELLINGTON REGION AND IMPLICATIONS FOR FARM MANAGEMENT

1625-1640 **Discussion**

1640-1700 **Poster Papers**

Gary Bedford
Taranaki Regional Council, Stratford
SCIENCE AND POLICY: SOIL CADMIUM IN THE TARANAKI ENVIRONMENT

Jeff D Morton and A H C Roberts
MortonAg, Napier
INVESTIGATING THE CADMIUM STATUS OF A WAIKATO DAIRY FARM

Matthew Taylor and G Sneath
Waikato Regional Council, Hamilton
CURRENT STATE AND TREND OF CADMIUM LEVELS IN SOIL, FRESHWATER AND SEDIMENTS ACROSS THE WAIKATO REGION

Hadee Thompson-Morrison, C Anderson, P Jeyakumar, T Geretharan, J Cavanagh and B Robinson
Institute of Agriculture & Environment, Massey University
COST-BENEFIT ANALYSIS OF CADMIUM MANAGEMENT IN NEW ZEALAND'S HORTICULTURAL SOILS

Mike Hedley, A Stafford, C Anderson, J Jeyakumar, B Kusumo, C Mitchell and R Calvelo-Pereira
Fertilizer & Lime Research Centre, Massey University
MITIGATING ELEVATED TOPSOIL CADMIUM WITH INVERSION TILLAGE

T (Gere) Geretharan, P Jeyakumar C W A Anderson and M Bretherton
Institute of Agriculture & Environment, Massey University
EFFECTS OF SOIL PROPERTIES ON BIOAVAILABILITY OF FLUORINE TO MICROORGANISMS

Seethal Sivarajan, J Lindsay, S Cronin and T Wilson
School of Environment, University of Auckland
REMEDIATION AND RECOVERY TECHNIQUES FOR VOLCANIC ASH-AFFECTED PASTURE SOILS OF NEW ZEALAND

Kyle Devey, R Hill and A McLachlan
Hill Laboratories, Hamilton
THE MEASUREMENT OF EXTRACTABLE ORGANIC SULFUR BY NEAR-INFRARED SPECTROSCOPY

1700-1800 **Poster Papers on Display**
Informal Drinks In The Ag Hort Lecture Block

1815- **Workshop Dinner at Wharerata**

Thursday 9th February

Session 8 : Water Management

Chairman: **Emeritus Professor Russ Tillman**
Fertilizer & Lime Research Centre, Massey University

0850-0900 **Brent Clothier and S Green**
Plant & Food Research, Palmerston North
THE LEACHING AND RUNOFF OF NUTRIENTS FROM VINEYARDS

0900-9010 **Matt Norris, P Johnstone, S Green, G Clemens, C van den Dijssel, P Wright, G Clark, S Thomas, R Williams, D Mathers and A Halliday**
Plant & Food Research, Havelock North
ROOTZONE REALITY – A NETWORK OF FLUXMETERS MEASURING NUTRIENT LOSSES UNDER CROPPING ROTATIONS - SUMMARY OF YEAR 2 RESULTS

0910-0920 **Steve Green, M Black, D Armour, S Mahupuka, C van den Dijssel, N Arnold, J Liu, J Herrick and B Clothier**
Plant and Food Research, Palmerston North
MONITORING THE SOIL WATER BALANCE AND DRAINAGE LOSSES FROM KIWIFRUIT ORCHARDS IN THE BAY OF PLENTY REGION

0920-0930 **M S Srinivasan and G Elley**
NIWA, Christchurch
JUST-IN-CASE TO JUSTIFIED IRRIGATION: IMPROVING WATER USE EFFICIENCY IN IRRIGATED DAIRY FARMS

0930-0940 **Bridgit Hawkins**
Regen Ltd, Wellington
MANY TO ONE: HOW CAN DATA BE AGGREGATED TO TELL THE STORY OF INDIVIDUAL FARMER CHANGES TO THEIR COMMUNITIES

0940-0950 **Jeff Brown**
Fonterra, Palmerston North
COMPLEXITIES ASSOCIATED WITH INDUSTRIAL RESOURCE CONSENTS FOR LAND TREATMENT SYSTEMS WHERE SPECIFIC LIMITS ARE SET WITH OVERSEER

0950-1000 **Ahmed Al-Muaini, Abdullah Dakheel, S Green, Al-Hareth Abdullah, Abdul Qader Abdul Rahman, Wasel Abdelwahid Abou Dahr, S Dixon, P Kemp and B Clothier**
Environment Agency, Abu Dhabi
IRRIGATION MANAGEMENT WITH SALINE GROUNDWATER OF DATE PALM CULTIVARS IN THE HYPER-ARID UNITED ARAB EMIRATES

1000-1015 **Discussion**

1015-1045 **Morning Tea**

Session 9 : Our Land & Water - National Science Challenge

Chairman: **Professor Rich McDowell**
AgResearch and Lincoln University, Canterbury

1045-1055 **Ken Taylor and R McDowell**
AgResearch, Christchurch
INCENTIVES, OPTIONS AND ENABLERS: INTEGRATIVE SCIENCE TO ACHIEVE THE OUR LAND AND WATER NATIONAL SCIENCE CHALLENGE MISSION

1055-1105 **Caroline Saunders, P Dalziel and A Renwick**
Lincoln University, Canterbury
INTEGRATING VALUE CHAINS TO REWARD SUSTAINABLE LAND USE PRACTICES

1105-1115 **Chris Tanner, R Muirhead, S Carrick, M Close, R Stenger, M Srinivasan, R Monaghan and S Singh**
NIWA, Hamilton
A FRAMEWORK FOR UNDERSTANDING THE LINKAGES BETWEEN LAND AND WATER QUALITY IMPACTS

1115-1125 **Scott Larned, T Snelder, M Schallenberg, R McDowell, C Rissmann, M Beare, G Tipa, S Crow, C Daughney, A Herzig and G Sevicke-Jones**
NIWA, Christchurch
SHIFTING FROM LAND-USE CAPABILITY TO LAND-USE SUITABILITY IN THE OUR LAND & WATER NATIONAL SCIENCE CHALLENGE

1125-1135 **Melissa Robson, J Foote, P Barker, G Lauder, G Nicholas, S Greenhalgh, B Small, R Williams, R Smith, T von Pein, G Haremate and G Bammer**
Landcare Research, Christchurch
THE COLLABORATION LAB: THE TRANSFORMATIVE ROLE OF COLLABORATION IN MANAGING OUR LAND AND WATER

1135-1145 **Alan Renwick, A Wreford, R Dynes, P Johnstone, G Edwards C. Hedley, W King and P Clinton**
AgResearch, Christchurch
NEXT GENERATION SYSTEMS;
-A FRAMEWORK FOR PRIORITISING INNOVATION

1145-1200 **Discussion**

1200-1300 **Lunch**

Session 10 : The Challenge of Implementation

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

1300-1310 **Sophie Blair, N Pyke and D Ward**
Foundation for Arable Research, Christchurch
EAST ASHBURTON GROUND WATER QUALITY
– A COMMUNITY APPROACH

1310-1320 **Eva Harris**
Irrigo Centre, Ashburton
CASE STUDY IN COLLECTIVE NUTRIENT MANAGEMENT

1320-1335 **Andrew Kempson**
Fonterra, Hamilton
FARM ENVIRONMENT PLANS AS A COMPONENT OF INDUSTRY AUDITED SELF-MANAGEMENT

1335-1350 **Nathan Heath** *Invited speaker*
Hawkes Bay Regional Council
THE EVOLUTION AND DEVOLUTION OF IMPLEMENTATION

1350-1430 **A Panel Discussion:**

'THE PIVOTAL ROLE OF THE RURAL PROFESSIONAL IN IMPLEMENTATION'

Closing Session : Back to the Future

1430-1450 **Russ Tillman** *Invited speaker*
Fertilizer & Lime Research Centre, Massey University

THE SUCCESS STORY OF DAIRYING AND THE ENVIRONMENT IN 2042 - HOW IT WAS ACHIEVED

1450-1500 Closing Remarks

1500 Afternoon Tea and depart

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30 YEARS OF NUTRIENT MANAGEMENT LEARNINGS FROM DENMARK: A SUCCESFUL TURNAROUND AND NOVEL IDEAS FOR THE NEXT GENERATION

Brian Kronvang, Gitte Blicher-Mathiesen and Jørgen Windolf

Department of Bioscience, Aarhus University, Denmark

Excess nitrogen (N) and phosphorus (P) emissions to surface waters are a high priority environmental problem worldwide for protection of water resources in times of population growth and climate change. As clean water is a scarce resource the struggle for reducing nutrient emissions are an ongoing issue for many countries and regions. Since the mid1980s a wide range of national regulatory general measures have been implemented to reduce land based N and P loadings of the Danish aquatic environment. These measures have addressed both point source emissions and especially also been devoted to reducing emissions from diffuse sources especially from agricultural production. Following nearly 3 decades of combating nutrient pollution our surface waters such as lakes and estuaries are, however, only slowly responding on the 50% reduction in N and 56% reduction in P loadings achieved during the last 40 years period. Therefore, the implementation of the EU Water Framework Directive in Danish surface waters still call for further reductions of N and P loadings from both point and diffuse sources. A new era of changing from national regulatory measures to targeted implemented measures was the outcome of a Commission on Nature and Agriculture established by the Danish Government in 2013. The Commission pointed to the need of increased growth and improved environment through a more targeted and efficient regulation by applying advanced technological mitigation methods that have to be implemented according to the local attenuation capacity for nutrients in the landscape.

As a follow up a national consensus model for N was established chaining existing leaching, 3D groundwater and surface water models that enable a calculation of the N dynamics and attenuation capacity within a catchment scale of 15 km^2. Moreover, several research projects have been conducted to investigate the effect of a suite of targeted mitigation measures such as restored natural wetlands, constructed wetlands, controlled drainage, buffer strips and intelligent buffer strips. The outcome and learnings from 3 decades of regulation of nutrients in Denmark and the new era of targeted regulation with its new needs of scientific knowledge on nutrient retention models and new technologies for mitigation will be shared in this presentation. Lastly, the Danish Government has in 2016 passed a new regulation of agricultural production allowing farmers to apply economic optimum levels of nitrogen to crops after nearly 18 years of regulation below economic optimum (1998: 10%; 2015: 21%).

The implications of this for the future Danish regulations of agricultural nutrient emissions will also be shared.

UPDATE ON THE ROTORUA LAKES NUTRIENT MANAGEMENT PLAN IMPLEMENTATION

Stephen Lamb

BOP Regional Council, Tauranga

Lake Rotorua is the largest lake in the Rotorua district. It is highly valued by iwi and community – and is of national importance. Lake Rotorua was returned to Te Arawa via the 2004 Deed of Settlement and the lakebed is vested in Te Arawa. The management of the Lakes is shared between the partners to the Rotorua Lakes Strategy Group (Te Arawa Lakes Trust, Bay of Plenty Regional Council and Rotorua Lakes Council). The Lake Rotorua catchment is dominated by pastoral farming and forestry. The catchment includes around 9,000 hectares of indigenous vegetation. Dairy farming occurs on about a quarter of the pastoral farming land in the catchment, with drystock landuse occupying the balance. Forestry occupies around 43% of land within the catchment.

The water quality for Lake Rotorua has been the subject of concern for a number of decades. The water quality of the 1960s was identified as a suitable and achievable target for the lake by the community. This has been endorsed through the Bay of Plenty's Operative Regional Water and Land Plan which established a target Trophic Level Index (TLI) for the Lake of 4.2. The Lake is co-limited by nitrogen and phosphorus and management of both these nutrients is required to achieve the TLI. Scientific research has shown that 435t/N and between 33.7 to 38.7t/P are the annual sustainable nutrient loads required to achieve and maintain the TLI of 4.2. The steady state nitrogen load is 755 t/N.

Nutrient management, lake health, cultural impacts, economic challenges and the required level of behaviour and land use change means this is a challenging issue for the Rotorua community, as well as the Bay of Plenty. There has also been considerable national level involvement in finding a proposed solution. The Proposed Rules have been developed as one element of an integrated framework that also includes an incentive scheme ($40million), gorse conversion funding and engineering solutions. Funding is also being provided for the development of provisional Nutrient Management Plans.

The Proposed Rules (Plan Change 10) were developed through a community group process. They are a combination of permitted activities (below certain thresholds) and Controlled Activity consent requirements. Nutrient Management Plans are the key element of farming enterprises reducing nitrogen loss down to Nitrogen Discharge Allocations (NDAs). The base data used by the Proposed Rules (for allocation) comes from a benchmarking exercise from the period 2001-04. While the rules are still only at the proposed stage, there are a range of implementation actions already occurring in preparation.

EFFECTIVE USE OF OVERSEER IN REGULATION

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In 2015 a collaborative project was launched to develop guidance on the use of OVERSEER® Nutrient Budgets (OVERSEER) model in Resource Management Act water quality management. The need for this project arose because of the growing role of OVERSEER in assisting regional councils to set and implement water quality objectives and limits under the National Policy Statement for Freshwater Management (NPS-FM). The project was governed and funded by regional councils, the ministries for Primary Industries and Environment and industry bodies. Initial project outputs were a stocktake of existing regional council uses of OVERSEER and a 'plain English' technical description of OVERSEER. The main output was 'Using OVERSEER in regulation - technical resources and guidance for the appropriate and consistent use of OVERSEER by regional councils' (Freeman *et al*, 2016).

That report provides detailed guidance primarily for regional councils on the use of OVERSEER within regional plans and resource consents, alongside the relevant assumptions, limitations and principles that need to be taken into account. The report concludes that OVERSEER is suitable for estimating diffuse nitrogen and phosphorus losses from rural land, within the context of implementing the NPS-FM. Particular attention is paid to managing the impact of version updates and the inherent uncertainties of such modelling. The report notes that the most appropriate specific approach to OVERSEER's use will depend on the water quality objectives being sought and the specific catchment characteristics such as land use patterns/trends and nutrient attenuation.

To ensure that OVERSEER continues to be used appropriately and effectively to assist in managing nutrient water quality, it will be necessary to both regularly review and update guidance on the model's use and to ensure that the model itself is improved to meet the needs of regulators, industry and landowners. It is likely that OVERSEER will become an increasingly important tool for use by regional councils in managing freshwater quality, in both regulatory and non-regulatory mechanisms. However, there are still some significant challenges facing the development, maintenance and application of OVERSEER, for example, what are the priorities for maintenance and development and how should that be funded?

MANAGING DIFFUSELY SOURCED NUTRIENT LOSS – BUILDING ON LESSONS LEARNED

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Managing diffusely sourced nutrients is both essential and difficult. Essential if we want to halt or reverse the decline in quality of our lakes and rivers to meet societal and market expectations. Difficult because we're dealing with incomplete information and complex interdependencies along with changing requirements needing a broad range of skills to resolve. It is as much a social, cultural and economic challenge as it is technical.

Managing diffusely sourced nutrients requires a fundamental shift in thinking and approach to managing land. Farmers have traditionally relied on development and intensification to keep ahead of inflation and grow their business. This often results in increased loss of nutrients to water. With a national imperative to maintain (and in some cases, improve) water quality as a bottom line, development must now consider potential for increased loss and if so, incorporate mitigation.

Regional councils around the country have grappled with the challenge and lessons continue to be learned. We share some of our observations with an emphasis on how we can build on those lessons. One key lesson learned is the significant influence rural professionals, academics and community leaders have in shaping attitudes and dealing with the challenge. Another is the need for a wide range of skill-sets covering multiple disciplines. Workshop participants are therefore crucial partners in meeting the challenges that lie ahead.

ENVIRONMENTAL CERTIFICATION:
ADDING VALUE FOR NEW ZEALAND'S PRIMARY PRODUCERS
OR A WASTE OF TIME AND MONEY?

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Environmental certification programmes for food products are increasingly common around the world. They offer a mechanism to strategically develop and promote a specific profile (or "story") for food products as well as supporting more sustainable food production and consumption patterns. Successful certification of a product leads to the opportunity to have an ecolabel logo on that product and/or to be used in marketing the product.

The purpose of these certification programmes varies according to different stakeholders' perspectives. From the perspective of the food producer, they include differentiating the producer's product in the marketplace in order to increase its market share, and by association enhancing the producer's reputation. From the perspective of the consumer, an ecolabel on a food product that represents an environmental certification enables the consumer to choose products that are aligned with their values. From the perspective of government, environmental certification programmes are seen as mechanisms for moving societies towards more sustainable consumption and production (SCP) systems through influencing producer activities and consumer purchasing choices, and driving eco-innovation in different economic sectors.

The continued existence, and increase in number, of environmental certification programmes over more than 30 years indicates that they serve a purpose. However, on the other hand, the process of gaining environmental certification can be time-consuming and expensive for a food producer. It is therefore pertinent to ask whether these programmes are efficient in achieving their objectives (i.e. Are they "eco-efficient"?).

Using examples from different environmental certification programmes, we discuss the eco-efficiency of these different characteristics and make some recommendations for future initiatives on environmental certification for New Zealand's primary producers.

ROBOTIC AGRICULTURE: FROM DREAM TO REALITY

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Developed agriculture uses massive amounts of energy in a myriad of forms, from the energy associated with chemicals used to control pests and diseases, through fertilisers, to the tractors themselves and the fuel to power them. This energy is often wasted as it goes off-target, is expensive and will become more so in the future.

Smarter machines should use the minimum amount of energy to turn the natural environment into useful agriculture thus cutting out wasted energy and reducing costs. As agricultural engineers we are continually looking to find ways of making the crop and animal production processes more efficient and have developed the concept of Precision Farming, where we recognise the natural variability found on our farms and change the management and treatments to suit.

My vision for the future is one where small smart machines move around the field establishing, tending and selectively harvesting the crops. Ten years ago I developed an autonomous tractor that could mechanically remove weeds, thus achieving 100% chemical reduction. Even then the tractor was too big and used more energy than was needed. Now one of my old PhD students has developed a laser weeding system that probably uses the minimum amount of energy to kill weeds, by using machine vision to recognise the species, biomass, leaf area and position of the meristem (growing point). A miniature spray boom of only a few cm wide can then apply a microdot of herbicide directly onto the leaf of the weed thus saving99.9% by volume of spray. Alternatively a steerable 5W laser can heat the meristem until the cells rupture and the weed becomes dormant. These devices could be carried on a small robot no bigger than an office desk and work 24/7 without damaging the soil or crop.

Another example is called selective harvesting. Currently many vegetable crops are harvested by hand, which is expensive even when using 'cheap' labour. Between 20 and 60% of the harvested crop is not saleable to the supermarkets as it may not have the desired quality attributes. Selective harvesting envisages a robot assessing all of the quality requirements and only harvesting produce that has 100% saleable characteristics. If some plants are too small they can be left until later until they grow to the correct size. As we know the position, size and expected growth rates we can schedule a more accurate second or third harvest regime.

By looking at all the operations needed to establish, care for and harvest crop plants and identify ways to minimise inputs, we can see how a new mechanisation system can evolve. If we stop defining what we now do by the way we have done it in the past and look at the fundamental requirements we can identify new techniques that not only meet the economic, environmental and legislative drivers but also do a better job of looking after the plants.

CAN LOW COST, CONSUMER UAV'S MAP USEFUL AGRONOMIC CHARACTERISTICS

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One of the ongoing challenges for spatial crop modellers has been to provide the high spatial and temporal resolution crop measurements needed to validate the biophysical predictions provided by the crop model and improve crop predictions by incorporating feedback from the crop into the model. Information which may be important to the model such as; plant population, leaf area index, % ground cover, crop height and biomass have been difficult to collect historically in a spatially dense and frequent manner.

One further limitation has been the models lack of spatial resolution, as they cannot recognise spatial variation in the crop, yet we live in an environment where we know spatial variation exists and failure to recognise this lacks credibility. To overcome some of these limitations we must find ways of collecting multi-temporal and spatially dense information using methods that are cost effective and widely available. A further requirement is to integrate information from other sources such as climatic (cloud cover and rainfall) and farm physical data into the crop model to provide daily updates of crop parameters.

This paper describes a cloud processing system provided by SoilEssentials that can use inexpensive UAV’s to solve a number of these limitations to crop models using extremely high spatial and temporal resolution RGB imagery. This imagery is captured using commercial off the shelf (COTS) UAV’s by relatively unskilled users already present on the farm. This enables farmers and agronomists to plan and execute UAV flights over crops and upload the large number of high resolution RGB images, captured by the UAV, to a cloud computing platform. This processes the imagery into a web based interface where the biophysical parameters are extracted from the images and used in various spatial crop models. The information provided by the crop model can inform variable rate application technologies such as fertiliser application and seeding. A case study using a potato growth model will be demonstrated.

THE ROLE OF PRECISION AGRICULTURE IN OPTIMISING SOIL NUTRIENT STATUS AND GRASSLAND PRODUCTIVITY IN NORTHERN IRELAND, WHILE REDUCING NUTRIENT LOSSES TO AIR OR WATER

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Precision Agriculture (PA) is not widely practiced in Northern European grassland systems, yet production and environmental benefits could potentially be achieved through the adoption of PA technology and a more precise soil management approach. Long term mismanagement of nitrogen (N) and phosphorus (P) applied to agricultural land has contributed appreciably to greenhouse gas emissions (GHG) and the eutrophication of freshwater bodies. In Northern Ireland, agriculture is responsible for 28% of total GHG emissions. Improving the efficiency of nutrient management on farms is therefore important if the UK target of an 80% reduction in GHG emissions by 2050 (relative to 1990), is to be achieved. The trophic status of our inland waterways and lakes are also cause for concern, with 63% of water bodies in Northern Ireland not achieving the “Good or better” status required by the EU Water Framework Directive.

The loss of nutrients from agricultural soils has been the single biggest cause of lake and river enrichment. With the introduction of a Nitrates Action Programme for Northern Ireland (under the EU Nitrates Directive) in 2006, restrictions have been placed on fertiliser N and P use in an attempt to minimise nutrient surpluses in our soil and N and P losses to water. However, while nutrient surpluses are contributing to environmental problems, areas of nutrient deficiency also exist. Grass yield variation within individual fields can be as much as 4 t ha^{-1} and has been linked primarily to variability in soil N mineralisation potential and N availability. Low soil potassium and sulphur levels are also common and 64% of our soils have recently been reported as having sub-optimal pH. Adopting a PA approach to grassland management could potentially improve the efficiency of nutrient management decisions, and so enhance production while minimising detrimental environmental effects. The pace of technology development in recent years has been rapid. Many new soil and crop sensors have come onto the market, along with navigation devices, Remote Sensing and Unmanned Aerial Vehicles. The uptake of new technology by farmers in grassland areas however has been slow. Research is required to demonstrate the production, financial and environmental benefits that potentially could be achieved by adopting PA technology and management approaches in Northern European Grassland systems.

THE CLASSIFICATION OF HILL COUNTRY VEGETATION FROM HYPERSPECTRAL IMAGERY

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Remotely sensed hyperspectral data provides the possibility to categorise and quantify the farm landscape in great detail, supplementing local expert knowledge and adding confidence to decisions.

This paper examines the novel use of hyperspectral aerial imagery to classify various components of the hill country farming landscape. As part of the Ravensdown / MPI PGP project, “Pioneering to Precision”, eight diverse farms, five in the North and three in the South Island were sampled using the AisaFENIX hyperspectral imager. The resulting images had a 1m spatial resolution (approx.) with 448 spectral bands from 380 – 2500 nm.

The primary aim of the PGP project is to develop soil fertility maps from spectral information. Images were collected in tandem with ground sampling and timed to coincide with spring and autumn seasons. Additional classification of the pasture components of two farms are demonstrated using various data pre-processing and classification techniques to ascertain which combination would provide the best accuracy. Classification of pasture with Support Vector Machines (SVM) achieved 99.59% accuracy.

Classification of additional landscape components on the same two farms is demonstrated. Components classified as non-pasture ground cover included; water, tracks/soil, Manuka, scrub, gum, poplar and other tree species. The techniques were successfully used to classify the components with high levels of accuracy.

The ability to classify and quantify landscape components has numerous applications including; fertiliser and farm operational management, rural valuation, strategic farm management and planning.

MONITORING OF CATTLE IN STREAMS AND WET AREAS ON A HILL COUNTRY FARM

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Grazing livestock are an important source of contamination of freshwater, particularly when they have direct access to streams. Cattle in particular, contribute to riparian habitat deterioration through stream bank destruction and direct defecation and urination in streams. Exclusion of stock or planting of riparian areas, are the most common catchment management methods used to protect waterways. Given the relatively low returns from beef and sheep farming, both of these strategies are very expensive and often logistically prohibitive in steep hill country landscapes. Despite this, policy trends indicate that fencing of streams in agricultural catchments may become mandatory in the future. It is important that we understand how much time cattle spend in and around hill country streams and wet areas (wetlands and hill side seeps), in order to quantify the likely environmental benefits from such policies.

The current study examined cattle movement data obtained using GPS collars from experiments undertaken at Massey University's hill country research farm, Tuapaka, near Palmerston North, to investigate the amount of time cattle spent in and around streams and wet areas. Animal movement data were collected from 3 separate herds in winter 2013 and 2014 and 2 herds in 2015. Permanent streams and wet areas were identified using a digital elevation model derived from 1m LiDAR data and ground-truthing.

This paper will quantify the time cattle spent in and nearby 2nd, 3rd and 4th order streams and wet areas, in contrast to time spent at water troughs, with the aim of quantifying the amount of time spent in these high-risk areas, when cattle are given unrestricted access in a wintertime hill country environment.

ROBOTIC WEEDING OF FIELD VEGETABLES OFFERS POTENTIAL REDUCTION IN HERBICIDE INPUTS OF AT LEAST 90%

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Weed control in field vegetables in the UK is increasingly challenging due to the loss of herbicide actives. Actives have been lost due to loss of approval by regulatory authorities and there is also little incentive to develop new selective herbicides for vegetables. Equally, policy makers and consumers demand fewer agro-chemical inputs. Selective herbicides are not, however, needed is removed if weed leaves are identified by image analysis and if droplets of herbicides are targeted to these leaves. No chemical is applied to the crop and none directly to the soil.

Research at Reading in conjunction with Concurrent Solutions llc in the USA, is developing a robotic weeder for field vegetables in the UK.

This paper describes

1) dose-response relationships for glyphosate (Roundup Biactive, 360 g/l glyphosate) applied to individual leaves of weeds, and
2) proof of concept field experiments with manually applied droplets to the naturally occurring weed population in a cabbage crop.

Efficacy of glyphosate droplet applications to control weeds in glasshouse and field and to prevent crop yield loss was assessed in comparison to weed-free (hand-weeded), and weedy controls. Reductions in herbicide were compared with use of the pre-emergence herbicide, pendamethalin (Stomp Aqua, 455 g/l pendimethalin at 2.9 l/ha before transplanting). For the field study, Savoy cabbages were transplanted at the 4-leaf stage in June 2016 using a randomized complete block design with 4 blocks.

Droplet applications, 3, 5 and 7 weeks after transplanting gave most effective weed control, reducing weed biomass by 92% compared to the weedy control and giving a crop yield, which did not differ significantly from the weed-free control. At the same time, the amount of herbicide applied was 94% lower than the recommended rate for pendamethalin and 85% less than a band spraying (inter-row) glyphosate treatment. Pre-emergence and band spray treatments gave significantly lower yields than the weed-free. Provided a systemic herbicide is used, droplets only need to be applied to one leaf but three treatments were essential to allow for differences in weed emergence times. The efficacy of droplet applications for controlling natural weed infestation in cabbages was demonstrated.

CAN SMART TOOLS AND TECHNOLOGIES HELP SOLVE THE CHALLENGES IN NUTRIENT MANAGEMENT?

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"If you can't measure it, you can't manage it." While arguably not completely true, this statement still has merit today. Legislation in New Zealand is increasingly focussing on managing nutrient leaching in order to preserve and improve the environment. While being miles away from the restrictions seen in other regions, such as Europe, this has increased compliance requirements of the primary sector. Our research into decision making and information management has shown that formalisation and the use of software solutions / apps is largely driven by compliance requirements arising from this. Other drivers for adoption are the perceived value add and low entry barrier in terms of cost. While documentation is an important means of fulfilling compliance requirements, it can also be a first step towards improvement.

The Agri One Centre of Excellence in Farm Business Management is a Joint Venture by Lincoln and Massey Universities and is funded by DairyNZ and RMPP via the Primary Growth Partnership. Providing an overview for farmers and rural professionals on digital resources is the Toolbox on our web site, which contains reviews of Apps, websites and other helpful tools available in the marketplace (http://www.agrione.ac.nz).

Recent developments reflect a movement is away from manual paperwork to automatic online recording of data. Smart, connected systems already today exchange information between entities and actors of the primary sector, such as AgHub, SmartMaps and the Fonterra Dairy Diary, thus helping to comply with regulations. Technologies such as variable rate irrigation and soil sensors can provide decision support and can help to prevent nutrient leaching.

In the future, New Zealand farmers will have to be able to be connected to stay on top. Smart systems will increasingly 'talk' to each other in order for collected data to be useful to the end-user and to have the biggest impact on their business (the Internet of Things). But all this available technology also creates confusion and requires knowledge and industry capability development to ensure the potential is are fully realised.

GEOSTATISTICAL DETERMINATION OF SOIL NOISE AND SOIL PHOSPHORUS SPATIAL VARIABILITY

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Noise in soil test results can be reduced by measuring phosphorus below the top 3cm of soil from ground level. This is significant for improving current soil nutrient testing methods by allowing better geospatial predictions for whole paddock soil nutrient variability mapping for use in precision fertilizer application. In this study 200 cores were collected from predetermined grids at two trial sites at 'Patitapu' hill country farm in the Wairarapa. The sites were selected according to accessibility and slope- Trial 1 was a 200m x 100m grid located in a gently undulating paddock. Trial 2 was a 220m x 80m grid located on a moderate to steeply sloped paddock. Each grid had cores taken at intervals of 5m, 10m and 20m. Core sites were mapped out on a Landsat 8 image (NASA) of the Trial sites using ArcGIS 10.2 (ESRI, Redlands Ca.) prior to going into the field; these were then marked out using a LEICA (real time kinematic GPS), pigtails and spray-paint on the ground. Cores were taken using a 30mm diameter soil core sampler. Trial 1 cores were cut into four sections according to depth: A – 0-30mm, B – 30mm-75mm, C- 75mm-150mm, and D- >150mm. Trial 2 cores were cut into three sections: A – 0-30mm, B – 30mm-75mm, C- 75mm-150mm. Olsen P lab results were collected for 120 of the 400 soil cores. These results were analyzed to compare the spatial variability of each depth. The results indicate that there is a significant decrease in variability from section A to section B for both trials. Section B and C for trial 1 have similar variability, whereas there is another significant drop in variability from section B to C in trial 2. Measuring samples below the top 3cm appears to effectively reduce noise, however measuring below 7.5cm for a steeply sloped paddock such as trial 2 may reduce variability too much as to no longer be representative of plant available P, and therefore misrepresenting the overall variability of soil P across a paddock or farm.

USE OF WIRELESS SENSOR NETWORK TECHNOLOGY FOR THE INVESTIGATION OF ROOT ZONE SOIL MOISTURE DYNAMICS IN NEW ZEALAND'S HILL COUNTRY

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Hill country farms play a critical role in the New Zealand's economy and precision agriculture solutions have been increasingly utilised to improve their profitability and resilience. The role of soil moisture, a highly variable factor in pasture productivity has received early recognition in hill country pastoral systems. Despite the importance of soil moisture, assessing and acquiring information on soil water content corresponding with the root zone remained a challenging task in these landscapes due to the complexity of the terrain, soil types and land use.

Wireless Sensor Networks (WSN) is a promising, new, in-situ measurement technology for monitoring soil moisture dynamics with high temporal resolution in agricultural soils. A monitoring network utilising WSN technology was designed and deployed over a hill country farm in the Wairarapa region of the North Island by the aid of Geographical Information System assisted spatial methodologies. As soil moisture distribution varies both vertically and laterally, 40cm long subsurface type multi-sensor probes were installed at 20 sites to take capacitance based readings at four consecutive depths.

Near real-time monitoring of soil variables will make it possible to better understand the dynamics of drying and wetting events and the soil moisture variability within the rooting zone. The integration of spatially distributed sensors and multi-depth soil moisture measurements from various hillslope positions showed considerable in soil water profile response to significant rainfall events on steep, rolling and flat surfaces allowing us to construct a clearer picture of the topographical controls on soil moisture distribution.

USING ELECTRICAL CONDUCTIVITY IMAGING TO ESTIMATE SOIL WATER CONTENT

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Measurement of volumetric soil water content (θv cm^{-3} cm^{-3}) requires collection and analysis of soil samples, which is expensive and time consuming, or soil moisture sensing, which is limited spatially by the number of sensors installed. Apparent electrical conductivity (ECa) of the soil profile can be used as an indicator of a number of soil properties, including soil moisture. Therefore, ECa sensors can be used to efficiently and inexpensively map θv along a transect or across a field.

In this study, EM4Soil inversion software was used to generate (i) two-dimensional depth profile models of electrical conductivity (ECa, mS m^{-1}) as measured by a multi-coil DUALEM-421S sensor and a DUALEM 1s sensor (ii) a correlation between the calculated conductivity profiles and the measured θv.

ECa survey data were collected along two transects (12 positions) and 8 randomly stratified positions in a field near Palmerston North. Soil samples were taken at 0.30 m increments to a depth of 1.5 m. The θv of these samples was determined in the laboratory. The appropriate calibration between ECa and θv was achieved using inversion parameters of forward modelling, an inversion algorithm and a damping factor of 0.04. We calculated the inverted ECa from the true electrical conductivity using a uniform initial model = 35 mS m^{-1}. In general, the results show that θv and ECa follow similar trends down the soil profile. Reasonably accurate relationships between ECa and θv were determined using a 'leave-one-out' cross validation approach (R^2 = 0.62 for DUALEM-421S and 0.58 for DUALEM 1s). The cross validation equation for the predicted versus measured θv for 99 samples has a good R^2 (0.62) and the RMSE= (0.04 cm^3cm^{-3}). We conclude that soil ECa can be used to indirectly estimate (θv) if the contributions of the other soil properties affecting the ECa measurement are known or uniform.

GROUND PENETRATING RADAR – THE PROS AND CONS OF IDENTIFYING PHYSICAL FEATURES IN ALLUVIAL SOILS

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Predicting soil drainage and zones where denitrification occurs requires knowledge of the spatially varying subsurface features, for example depth to gravel, soil thickness and water table fluctuations. Soil physical characteristics and depth to gravel play a vital role in water and nutrient movement through the soil profile. Although surface topography may give an indication of overland flow, the flow of water and nutrients through the soil profile may alter extensively from that at the surface.

Gathering data relating to the subsurface is becoming essential to understand flow pathways, potential zones of denitrification and nutrient loss. Identifying physical features that contribute to soil water flow pathways has not only been time consuming and labour intensive but is also limited to the immediate area of observation. The use of ground penetrating radar (GPR), a proximal sensing method can minimise the use of time-consuming methods such as pit excavations for identifying subsurface factors, enabling extrapolation of these observations to a wider area.

This research integrated the use of GPR, ground-truthing and a geographical information system (GIS) software package to produce a 2-D view of the change in gravel contours and soil thickness over two 0.4 ha plots at Dairy 1 farm, Massey University, Palmerston North. Additionally, water table depth was assessed between spring (September) and summer (February). On inspection of radargrams, gravel contours were more easily detected when soil moisture conditions were drier, likewise textural changes were more easily detected in these drier conditions. Water table depth fluctuated from 4 m to 5 m depth between spring and summer respectively, but was only identified in some radargram images. Change in soil moisture conditions between spring and summer had an overall effect on the quality of images collected, likewise antenna radio frequencies presented varying degrees of clarity in the radargram images.

GPR has the ability to efficiently identify soil physical characteristics, depth to gravel and water table under appropriate conditions. Therefore, the use of GPR has the potential to assist in future research projects that aim to understand nutrient movement and zones of potential denitrification in alluvial soils.

NUTRIENT BUDGETING FOR FARM AND ENVIRONMENTAL MANAGEMENT IN DENMARK
– EXAMPLES FROM CONTRASTING FARM TYPES

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The present paper presents farm nitrogen (N) and phosphorus (P) balances for Danish agriculture, used as indicators for the evaluation of developments in resource efficiency and environmental impacts. Over the past decades, a series of agro-environmental action plans have facilitated both significant reductions in N and P surpluses and improvements in the use efficiencies. Time-series of the relation between national inputs and outputs are reviewed, as indicators for the development, together with a methodology to map the flows of nutrients between the different compartments of agriculture (crops, livestock etc.), environment (water, air, soil) and the surrounding sectors (energy, fishery etc.).

The nutrient balances differ significantly between farm types (cash crop, cattle and pig farms), and so does the distribution between types of nutrient losses to the environment. An approach to distribute the farm N balance to different types of losses (nitrate to water, ammonia to air etc.) and soil-N changes is demonstrated based on results from the Farm-N model. Results show significant differences in the distribution in types of losses. For instance, cash-crop farms show negative soil-N balances, and relatively high Nitrate losses, while livestock farms show positive soil-N balances, with relatively higher ammonia losses from cattle farms compared to pig farms. Finally, the use of farm type modelling for solution scenarios analyses is presented. This include selected solution scenarios from the www.dNmark.org research alliance, and examples of trade-offs and synergies between measures to reduce N-losses while increasing N use efficiency.

MODELLING DAIRY FARM SYSTEMS:
PROCESSES, PREDICAMENTS AND POSSIBILITIES

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All you need to know, and more, about nutrient mitigation modelling. This paper will walk you through the process of nutrient mitigation modelling to demonstrate what today's farms may have to do to meet nutrient regulation in the future. It also demonstrates some of the pitfalls and challenges of mitigation modelling and looks into the possibilities for the future. Nutrient mitigation modelling is becoming prevalent as regional councils seek to understand the economic consequences of setting water quality limits under the Government's National Policy Statement on Freshwater. Some regional councils are using farm systems modelling to estimate the potential environmental and economic impacts of mitigating nutrient loss. Farm systems modelling aims to capture the complexity of a farm system and estimates the impacts of a change on farm. There is currently no comprehensive model that incorporates a farm's economic performance, nutrient pathways and biological feasibility. Therefore, farm systems modelling is a complex, multi-model, iterative process with no one solution. As there is potential for environmental regulation to significantly impact farm systems in New Zealand, it is important to understand how to model farm impacts in a robust way. This paper explains the process for modelling a dairy farm's nutrient losses and demonstrates how these could be mitigated within their farm system. It discusses some of the challenges of farm systems modelling and how these could be overcome as well as the possibilities of where farm system modelling can be used in science and policy development.

BALANCING OPTIMUM FERTILISATION AND N LOSSES IN DAIRY SYSTEMS

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A simulation study was carried out to investigate the effects on nitrogen (N) losses in dairy farming when fertilisation rates are optimised to achieve high pasture yields. The simulations were done for an irrigated ryegrass pasture in the Canterbury region of New Zealand using the Agricultural Production Systems Simulator (APSIM). A multi variate model, developed previously, was used to determine monthly required N fertilisation rates based on pasture N content prior to fertilisation and targets of 50, 75, 90 and 100% of the potential monthly yield. These monthly optimised fertilisation rules were evaluated by running APSIM for a ten-year period to provide yield and N loss estimates from both non urine and urine affected areas. A comparison with typical fertilisation rates of 150 and 400 kg N/ha/year was also done. Assessment of pasture yield and leaching from fertiliser indicated a large reduction in N losses when N fertilisation rates were controlled by the multi variate model. However, the reduction in leaching losses was much smaller when taking into account the effects of urine patches.

SENSITIVITY ANALYSIS OF THE SEEPAGE WETLAND MODULE IN OVERSEER

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NIWA, Napier

It is well known that natural seepage wetlands, commonly found along stream banks in pasture, remove nitrate through denitrification and plant uptake. A module was added to OVERSEER in 2009 which allows users to estimate farm-scale nitrogen loss reductions by seepage wetlands. DairyNZ commissioned NIWA to examine the sensitivity of the seepage wetland module in OVERSEER to the choice of input parameters, and to provide guidance to users on how best to estimate the key parameters.

MITAGATOR – THE POWER OF USING SPATIAL VISUALISATION TO IMPROVE THE UPTAKE AND ADOPTION OF NUTRIENT MANAGEMENT TOOLS

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In the development of decision support tools, the user interface, representation of model outputs, consideration of the end user of the model and the recipient of the tools outputs need to be considered in the design. MitAgator is a nutrient management tool under development that represents losses of Nitrogen, Phosphorus, sediment and E.coli spatially and numerically. As the nutrient management space is a sensitive space in terms of advisors being seen to be making judgements about the appropriateness of on farm nutrient losses the tool uses a non-judgemental framework to represent these losses. This decouples the initial discussion of the origin and management of nutrient flows from the appropriate magnitude of loss. The model then allows losses to be modified constrained by % reduction targets or financial constraints. Pilot testing with end users demonstrates more receptiveness to a visual representation rather than a numeric cue and it is envisaged this will enhance understanding and the likelihood of recommended on farm practice changes being adopted.

A STOCKTAKE OF NUTRIENT LOSS RISK IN THE AUSTRALIAN DAIRY INDUSTRY

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To help safe-guard the Australian dairy industry's reputation for clean and green milk production, a stocktake of the risk of nutrient loss to water was conducted at national and regional scales using readily available datasets.

Data describing the diverse dairy farming landscape (e.g. soil type, topography, climate) and farm practices (e.g. soil nutrient levels, stocking rates, effluent management, irrigation) across Australia were compared across regions. Combined, these data have been identified as important indicators of the potential for nutrient loss to waterbodies.

Landscape pressures were generally moderate to low at the national scale inferring good overall environmental credentials. At regional scales, high pressures from landscapes included high surplus water in the DairyTas, Gippsdairy and Western Dairy regions, high runoff potential in the Western Dairy and Subtropical dairy regions and high deep drainage potential in the DairyTas region. There was also a high potential for soil phosphorus fixation in the DairyTas region, presenting risk for loss via erosion but a low risk via drainage. More than 25% of dairy land was naturally <30 m from waterways nationally, and in WestVicDairy, DairyTas, Murray Dairy, and DairySA.
Pressures from practices were moderate at national and regional scales except for high soil test P levels, presenting a potential P source for loss in runoff or drainage, high modal herd size per farm (500-700 cows) in the DairyTas region and moderate to high effluent management risk across all regions.

Priority regions and practices for reducing risks were identified as nitrogen management on well-drained soils in Tasmania, management of runoff of phosphorus in surplus water in the Western Dairy region, and management of paddocks close to waterways and of effluent across all regions. Risks at catchment scales in some intensive and developing catchments in Victoria and Tasmania are being studied.

The 2014-2016 stocktake provides a baseline against which to measure the financial and environmental returns on efforts to maintain and improve water quality across the diverse dairy farming landscape of Australia. Increased spatial resolution of collection of management practice data would help to evaluate risk profiles across the industry.

DEVELOPING A FARM-SCALE GREENHOUSE GAS CALCULATOR FOR SHEEP AND BEEF FARMS

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In New Zealand, agriculture accounts for ~48% of greenhouse gas emissions at the industry level, but a robust understanding and calculation of emissions at the individual farm level is needed.

We developed a farm-scale greenhouse gas calculator based on the methodology used in the national agricultural inventory model (Pickering & Wear, 2013), designed to accept both farm and industry level data. The gases considered were CH_4 from enteric fermentation and manure management and direct and indirect N_2O from animal excreta and fertiliser N applied to soils. We also included the ability to account for the effect of slope on direct emissions from excreta as described in Saggar et al. (2015).

The farm scale calculator was run using the national level data for sheep and beef population and mean weight from the agricultural inventory model for the 2008–09 and 2009–10 farming years and the results compared with the national inventory model over that time period. For enteric CH_4, manure management CH_4, and N_2O emissions from animal excreta, the farm scale calculator was within ±4% of the agricultural inventory model. When the slope effects were included in the farm-scale calculator the excretal N_2O emissions dropped by around 27% for beef and 50% for sheep.

The farm-scale calculator was then run for each of the 17 sheep and beef farm categories used by Beef + Lamb New Zealand using average data from the Sheep and Beef Farm Survey (Beef + Lamb New Zealand, 2015) for the year 2013–14. Average annual farm emission rates ranged from 0.41 (Otago/Southland high country) to 4.54 (Marlborough-Canterbury mixed farming) tCO_2e/ha. Total farm emissions ranged from 821 (Taranaki-Manawatu intensive finishing) to 3,933 (Marlborough-Canterbury high country) tCO_2e/y. The number of animals, either total or per hectare, had the greatest influence on emissions. However, animal weight data for each farm type were not available, which would have affected the enteric CH_4 emissions. N_2O emissions were also affected by slope, but only accounted for 10–20% of the total emissions.

FERTILITY STATUS OF DRYSTOCK PASTURE SOILS IN NEW ZEALAND, 2009-2015

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The fertility status of topsoils (0-7.5 cm) from drystock farms in New Zealand was assessed with respect to Olsen P, Quick Test K (QTK), sulphate-S (SO_4-S), and pH for the period 2009-2015, focusing on the proportion of farms under optimal soil test categories. The soils were grouped according to soil types namely: Sedimentary, Ash, Pumice and Peat (Organic). The proportions of farms with optimum soil test values during the 7-year period fluctuated as follows: QTK [Sedimentary (32-36%); Ash (23-28%); Pumice (11-20%); Peat (15-30%)]; Olsen P [Sedimentary (26-30%), Ash (25-28%), Pumice (11-20%), Peat (8-25%)]; SO4-S [Sedimentary (7-10%), Ash (9-11%), Pumice (11-20%), Peat (<10%)]. For pH, between 18-26% of the farms are in the optimum range for inorganic soils and quite similar to the Peat soils (15-33%). More than 30% of the inorganic soil types are below the optimum pH range while it was only 10% or less for Peat soils. Considerable opportunities exist for optimising levels of the nutrients P and S, and pH values in drystock inorganic soils which have been historically underfertilised.

ZONAL DIFFERENCES IN SOIL FERTILITY ON CANTERBURY DAIRY FARMS

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During the past two decades there has been an exponential increase in the number of dairy conversions in Canterbury. Many factors have been considered when creating the design and layout of these farms. These considerations have led to the majority of recently converted farms being designed to have large, long and sometimes narrow paddocks. In recent times Ravensdown Agri Managers and their customers have observed that pasture quality, persistence, composition, growth rate, fertiliser response, irrigation response, drought tolerance, insect and disease pressure can vary greatly within these paddocks. These paddocks often performing better at the cow laneway (front) ends and under performing at the ends furthest from the cow laneways (back).

Grazing practices and animal behaviour means animals are spending more time in the front ends of these paddocks which results in disproportionate distribution of excreta. Nutrient transfer from the back to the front is the likely cause of differences observed in pasture performance between the front and back of the paddocks.

Soil samples were collected from two farms to quantify nutrient transfer. Paddocks were split into back, middle and frontal zones and sampled accordingly. Over the two farms significant differences between zones were observed for pH, Ca, Mg, K and Na in the 0 – 7.5 cm soil layer. Olsen P showed a trend on one farm but data from the second were not utilised since zonal differential P fertilisation is already practiced to counter effects of nutrient transfer. Subsurface 7.5 – 15 cm soil samples from one property showed zonal differences established for P, K, Mg and Na over a period of 10 years.

Mean differences between back and frontal zones for the 0 – 7.5 cm soil layer are 25 kg/ha Mg and 42 kg/ha K, while the gradient in the 7.5 – 15 cm soil layer are 17 kg/ha Mg and 17 kg/ha K.

Economic and environmental considerations necessitate these changes over time be taken into account in order to optimise nutrient management under these intensive farming systems. This may require zonal sampling within paddocks to guide variable rate fertiliser applications within dairy paddocks.

GIBBERELLIC ACID APPLICATION IN SUMMER (IN CONJUNCTION WITH WETTED, NBPT-TREATED PRILLED UREA) SUBSTANTIALLY INCREASES IRRIGATED PASTURE PRODUCTION ON FIVE DAIRY FARMS IN VICTORIA, AUSTRALIA

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The growth promotant gibberellic acid (GA) is most commonly used to increase pasture production in late autumn -winter, usually in conjunction with granular urea or liquid nitrogen products. However, the high cost of the liquid nitrogen (per unit N), and the inefficiency of granular urea, has seen many farmers experiment - often unsuccessfully with using GA alone. Earlier trials demonstrated the greater efficiency of wetted, nbpt-treated prilled urea.

There is little published research on the use of the GA outside the winter months. It is widely believed, especially in New Zealand, that the use of GA has little benefit in warmer months. However, most trials have been conducted in low fertiliser N use conditions. Few if any trials with GA have been conducted in conditions where daily maximum temperatures are regularly exceeding 300C, where heat stress limits ryegrass growth. Temperature-induced reductions in irrigated pasture production have serious effects on farm profitability, as increased bought-in feed must be used.

Ten irrigated dairy farms in the Gippsland area of eastern Victoria, Australia, are currently working collaboratively to reduce their nitrogen inputs, by using wetted, nbpt-treated prilled urea (ONEsystem®), applied using VRA technology, and sometimes in conjunction with GA. Over the entire year nitrogen (N) costs and N inputs are expected to be reduced by 30% and 50% respectively. Previous trials using GA combined with ONEsystem® have shown considerable benefits.

To specifically examine the potential of GA plus ONEsystem® under very warm conditions, trials were conducted on five of the farms from late December – mid January, during 3 weeks with 7 days with maximum temperatures of 32-380C. The much higher DM responses achieved with GA combined with ONEsystem® compared to ONEsystem® alone suggests that GA assists ryegrass to cope physiologically with heat stress and continue growth, provided fertiliser N is being applied in an easily utilised form. The higher water content of the GA-treated pasture is indicative of reduced transpiration losses.

THE COMMERCIALISATION OF THE SPIKEY® TECHNOLOGY FOR THE DETECTION AND TREATMENT OF FRESH URINE PATCHES

Bert F Quin, Geoff Bates and Peter Bishop

Quin Environmentals, Auckland

Development of the Spikey® technology for detecting fresh urine patches in 2016 has focused on designing and building a much wider (8m) unit for mounting on a farm tractor 3-point linkage. This size has been determined as being the most practicable and cost-effective option for medium-large dairy farms who want their own Spikey®. Travelling at 12 to 16 km/hr, it takes less than 10 min/ha to detect and treat fresh urine patches, or 30 min on a typical 120 ha farm grazing 3 ha a day. The unit comprises a centre 2.8m module, and two outer 2.8 modules which are hydraulically foldable to allow passage through gates and along lanes.

Recent commercial investment will allow Pastoral Robotics Ltd to build up to 6 of these 8m units in 2017 for delivery to high-profile dairy farms throughout NZ. Retail prices are expected to be in the vicinity $50,000 (+GST). Ultimately, it is intended to build wider units for contractor use and to integrate other features such as prilled urea spreading (ONEsystem®). This investment will also permit further development of the prototype Mini-ME® autonomous robotic tow vehicle. For cost and OSH reasons, Mini-ME® is small (1.2m length) and is designed to travel at only 4 km/hr and pull a 2m-wide Spikey®. However being driverless, these size restrictions are not commercial barriers, as the Mini-ME® towed Spikey® will be able to cover the land grazed in any one day in about 8 hours. Commercialisation of Mini-ME® is expected in 2019, and will enable many other farm tasks that are currently require considerable labour input to be conducted simultaneously.

Research into appropriate treatments to simultaneously apply to the fresh urine patches detected is being conducted by several research institutions and by Pastoral Robotics Ltd (PRL) itself. Given the current unavailability of the nitrification inhibitor DCD, PRL considers that its proprietary product ORUN®, which contains the urease inhibitor nbpt and the growth promotant gibberellic acid (GA3), to currently be the most advantageous from a combined environment and farm profitability perspective, except in high drainage conditions.

In 2017 PRL is funding an independent nationwide series of trials to determine the average increase in size and DM of urine patches and reduction in nitrate leaching obtained from realistically-applied real urine. These trials are designed to elimination PRL concern that earlier research on urine applied in a very controlled fashion, especially within rings (whether left in place or even removed after urine application) artificially restricts the ability for lateral-spreading of urine-urea treated with nbpt, which also minimises the effectiveness of the GA3.

EFFICACY OF SPIKEY®-APPLIED NITROGEN TRANSFORMATION PROCESS INHIBITORS FOR REDUCING NITROGEN LOSSES FROM URINE APPLIED TO WELL-DRAINED DAIRY SOILS IN AUTUMN–WINTER

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Urine patches deposited by grazing livestock, which account for much of agricultural nitrogen (N) loss in New Zealand, arise mainly through N leaching to ground water and ammonia (NH_3) and nitrous oxide (N_2O) emissions to the atmosphere. We evaluated the N-loss efficacy of three different N transformation process inhibitors when applied to urine-amended soil 4 h after urine deposition in (a) an autumn-initiated field trial in the Manawatu, and (b) a winter-initiated lysimeter trial in the Waikato. The N transformation process inhibitors were: a urease inhibitor (UI; N-(n-butyl) thiophosphoric triamide); a nitrification inhibitor (NI; nitrapyrine); and Orun (O; a combination UI and plant growth promotor, gibberellic acid).

Manawatu: Soil conditions were wet at the time of treatment application (50 mm rain in previous week) and remained wet throughout (220 mm rain in the 4 weeks post application). Approximately 7% of urine N applied (660 kg N/ha) was volatilised as NH_3; applying a UI reduced emissions by 23%, whereas applying a NI had no significant effect on the amount of NH_3 volatilised. N_2O emissions, which were highest from the U and U+UI treatments (average 10.1 kg N/ha; EF3 1.49%), were reduced by 30% in the U+NI+UI and U+O treatments and by 60% in the U+NI treatment (4.4 kg N/ha; EF3 0.63%). Soil inorganic N concentrations over time reflected treatment differences observed in gaseous N emissions. Net herbage DM and N accumulated in the 8 weeks after treatment application were not significantly different between any of the urine and urine + amendment treatments, but were significantly greater than in the control plots (940 vs 1355 kg DM/ha; 34 vs 55 kg N/ha).

Waikato: Soil conditions were wet at the time of treatment application (73 mm rain in previous 14 days), 28 mm rain fell within 24 h of treatment application and 144 mm in the 4 weeks post application. N_2O emissions were much lower than in the Manawatu field trial, and adding an amendment shortly after urine was applied had no significant effect on total N_2O emissions (range: 0.33 – 0.44 kg N/ha) or EF3 (range: 0.08 – 0.10%). Measurement of N leaching is ongoing.

THE USE OF VARIABLE RATE FERTILISER APPLICATIONS IN NZ HILL COUNTRY

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Identifying the productivity potential of differing land management units, undertaking sufficient soil and herbage sampling to assess the soil characteristics and fertility across these land management units and then fertilising them to the economic optimum that matches the assessed potential is the basis of a variable rate strategy.

Four scenarios were analysed using the AgResearch PKS lime econometric model comparing a variable rate to a blanket fertiliser strategy. The scenarios represented typical North Island and South Island hill country farms with the farms classified in to land management units representing different slope classes. Soil fertility levels for each slope class were extrapolated from Ravensdown's Primary Growth Partnership (PGP) research farms where a significant number of soil tests have been sampled across slope classes and seasons. The analysis considered P and S requirements only.

The analysis showed that in comparison to a blanket application the variable rate strategy produced a higher 10 year cumulative net present value (NPV) for all four scenario's modelled. A sensitivity analysis also showed that the variable rate strategy was more sustainable for farm profitability in the face of volatile returns with positive cumulative NPV's observed within 9 years in all the scenarios tested compared to the blanket application.

Operationally, technological advancements with the use of differential correction to GPS guidance systems combined with automated flow control in topdressing aircraft are also discussed in terms of the implications that variable rate strategies can increasingly be put into practice more effectively.

POTASSIUM REQUIREMENTS OF NEW ZEALAND HILL PASTURES

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Clover cover on grazed pastures (5 – 10%) on New Zealand soils used for sheep and beef farming is limited mainly by the lack of phosphorus (P) and sulphur (S), soil moisture deficits and competition for nutrients and light from low fertility-demanding grasses. Most hill soils are sedimentary in origin and moderate weathering of potassium (K) from clay minerals and low plant demand ensure that the K supply is adequate for pasture requirements. Soils from pumice and ash tend to have a lower K supply from their rhyolitic and andesitic parent materials. Flat and easy slope trial sites, (three on sedimentary soils, two on pumice soils) with low soil QT K levels of 2 - 4 and initial 10 – 40 % clover cover were selected for K response trials over three years. Only at one site on a sedimentary soil in one year were any significant annual pasture dry matter (DM) production responses to K fertiliser measured. In the years of average to above average rainfall, especially on two sites with less slope, clover cover in the spring increased with rate of K but this response was not reflected in total pasture DM production.

Of the three major nutrients required by clovers, P and S are the two most lacking in sheep and beef pastures and with soil K levels being generally in or above the optimal range, it makes most economic sense to optimise the P and S inputs and rely on the supply of K from the soil mineral reserves. The soundness of this strategy was confirmed by the modelling of a typical hill sheep and beef farm with average soil QT K 5 through the AgResearch PKS Lime econometric model. Over the next twenty years, a capital or annual maintenance application of K resulted in small to large declines in Net Present Value compared with annual application of P and S only. Pasture production responses to fertiliser K on most pastures with soil QT K levels in the economic optimum range of 4 - 5 on sedimentary soils will be small and unprofitable. Soils derived from pumice and ash are more likely to have soil QTK levels below the economic optimum of 4 – 5 and may require 20 – 40 kg K/ha/yr.

Examination of two large laboratory databases of soil QT K levels on sheep and beef farms comprised of 120000 paddock samples over the last 7 – 10 years confirmed that 97% of the results were in or above the economically optimal range for pasture production. Nor had there been any decline in soil QT K levels over that time. These results indicate that the recommendations made for K fertiliser on pastures grazed by sheep and beef cattle are generally sound and there is no foundation for any fears of a widespread shortage of K for optimum pasture and clover growth.

A COMPARISON OF THE EFFECTIVENESS AS PASTORAL FERTILISERS OF TWO PROPRIETARY PHOSPHATE PRODUCTS COMPARED TO SUPERPHOSPHATE

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A field trial was established by Terracare Fertilisers Ltd on an Allophanic soil on the side of Mount Pirongia in March 2009. This trial compared phosphorus applied to pasture at 20, 40, 80 and 120 kg/ha in three forms of fertiliser – conventional superphosphate, a fully-reverted dicalcic product, DP65, and a proprietary product from Terracare, Replenish, which contains dicalcium phosphate as part of its composition.

The trial continued for three and a half years, until December 2012 during which time the fertiliser treatments were re-applied twice giving a total of three applications.
Pasture was harvested whenever the ryegrass component of the sward reached the three-leaf stage, and production (in terms of dry matter (DM) yield) was recorded for each plot.

The site was soil sampled (0-75mm) at the start of the trial, and then just before each re-application of treatment fertilisers as well as on completion.

Pasture yield
There were significant responses to both the rate and form of P fertiliser throughout the trial.

Averaged over the duration of the trial, the annual yield for the control treatment was 8,450 kg DM/ha, while at 120 kg P/ha/year, superphosphate gave 11,010 kg DM/ha, Replenish, 12,500 kg DM/ha and DP65, 11,680 kg DM/ha.

Soil tests
The pattern of soil Olsen-P tests differed between fertilisers. Superphosphate increased Olsen P more than either DP65 or Replenish, with test results on the 120 kg P/ha treatments reaching 31 on the superphosphate 22 on the Replenish, and 19 on the DP65, treatments.

Soil Resin P tests were not affected by the form of P used, and so may be a more reliable test to use when assessing the performance of dicalcic P fertilisers than the Olsen P test.

REDUCTION OF NITROGEN AND PHOSPHATE FERTILISER INPUTS WHILE INCREASING PASTURE PRODUCTION

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Soil micro-organisms play a significant role in plant nutrient uptake and overall pasture and crop production. Micro-organisms aid in the conversion of atmospheric gases to plant available nutrients and facilitate locked up nutrients within the soil particle to be utilised by plants. However, the role of micro-organisms within the soil has been recently overlooked. Not only have pastures become heavily reliant on soluble synthetic fertilisers, but it seems New Zealand's farmers have too, spending approximately 1.5 billion dollars on fertiliser per year.

The two most applied fertiliser nutrient inputs are nitrogen and phosphorous. Phosphate fertiliser research in New Zealand has shown that where less soluble phosphate fertilisers are used, optimal pasture production can be achieved with lower soluble phosphate levels in the soil. Soluble phosphate and nitrogen fertiliser applications reduce mycorrhizal activity within the rhizosphere and consequently increase the plants reliance on high amounts of these soluble nutrients.

Recent developments in fertiliser strategies have shown a potential for humic compounds to aid in reducing synthetic fertiliser inputs, while maintaining pasture production. Humic acid encourages soil micro-organism activity and improves nutrient cycling and efficiency. Humic compounds also chelate soluble nutrients and increase plant root mass further improving water and nutrient uptake.

When planning to improve nutrient efficiency and plant uptake of nutrients it is important to consider the interaction of plant roots and plant symbionts such as mycorrhizal fungi and their associated bacteria. Consumers are actively becoming more aware of the impact their food production has on the environment. Nitrogen and phosphorus losses to water that result from use of soluble phosphorus and nitrogen fertilisers can have a detrimental impact on the environment and therefore the opportunity to use humic acid and other microbial stimulants along with slow release fertilisers should not be disregarded.

COMMERCIALISATION OF THE ONESYSTEM® WETTED, NBPT-SPRAYED PRILLED UREA TECHNOLOGY IN NEW ZEALAND AND VICTORIA, AUSTRALIA

Bert F. Quin, Shane Harold, Stewart Spilsbury and Geoff Bates

Quin Environmentals, Auckland

Granular urea fertiliser is relatively low cost per unit nitrogen (N) and has a high N content of 46%. These factors make it convenient to transport and store, and it's granular (5mm) size makes for wide and therefore economical spreading; its use in New Zealand (NZ) has grown to over 600,000 tonnes product annually, the large majority on dairy and intensive beef farms. However, it is known to be agronomically very inefficient. Typical EDM factors (extra kg dry matter per kg N applied) range from 5-20, with a widely accepted default factor a 10. This represents an N Utilisation Efficiency (NUE) of only 30%.

Technology developed in 2005 to crush and fluidise of granular urea in an on-board spreading truck system greatly increased NUEs but the high cost of equipment maintenance and much narrower (10m) spreading width~~s~~ increased operating costs and limited the uptake of this technology. The introduction of the ONEsystem® as a quad-bike tow-behind proof of concept research trial prototype in 2014 demonstrated that these much higher NUEs could be obtained far more easily and cheaply, and very acceptable spread widths obtained. However, significant obstacles have had to be overcome to get the technology to the truck-based size required for adoption by spreading contractors and large dairy and intensive beef farms in NZ.

The fundamental problem is that the existing fleet of spreading trucks in New Zealand use chains or rubber belts to deliver product from the hopper to the spinning discs. While these systems work well for granular products applied at over 70 kg/ha product weight, product delivery generally becomes unacceptably variable at lower application rates. In the case of NZ, his problem was successfully overcome by the development of totally new technology for delivery of the product to the spinning discs for truck-mounted systems. This enables application rates as low as 20 kg product/ha to be achieved with over 20m spread and CVs well below 15%. In Gippsland, Victoria , where the first ONEsystem® licence is already operating, the concentration of sufficient farmer clients in a small geographic area has allowed the use of Kuhn tractor-mounted technology with in-built spreading modes for both prills and granules.

The proven efficiency of ONEsystem® will ironically be a significant barrier to commercialisation in a duopoly where both players are dependent for much of their current net profit on granular urea. However, as already seen with Sustain® and N-Protect®, farmer demand eventually gets results.

TRIALS AND TRIBULATIONS WITH USE OF GA_3 ON PASTURES – WHAT DO LONGER TERM TRIALS TELL US?

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Ballance carried out extensive field trials in New Zealand and Northern Ireland over the period 2013-2016 to evaluate the effectiveness of gibberellic acid (GA_3) applied with or without N-fertiliser. At GA_3 application rates of 8-30 g (active)/ha, these trials showed that there was a rapid increase in pasture dry matter (DM) production to GA_3 at the 1st harvest, relative to control and nitrogen only treatments. However, this was followed by a very consistent depression in pasture growth rate at the 2nd and/or 3rd harvests. This depression in pasture growth rate was consistent regardless of whether GA_3 was applied with or without N-fertiliser, indicating that the effects of N-fertiliser and GA_3 were additive. As a consequence of this depression in pasture growth rate, total pasture DM yield measured over 2-3 harvests was not increased by application of GA_3, although GA_3 influenced the timing of when this feed was generated.

SOIL ACIDITY IN THE KAKANUI RANGES

Hendrik Venter

Ravensdown, Analytical Research Laboratories

Aluminium toxicity is the primary yield limiting constraint associated with acidic soils, limiting the ability of roots to utilize soil moisture and nutrients. Elevated Aluminium levels were observed for routine customer samples received from the Kakanui ranges. Prominent commercial laboratories in New Zealand measure only 0.02 M $CaCl_2$ extractable Aluminium while exchangeable Aluminium measured in 1M KCl is also an established method no longer offered in New Zealand. In order to compare these two different test methods for Aluminium on Firm Brown soils, surface and subsoil samples in 15 cm increments up to 60 cm were obtained from a farm located in the Kakanui ranges. Samples were analysed for extractable Aluminium, exchangeable Aluminium, basic cations in 1M Ammonium acetate, pH in water and 1 M KCl.

Surface soils (0 – 15 cm) that received no lime had mean values for pH (H_2O) 4.9, pH (KCl) 3.7, extractable Aluminium 23 mg/kg and exchangeable Al saturation of 61 %. Where lime was applied in the past, mean values were pH (H_2O) 5.7, pH (KCl) 4.5, extractable Aluminium 2 mg/kg and exchangeable Al saturation of 8 %. Subsurface soil layers 15 – 30 cm, 30 – 45 cm and 45 – 60 cm had mean values ranging for pH (H_2O) 5.3 – 5.4, pH (KCl) 3.8 – 3.9, extractable Aluminium 17 - 25 mg/kg and exchangeable Al saturation of 49 – 76 %. Poor root penetration into the subsoil beyond 15 cm as observed during sample collection is likely a result of high soil acidity levels. Relationships between soil acidity parameters weakened progressively from the 0 – 15 cm down to the 45 – 60 cm soil layer.

Ameliorating surface soil acidity through liming is standard practice while ameliorating subsoil acidity is either done through subsoil liming, surface application of lime or gypsum. A soil – gypsum laboratory incubation showed this soil to be unresponsive to gypsum for decreasing exchangeable Aluminium concentrations, although Aluminium saturation decreased.

NUTRIENT CONTENT OF LIQUID AND SOLID EFFLUENTS ON NZ DAIRY COW FARMS

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Since around 2000 there has been an intensification on New Zealand dairy cow farms due to higher stocking rates, an increased use of nitrogen fertiliser and greater reliance on imported feed supplements. As a result on-farm structures such as feed pads or animal shelters/housing have been constructed by farmers so that they can achieve better feed conversion efficiencies for this expensive food. Because cows are concentrated for longer periods on these structures greater amounts of effluent are now being generated on farms than pre-2000.

On-farm effluent management is now much more complex as farmers can be faced with having to treat different forms of effluent as either liquids, slurries or solids. In addition Regional Councils have been enforcing more stringent environmental regulations, e.g., the requirement for greater effluent pond storage and the focus on nitrogen loading rates to pastures. Therefore the modern NZ dairy farmer is challenged with the containment, treatment, and land application of a wide range of effluents with different physical and chemical characteristics.

Much of the published information of effluent composition is from pre-2000 data which reflected mostly all-grass dairying. Laboratory chemical analysis have been collated and summarised to provide updated data that reflects current dairying practices concerning farm dairy effluent (from sumps and storage ponds), dairy slurries and solids (from feed pad scrapings, weeping walls, static screens and mechanically separated), plus similar materials from animal shelters/housing.

GETTING DAILY WATER IRRIGATION RECOMMENDATIONS DIRECT TO FARMERS

Bridgit Hawkins

Regen Ltd, Wellington

Smart tools enable farmers to operate at best practice, and to report on their actions. Regen Water is a smart tool to get daily water irrigation recommendations direct to the farmer. It is an automated, cloud-based service that uses sensor data, weather forecasts and predictive models to put best practice daily water irrigation scheduling in farmers hands via a mobile application. In addition to daily recommendations, all irrigation actions carried out and soil conditions are continuously recorded and available for regulatory reporting.

Best practice irrigation management is essential to ensure the maximum benefit can accrue from irrigation while at the same time minimising the negative environmental impacts. For an irrigator to apply best practice irrigation management every day they need to have at hand a wide array of knowledge about their soil type, irrigation system and crop requirements along with up-to-date information on the current soil water deficit and the forecast weather. All of this information then must be processed through to establish if irrigation is required and to what depth. The Regen Water service does exactly this for the irrigator.

To deliver the service Regen utilises on-farm sensors to automatically and constantly measure variables of interest, telemetry to capture the data, the cellphone network to transmit the data, the cloud to store the data. Once in the cloud the Regen application uses modern software tools to run sophisticated processing algorithms which transform the raw sensor data into useful information. The resultant information is then displayed in easy to interpret visual format via a mobile application and a desktop view. As the data and the processed information is all securely stored in the cloud it is accessible to authorised users from any location with an internet location.

Consent conditions attached to water irrigation are continuing to evolve and require a greater and greater level of detailed recording. The Regen Water service collects all the required information in the process of providing the daily recommendation, so not only is the irrigator able to operate best practice they are ideally placed to provide auditable evidence of this when required.

THE IMPACT OF USING TREATED SEWAGE EFFLUENT TO IRRIGATE ARID FORESTS IN THE HYPER-ARID DESERTS OF ABU DHABI

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The arid forests of Abu Dhabi provide a variety of valuable provisioning, regulating and cultural ecosystem services. However, the forests need to be irrigated. They are in a hyper-arid environment. Her Excellency Razan Khalifa Al Mubarak, head of EAD, has said that for arid forestry "... *our objective is to ensure that recycled water is used for irrigation, while conserving groundwater resources.*" Over the last two years we have carried out experiments at two desert locations, Madinat Zayed and Al Salamat, on four arid-forest species: Al Ghaf, Sidr, Arak and Samr. This has involved the use of both groundwater and treated sewage effluent (TSE) to irrigate the trees.

Here we show new results from our work on Al Ghaf and Sidr trees. We highlight that for both species, the summer 'deciduous behaviour' determines tree water use and irrigation requirements. For the Sidr trees, the irrigation response with TSE continues to be dramatic, and suggests how TSE water use can be reduced, so that more value can be achieved with the same amount of TSE.

We also describe the new experimental set-up on the Arak trees where we are using weighing lysimeters to monitor tree-water use, because these multi-stemmed trees are not suitable for using heat-pulse sap-flow monitoring. We also comment on the different experimental set-up we have adopted for the Samr trees, where we have been able to insert heat-pulse probes into the roots of several of the trees. These roots are apparently drawing water from beyond the small zone that is just wetted by the drippers.

We conclude with a discussion of how these results are being used to guide policy development in relation to groundwater usage, and the implementation of TSE irrigation of arid-zone forests.

PREDICTING LAND-BASED NITROGEN LOADS AND ATTENUATION IN THE RANGITIKEI RIVER CATCHMENT – THE MODEL DEVELOPMENT

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Under the National Policy Statement for Freshwater Management 2014 (NPSFM), Regional Councils are required to produce a set of 'freshwater resource accounts' for defined individual Freshwater Management Units (FMUs) in their regions. This requires establishment of a freshwater quality accounting system which is based on measured, modelled or estimated loads of relevant water contaminants in groundwater and surface water bodies.

Nutrient budgeting tools (such as Overseer NB) have been developed to account for nutrient flows and losses from farming systems. However, these models mostly account for nutrient flows within the farm boundary and predict nutrients losses from the root zone. Catchment characteristics like land use, topography, rainfall, soil type, underlying geology, and subsurface geochemistry may further affect the transport and transformation of nutrients such as nitrate-nitrogen (NO_3-N) along flow pathways from farms to rivers and lakes.

We investigated and developed a simple model to account for the influence of different soil types and underlying geology on the transformation of nitrogen (N) in the Rangitikei River catchment. The main soil and rock types of the catchment were classified into low, moderate and high N attenuation capacities, depending on their texture, drainage rate and carbon content. These N attenuation capacity classes were assigned a nitrogen attenuation value in order to predict nitrogen loads to the river. The river N loads predicted in this manner were compared with the N loads measured in the river.

We found that the nitrogen loads measured in the river were significantly smaller than the estimates of the quantities of nitrogen leached from the root zone. The prediction of N loads in the river was significantly improved by incorporating the spatial effects of different soil types and underlying geologies on N attenuation in the subsurface environment of the Rangitikei River catchment.

PREDICTING LAND-BASED NITROGEN LOADS AND ATTENUATION IN THE RANGITIKEI RIVER CATCHMENT – THE IMPLICATIONS FOR LANDUSE

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Regional Councils are required to produce a set of 'freshwater resource accounts' for defined individual Freshwater Management Units (FMUs) in their regions. One of the benefits of these accounts is that they can assist in the management of the impacts of landuse on freshwater quality.

Accounting exercises need to predict the attenuation in nitrate-nitrogen (NO_3-N) that occurs along flow pathways from farms to rivers and lakes. This nitrogen attenuation capacity is often highly variable between, and within, catchments and is dependent on characteristics like; land use, topography, rainfall, soil type, underlying geology, and subsurface geochemistry. A simple model was developed to account for the influence of different soil types and underlying geology on the transformation of nitrogen (N) in the Rangitikei River catchment.

The model was then used to investigate the effects of changing landuse intensity, i.e. nitrogen leaching from farm systems, on water quality in the Rangitikei River. Three scenarios were considered; decreasing nitrogen leaching from low N-attenuation areas, increasing nitrogen leaching in high N-attenuation areas, and a combination of these two strategies.

Decreasing the intensity of landuse in low N-attenuation areas in the Rangitikei catchment decreased N leaching from farms slightly but substantially lowered the N load in the River. Increasing the intensity of landuse in high N-attenuation areas in the catchment generated a large increase in the quantity of N leached from farms but resulted in a relatively small increase in N load in the River. Where both the intensity of landuse in high N-attenuation areas was increased and the intensity of landuse in low N-attenuation areas was decreased, N loss from agricultural land was greater but, importantly, N load to the River was lower. The approach described here is useful to identifying the potential (so-called) 'head space' for increased N leaching from farms within catchments and more efficiently allocating landuse intensity to contrasting landscapes.

SPATIAL TARGETING OF MITIGATION STRATEGIES TO REDUCE NUTRIENT LEVELS IN WATERWAYS WHILE MINIMISING PRODUCTION LOSS

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This talk discusses recent adaptations to the Land Utilisation and Capability Indicator (LUCI) spatial framework that enhance its ability to predict water quality outcomes, and to quickly target where management interventions could improve water quality while minimising productivity loss. LUCI is an integrated framework considering how land use and management impact a range of landscape provisions including flood mitigation, water supply, greenhouse gas emissions, biodiversity, erosion, sediment and nutrient delivery to waterways, and agricultural production. Past versions of LUCI inferred nutrient loads from simple export coefficients, generally based on nationally available land cover categorisations. New methods that also account for soil type, slope, management, and climate among other factors have now been developed, trained off a combination of data and other models, most notably Overseer. This new and more nuanced approach is demonstrated, and “validated” against data. A new automated method to identify opportunities to both reduce nutrient load and to intercept nutrients enroute to waterways while minimizing productivity loss is presented, and demonstrated at both farm and catchment scale.

DEVELOPING N & P EXPORT COEFFICIENTS FOR RURAL NEW ZEALAND LANDSCAPE MODELLING IN LUCI

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Increasingly New Zealand farmers and land managers are expected to reduce nutrient losses from their land to water. A number of models and methods are routinely used to assist with this task, but few offer quantification and solutions at fine spatial scale, yet are easily applied. The Land Utilisation & Capability Indicator (LUCI) is an option in this regard.

LUCI is a GIS framework that considers impacts of land use on multiple ecosystem services in a holistic and spatially explicit manner. A number of ecosystem service stocks and associated indicators and processes, including water quality (e.g. total nitrogen, TN and total phosphorus, TP), can be assessed. In LUCI models can be run for individual ecosystem service analysis and to analyse the interrelationships between ecosystem services.

We are currently developing a bespoke version of LUCI for the Ravensdown co-operative that will assist New Zealand farmers and other land managers with decision making around farm ecosystems, in particular water quality. LUCI water quality models use an enhanced, spatially representative export coefficient approach and one aim of the collaboration is development of suitable export coefficients for use in LUCI when applied in the New Zealand rural environment.

Using a small agricultural catchment case study (Massey University Tuapaka Farm), I will discuss ongoing work to develop unique algorithms that consider climate, soil, hydrological and land management variables, and their combinations, to calculate TN and TP export coefficients for pastoral land covers. I will briefly discuss the sensitivity of TN and TP predictions in LUCI to datasets of different resolution and accuracy and make comparisons among LUCI, OVERSEER and actual TN & TP measurements.

USING MONTHLY STREAM WATER QUALITY DATA TO QUANTIFY NITRATE TRANSFER PATHWAYS IN THREE WAIKATO CATCHMENTS

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Monthly water quality sampling at the catchment outlet is carried out at many sites across New Zealand for state of the environment monitoring. This data is used for trend analysis, but little else. We have been exploring approaches for using this data in conjunction with concurrent stream flow data to identify and quantify the principal nutrient transfer pathways within catchments. In particular, monthly data may provide sufficient information for an inverse modelling approach.

Three contrasting mesoscale catchments were chosen for this study: (1) the Tahunaatara Stream (208 km^2) in the Upper Waikato sub-region, (2) the Puniu River (519 km^2) in the Waipa sub-region, and (3) the Mangatangi River (195 km^2) in the Lower Waikato sub-region. By considering four years of monthly water quality data from these catchments, alongside daily rainfall, potential evapotranspiration, and stream flow measurements, we were able to use the daily time step, spatially lumped catchment model "StreamGEM" with the Markov Chain Monte Carlo algorithm "$DREAM_{ZS}$" to predict daily stream flow and nitrate fluxes arriving at the catchment outlet via near-surface (NS), shallow fast seasonal groundwater (F), and deep slow older groundwater (S) flow paths, as well as to estimate the reliability/uncertainty of these predictions.

Despite high uncertainty in some model parameters, the flow and nitrate calibration data was well reproduced across all catchments (Nash-Sutcliffe in the range 0.70–0.83 for daily flow, and 0.17–0.88 for nitrate concentration, both on log scale). Proportions of flow attributed to near-surface, fast seasonal groundwater and slow older groundwater were well defined, and consistent with expectations based on catchment geology. Fast groundwater carried the bulk of the nitrate (range 31–97%) in all of these catchments, although contributions from slow groundwater were also high at Tahunaatara (range 18–63%), while contributions from near-surface flow were high at Mangatangi (range 24–63%).

This research highlights the potential of process based, spatially lumped modelling with commonly available monthly stream sample data, to elucidate high resolution catchment function, when appropriate calibration methods are used that correctly handle the inherent uncertainties.

EXPORT OF NITROGEN AND PHOSPHORUS FROM ARTIFICIALLY DRAINED DAIRY PASTURES IN THE HAURAKI PLAINS

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Artificial drainage is one of the fastest transfer pathways from the paddock to surface waters, with the potential for N and P lost from the root zone reaching surface waters essentially unattenuated. The N and P exports measured during the 2016 drainage season on two dairy farms in the Hauraki Plains will be presented and discussed. These two sites differ in their farming practices, soils, groundwater level dynamics and the reason why artificial drainage is installed.

At the Waharoa site, the soil profile becomes saturated from the "top down" due to low permeability zones within the soil zone, and drainage discharge began eight weeks earlier (mid-May) than at the Tatuanui site (mid-July). A shallow groundwater table seasonally rising into a fairly permeable soil zone is thought to cause wetting from the "bottom up" at Tatuanui.

The initial nitrate-N concentrations in Tatuanui drainage water were less than 1 mg/l NO_3-N. However, two weeks later nitrate-N concentrations had increased to nearly 9 mg/l NO_3-N coinciding with peak drainage flow rates of 10 l/s. The initial low nitrate-N concentrations are considered to result from the mixing of the leachate draining from the soil zone, with reduced shallow groundwater. Once the water table had risen to the depth of the installed drainage, the drainage water exported was considered to be dominated by the water percolating through the soil zone, in response to rain.

Nitrate-N represented approximately 80% of the total-N discharged (data up to mid-Oct 2016) at both sites. While NH_4-N and Organic N made up the remainder in nearly equal proportions at the Tatuanui site, at the Waharoa site the NH_4-N exported was less than 1% of the total N. The highest total-P concentrations occurred in the early part of the drainage season due to the influence of the reduced groundwater and at the peak flows in drainage events. Once the drainage was dominated by soil leachate, the total-P concentrations were generally low (< 0.004 mg/l). At both sites, dissolved-P represented about 60% of the total-P measured, and dissolved reactive P accounted for approximately 25% of total-P.

SELECTION OF CATTLE SUPPLEMENT FEEDING AREAS TO REDUCE NUTRIENT AND SEDIMENT LOSS IN SURFACE RUNOFF

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Nutrient and sediment loss from hill country can impair water quality of receiving streams and rivers. This study quantified the surface nutrient and sediment runoff loss associated with feeding hay supplements to cattle in hill country on two contrasting soil types. The research was carried out at Massey University's hill country farm called Tuapaka, located near Palmerston North, NZ. Two sub-catchments (~0.3 ha) were defined using 1 m LiDAR digital elevation data and then instrumented to collect surface runoff. One sub-catchment was comprised of a Korokoro soil which is at higher risk of surface runoff due to its imperfect drainage and medium P sorption capacity. The second sub-catchment was made up of Ramiha soil which has a low risk of surface runoff due to good drainage and higher P sorption capacity.

Runoff samples were collected over a 43 day period during winter 2015. During this time, two herds of 16 mixed aged Angus cows were fed 2 kg DM/cow/day of hay in a defined feeding area within each sub-catchment. There were 7 runoff events over the study period. There was 4.5 times the volume of surface runoff measured from the Korokoro soil compared to the Ramiha soil. As a result, the Korokoro soil lost 4.5, 7.3, 5.5 and 2.5 times the amount of total N, total P, dissolved reactive P and sediment, respectively, compared to the Ramiha soil. Surface losses of nitrate-N from the Ramiha soil were undetectable over the study period, but were <0.07 kg/ha from the Korokoro soil. Whilst total nutrient losses were low over the short study period (<0.22 kg total P/ha and <0.7 kg total N/ha), the results highlight the benefits of strategically placing cattle feed supplements in winter on areas less prone to surface runoff. These findings are important as they present a simple, cost neutral method of reducing nutrient and sediment losses in sensitive agricultural environments.

ASSESSING FARM-SCALE NUTRIENT FLOW PATHWAYS AND NITRATE ATTENUATION IN RANGITIKEI SAND COUNTRY

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Recently, there has been significant agricultural development in lower North Island coastal dune areas, extending partly across the lower coastal parts of the Rangitikei River catchment. With the introduction of irrigation, coastal dune areas have become viable for production. However, little is known about transport and fate of nutrients lost from intensive farms in this environment.

A case study farm was selected and monitored for six months from April to September 2016, in order to assess flow pathways and transformation 'attenuation' of nitrogen (N) and phosphorus (P) in an intensively-farmed dairy farm within the Rangitikei sand country. The farmland was previously sand dunes, but is now in pasture with centre pivot irrigation. A total of nine piezometers and twelve surface water sample sites were established to monitor shallow groundwater and surface waters in drains and stream flowing through the farm. The shallow groundwater piezometers were divided between four sites covering main soils types on the farm, and extended to depths of 3 and 6 m below ground level (bgl). The groundwater samples were collected monthly and analysed for nitrate-N, ammoniacal-N, total-N, dissolved reactive P and total-P to monitor nutrient flows. Dissolved organic carbon, manganese, iron and dissolved oxygen parameters were also measured and analysed to assess the reducing potential of the shallow groundwater. The surface water samples were collected fortnightly and analysed for different forms of N and P to assess any potential loss of nutrients through open surface drains and the freshwater stream that runs through the property.

This six-month intensive monitoring of the farm found that the open surface drains on the property accumulate nitrate-N and could be a significant contributor of nitrate-N to the local stream. Also, dissolved reactive P was more common in shallow groundwater environment. The shallow groundwater appears to have a strong reducing environment, conducive for potential denitrification of nitrogen leached from the soils surface. This could have implications for land and N management strategies in the future. These research findings will help to develop appropriate in-field or edge-of-field management practices, and inform nutrient management plans for intensified land use to maintain or enhance water quality in the region.

ADVANCING ON-FARM PHOSPHORUS LOSS MITIGATION IN CONJUNCTION WITH APPLIED RESEARCH ON A NEW MITIGATION TOOL - THE DETAINMENT BUND

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Phosphorous is applied as fertilizer to pastoral agricultural systems in New Zealand, to enhance productivity that could be limited by low soil P availability. Short, intense rain events that cause storm water surface runoff transport significant amounts of P and sediment to receiving waterways from farmland. Biological productivity in freshwater ecosystems is often P limited, and added P may have environmental implications. A 2010 study found ~32% of New Zealand lakes could be eutrophic or worse.

Utilizing cost-effective strategies on farmland to lessen the amount of P reaching waterways and lakes is a high priority because treating lake water can be expensive. Detainment bunds are storm water retention structures with a high ponding volume relative to catchment size. DBs constructed in targeted hydrological pathways in farm catchments have been identified as a possible way to lower the amount of P carried by surface runoff to lakes.

Twenty-two DBs have been constructed in the Rotorua district in recent years. Previously, an MSc research student conducted research on the performance of 3 of the DBs. Settled sediments transported by storms and grab samples of storm water passing through the DBs were analysed. Results showed that ponding water for 3 days behind a DB allows P associated with particulates to settle out of the water column, although dissolved nutrients may not be impacted. The current 'Phosphorus Mitigation Project' PhD research will further investigate the potential of DBs to be a cost-effective way to manage P runoff from productive farmland before being considered for widespread promotion. Improved data and sample collection over a 3-year period will attempt to identify specific quantities and fractionation of P entering and leaving the DB. Mechanisms and processes affecting P dynamics under ponded conditions will be investigated to advance understandings, and potentially optimize this strategy, to limit P loss from agricultural fields into Lake Rotorua.

The Phosphorus Mitigation Project is funded by DairyNZ, Beef + Lamb NZ, NZ Deer Industry, the Sustainable Farming Fund, Ballance Agri-Nutrients and three Regional Councils. Supporting institutions include Massey and Waikato Universities with advisory assistance from staff at NIWA and Lincoln University.

UNDERSTANDING THE INEFFECTIVENESS OF CU AND ZN IN REDUCING UREA HYDROLYSIS LOSSES FROM GRAZED DAIRY PASTURE SOILS

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The intensification of dairy farming in New Zealand (NZ) has resulted in an increase use of urea nitrogen (N) fertiliser and, consequently, higher potential ammonia (NH_3) emissions. The commonly used urease inhibitor, N-(n-butyl) thiophosphoric triamide (nBTPT), (i.e. Agrotain®), does reduce NH_3 emissions when applied with urea fertiliser or cattle urine but it is short-lived (7-14 days). In some studies micronutrients such as Cu and Zn have been shown to inhibit soil urease enzyme activity (UEA) and reduce NH_3 emissions over a longer duration than nBTPT.

In a recent study (Adhikari et al., 2016) using 24 dairy farm soils of the Waikato region, with contrasting inherent Cu and Zn levels and soil carbon (C), did not observe any significant negative correlations between soil UEA, and inherent Cu and Zn levels. This current study was conducted using 4 dairy farm soils with contrasting soil C levels to quantify the effect of adding different amounts of Cu and Zn to soils on UEA. There was no significant reduction on soil UEA by any of these treatments. In addition, laboratory study was conducted to determine whether effectiveness of Cu and Zn at inhibiting soil UEA by using soil supernatant from 2 dairy farm soils. This was conducted to test whether reducing the potential for Cu to complex with soil organic matter would increase Cu bioavailability and improve its effectiveness at inhibiting urea hydrolysis. All treatments with Cu showed significant reductions in urea hydrolysis, but not for Zn. This result suggests that while Cu does inhibit urea hydrolysis, its ineffectiveness in pasture soils could potentially be attributable to the high organic C content present, which promotes immobilisation of Cu through adsorption and chelation causing, reduced bioavailability. Although most of the Zn added was bioavailable, the observed levels of bioavailable metal had no effect on soil UEA.

CURRENT CHALLENGES IN GOLD3 KIWIFRUIT NUTRIENT MANAGEMENT RESEARCH

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The current nutrient management practices for G3 need to be optimized in a sustainable manner to potentially improve fruit production with an assurance of high quality standards and minimal impact on environment.

This study will take into consideration the current nutrient management practices and is aimed to manage vine vigour and develop best nutrient management practices to optimize fruit quality and production and preserve environmental quality with cost-effective inputs. It needs profound understanding of source-sink relationship, effective application methods for different nutrients and their interaction, environmental impact and cost efficiency.

The paper will focus on the role of nitrogen (N) and potassium (K) and their interaction with other macro/micro nutrients on nutrient uptake and availability, vine vigour, growth and quality of fruit. Specifically, this paper will discuss and investigate the effect of different forms, rates, and timing of application of soil and foliar applied N and K fertilizer on production and fruit quality.

The paper will also discuss the nutrient budgeting and approaches to minimize environmental footprints.

NUTRIENT INTERACTIONS WITH ACTIVATED CARBON'S SURFACE CHEMISTRY

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Inorganic nitrogen contaminants (INC) (NH_4^+, NO_3^-, NO_2^-) pose a significant risk to the environment and their remediation methods are highly sought after. Application of carbonaceous material (CM) to adsorb INC has gained a lot of interest since past few years. However, INC interactions with surface functional groups of carbon are not well characterized. In addition, the fundamental mechanism of INC chemisorption with AC surface is poorly understood.

Acid-base interaction, cation exchange mechanism, electrostatic interaction, H-bonding, and ion-exchange are the chemisorption mechanisms that are proposed for various INC species adsorption on CM. Most of the studies have varying mechanisms predicted for a single INC species interaction with CM. Reasons cited for differences in observations are different source materials for CM, varying physical and chemical treatments given to CM, and inconsistent experimental parameters. Based on these studies and proposed hypothesis, it is extremely difficult to develop a standard adsorption mechanism.

This research has reviewed the role of various SFG and important factors influencing chemisorption of individual INC. With this understanding, regardless of several varying parameters, the interaction of given CM with INC can be predicted based on SFG analysis which aids in better predictability and process control for adsorption. Oxygen containing surface functional groups (OCSFG) have the major influence over adsorption of INC compared to basic SFG. A given SFG has been found to have more than one type of influence (positive and/or negative) on INC adsorption. It was also evident that, along with SFG, physical properties of CM and matrix play an equally import role. The next challenge lies in understanding the changes in SFG of CM during long-term exposure in soil or water, and how it impacts transformation of INC.

NITROGEN LEACHING, PRODUCTIVITY AND PROFIT OF IRRIGATED DAIRY SYSTEMS USING EITHER LOW OR HIGH INPUTS OF N FERTILISER AND FEED: THE PASTORAL 21 EXPERIENCE IN CANTERBURY

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Dairy systems in Canterbury are based on two main parcels of land: the milking platform (MP), and support land (SL) for growing winter crop to feed dry cows. Production, profit, and nitrate leaching rates of two irrigated MP systems and three irrigated SL options were compared for 4 years in Canterbury. The MP systems were: 'low input' (LI), operating with 150 kg N/ha and 0.3 t DM imported supplement per cow per year, with a stocking rate of 3.5 cows/ha; and 'high input' (HI), operating (320 kg N/ha, 1 t DM/ha imported supplements, and 5 cows/ha). These systems represented a lower input strategy for reducing N losses (with questions regarding impacts on pasture growth rates, utilisation of pasture, and total production) versus a continuation of the historical industry trend of increasing intensification on the MP.

Three SL treatments were also compared: kale sown in October (K1); kale sown in December following harvest of a catch crop of oats that was sown immediately after winter grazing was completed (K2); or fodder beet sown in October (FB).

Compared with HI, the LI strategy resulted in 23% less nitrate leaching (Overseer 6.2.2) on the MP and was more profitable at milk prices below $6.30/kg milksolids. When all hectares used for feed production (MP, SL, plus areas providing imported supplements) were considered, nitrate leaching was higher under HI than LI (mean across SL treatments of 66 versus 52 kg N/ha per year respectively: Overseer 6.2.2) and higher under K2 than FB (68 versus 49 kg N/ha per year). When scaled to a 160 ha MP, the commensurate wintering area contributed 1.2 times the total amount (kg) of N leached when the crop was K2 versus only 0.4 of the total amount of N leached from the MP when the crop was FB, due to the high yield of FB and associated reduced area required to meet fed demand. Direct measures of leaching from SL using suction cup samplers confirmed lower leaching losses from FB than from kale. Significant opportunities for reducing leaching from SL using catch crops (e.g. K2) were also identified.

APPLYING PASTORAL 21 FARMLET RESEARCH TO A WHOLE FARM

Ron Pellow

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The P21 research had impressive goals; profitable, simple, adoption-ready systems that lifted production and reduced nutrient loss. Farmlet comparisons were a core component and can be a valuable means of determining, and demonstrating comparative performance. Great farmlet research however does not automatically result in rapid uptake at scale, and results at scale, in a whole farm system may not replicate the farmlet results.

Faced with a choice between significant infrastructure investment, to reduce nutrient losses (primarily N-leaching) or scale up the lower input, high productivity, lower nutrient loss P21 research (LSE), Lincoln University Dairy Farm chose the latter.

Three years of research, two kilometres away, with 29 cows on 8.25 hectares showed that a system based on less N-fertiliser and imported feed, that achieved high production from home grown, grazed pasture could maintain profitability. N- leaching was estimated to be significantly lower, on a like for like soil type / assumption basis.

Transitioning into the system was straight forward, backing out of it, however, if it was not scalable, could be very costly. One of the key changes, for example, was an 11% reduction in cow numbers. While it's relatively easy to sell lower performance animals to reduce herd size, replacing these, if required, would result in purchasing higher value animals.

Modelling of the system confirmed the research results - it looked feasible - though the system was tight on feed supply, and required high levels of overall production to achieve the desired level of profitability. Not initially apparent from the research was the potential impact of regrassing on feed supply, which had been a core part of LUDF's push to lift productivity from pasture.

Now into the third year of running this farm system, experience at LUDF has shown the 'LSE' farmlet system was adoptable and could be profitable while also reducing Overseer® modelled nitrogen nutrient losses. Whilst there were a number of key learnings discovered in the first year, and subsequently refined, the farm's performance clearly shows this research can be applied to a whole farm.

USING DURATION CONTROLLED GRAZING AND DIET TO MANIPULATE N LEACHING LOSSES

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As part of the Pastoral 21 (P21) research programme a farm scale trial was established in 2013 at Massey University's Dairy 4 Farm to test the hypothesis that a commercial, system 3-4 dairy farm, operating a free stall barn as a standoff/feeding facility and practicing duration-controlled grazing (DC) could alleviate winter-spring treading damage on imperfectly drained soils. This would increase pasture production, and at the same time reduce N leaching loss and P contamination via runoff, when compared to a dairy farm operating a standard feed pad system.

Two 200-cow farms were set up. The "House" farm (2.88 cows/ha, 69.5 ha effective) utilised a 200-cow free-stall barn to winter all cows on-farm and practice DC grazing in summer and autumn to reduce the excretal load on pastures, and in winter to reduce the treading damage. The "Standard" farm (2.63 cows/ha, 76 ha effective) was managed as a typical pastoral based, system 3-4, farm in the Manawatu region with an uncovered concrete feedpad (250-cow capacity), which was used to feed maize and pasture silage supplements to this herd and 40% of the cows in the herd were grazed off over the winter period. Farms were matched with a similar distribution of soil types, overall fertility, distance to the milking shed, and herd characteristics (age and average BW of 122 ± 1% and PW of 145 ± 1.5%). Both farms had a spring seasonal calving pattern. The dominant Pallic soil types on both farms were mole and pipe drained Tokomaru silt loam and Ohakea silt loam, with small areas of Halcombe hill soil on the easy slopes. Mole and pipe drainage water quality was monitored at the paddock scale.

Total milk solids production (2014/15 and 2015/16) per hectare was on average 8% higher in the House (1317 kgMS/ha) than the Standard (1211 kgMS/ha) system. Year-round DC grazing (50% of the cows time off paddock) achieved a 48% reduction in nitrate leaching, whilst DC grazing only in late-summer/early-autumn (~20% time off paddock annually) achieved a 29% reduction in nitrate leaching. Differences in P runoff between the systems were not significantly different.

The operating costs (including depreciation on capital) for the House and the Standard systems were $5.73and $4.61 /kgMS, respectively. The increased production was not sufficient to cover the higher operating costs of the House system.

FOLLOWING THE NITROGEN: EXPLAINING THE REASONS FOR DECREASED N LEACHING IN THE WAIKATO P21 FARMLETS

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The objective of Phase 2 of the Pastoral 21 (P21) programme was to increase profitability of pastoral farming while reducing environmental footprint. Dairy farmlet studies were set up in four major dairying regions of NZ (Waikato, Manawatu, Canterbury, Otago/Southland), and designed to represent regionally relevant issues and farm systems. One of the key achievements of the programme was the 30% average reduction in nitrogen (N) leaching losses demonstrated across the four dairy regions.

The P21 Waikato farmlet had a strong focus on N management and compared two systems: 'Current' (representing a 'typical' Waikato dairy system), and 'Future' (combined approaches designed to meet the dual aim of improving profitability and productivity while reducing N leaching). Field measurements of N leaching were made using porous ceramic cups for 5 seasons during 2011-2016. Leaching measurements were supported by animal feeding and production data as well as modelling of N leaching and N flows.

Field measurements of N leaching demonstrated a reduction of 40-50% was achieved on the Waikato farmlet, with only minor impact on milk production, which is an average of 5 years of measurement. Leaching gains were achieved using a combination of reduced fertiliser N use and lower stocking rate, and removing cows from pasture during key periods of N leaching loss risk.

This paper describes how the reductions in N leaching were achieved in the P21 dairy farmlets, using the Waikato farmlet as the main example. Also, importantly, we present what was learned in terms of understanding N flows in the farm system.

A SUMMARY OF KEY MESSAGES ARISING FROM THE PASTORAL 21 RESEARCH PROGRAMME

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Pastoral 21 (P21) was a research programme jointly funded by MBIE, DairyNZ, B+L New Zealand, Fonterra and DCANZ. Phase 2 of the programme ran during the period 2011-2016. The overall goal was "to deliver industry-accessible, adoptable, systems-level solutions for profitably increasing production while reducing environmental 'footprint' (nutrient losses to water), that had been field tested for demonstrable efficacy and value".

This required a team covering a wide range of disciplines and research organisations. The programme was structured into three main themes:

- **Next generation dairy systems** – 'Future' and 'Current' dairy production systems were compared in Waikato, Manawatu, Canterbury and S. Otago to test the hypothesis, established by pre-experimental modelling, that profit could at least be maintained while nitrogen and phosphorus losses to water could be decreased by up to 30%.
- **Mixed livestock systems** - Research supporting the mixed livestock sector focused on improving early spring feed supply and summer-autumn feed quality. Solutions to spring feed supply focused on establishment of new plant genetics in uncultivable hill country and spring management of lucerne swards. Spring/autumn feed supply focused on novel legumes, legume-grass combinations and grazing management.
- **Breakthrough technologies** – new ideas and concepts were evaluated for their potential to contribute to the overall goal of maintaining or increasing farm profitability while reducing nutrient losses to water. Technologies either had a 'feed' or 'environment' focus.

Overall, the research has clearly demonstrated a range of options available for farmers to decrease N and P losses to water, but achieving increases in profit generally remained elusive in the dairy systems research. Whilst the N and P management strategies will provide options for creating headroom in catchments, future research is still required to identify management systems and farming technologies that deliver greater profitability (without compromising gains in 'footprint').

In this paper, we summarise some of the key messages arising from the research programme. Due to constraints of time, focus is placed on dairy production systems, although much of the information is also of direct relevance to the mixed livestock sector.

OPTIMISE USE OF RESOURCES:

CURRENT AND FUTURE APPROACHES

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The NZ Government has set a goal to double the value of export earnings from the primary sector by 2025 to $64bn from $32bn. This requires earnings growth of 5.5%pa. This cannot be met by increased on-farm production alone, as there is growing pressure for this sector to reduce its current environmental footprint to protect our living environments for a rapidly expanding range of activities beyond just food and fibre production.

Farmers are well used to operating within boundaries including financial and feed supply boundaries which are part of everyday life. Adding limits on emissions to receiving environments to that list is an emerging challenge, made doubly demanding if just increasing production remains the primary mechanism for increasing income and maintaining profitability. In this paper we will present findings from a new farm systems modelling approach that has the capability to optimise the farms resources within ecological limits. Further the paper will also explore the rapidly growing interest in configuring the farm business in direct response to signals from the market in an effort to capture greater value for our produce and the country, and for more of that value to be retained behind the farm gate. Constructing the supply chain backwards from the market as part of paradigm shift from volume to value, will involve new supply chains, with the producer required to make significant changes to the current farm system to be able to participate. We will provide an example where the farm systems analysis is driven by the market's specifications, rather than just maximising the resource use of the farm.

EFFECTS OF GRAZING MANAGEMENT ON NUTRIENT ANION AND CATION LOSSES IN DRAINAGE WATERS FROM DAIRY PASTURES

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In pastoral grazing systems, livestock return high concentrations of nutrients back to pastures unevenly through urine and dung. Nutrients that accumulate in urine patches during the summer-early winter period are subject to leaching during the subsequent winter-spring drainage season. While much research has focused on mitigating the losses of nitrogen and phosphorus to water from agricultural soils, there are few studies available on the effects of mitigation practices on the losses of other nutrients, namely sulphur and the nutrient cations.

Reducing the duration cows spend grazing paddocks by increasing the time they spend on standoff facilities has been shown to reduce nutrient losses to water. One such grazing management strategy is the use of year-round, duration-controlled (DC) grazing, where stock only graze for 4 hours at most grazings. The 3-year (2009-2011) study of Christensen (2013) showed that DC grazing reduced leaching losses of NO_3^- and K^+, compared to standard grazing (SG) practices. However, losses of other nutrient anions and cations were not fully evaluated. This current study quantified the anions (namely NO_3^- and SO_4^{2-}) and cations (namely K^+, Mg^{2+} and Ca^{2+}) leaching losses from two grazing management treatments (DC and SG) in a grazed plot trial over 5 years (2009-2013).

On average DC reduced the amounts of NO_3^- and K^+ leached by 55% and 49%, respectively, while reductions in SO_4^{2-}, $Ca^{2+}$and Mg^{2+} losses were 11.1%, 17.4% and 14.9%, respectively. In 2012, the chloride (Cl^-) and sodium (Na^+) in drainage water were also analysed. Duration-controlled grazing reduced Cl^- and Na^+ leaching by 51% and 34.6%, respectively. Decreases in NO_3^-, K^+ and Cl^- drainage losses with DC were in proportion to the decrease in grazing time, but not for SO_4^{2-}, Ca^{2+} and Mg^{2+} losses. The size of the reductions in losses supports the view that the urine spot was likely to be the predominant source of leaching losses for NO_3^-, K^+ and Cl^-, but not for SO_4^{2-}, Ca^{2+} or Mg^{2+}. The Na^+ leaching reduction was not directly in proportion to the reduction in grazing time, but the size of the reduction suggests that the urine spot was still the major source of loss for this nutrient.

A LONGITUDINAL STUDY TO ESTIMATE NH_3-N LOSSES ASSOCIATED WITH TEMPORARY HOUSING OF DAIRY COWS AND MANURE MANAGEMENT

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Duration controlled grazing systems for dairy cows to reduce N loss to water involves temporary housing (naturally ventilated barns) to reduce urinary load on paddocks. However this temporary housing system results in N loss as NH_3 during housing and at subsequent stages of manure management (housing, storage and land application). Methods appropriate for estimating these losses from each stage have been developed and used to undertake a longitudinal study to quantify NH_3 losses associated with partial grazing/housing and manure management system. This comprises measurement of ;N loss during the deposition of cow waste (urine and dung) on the floor (0-2 hr from deposition); transfer of cow waste to the collection channel (0-2.25 hr); total N loss from the channel (16-32 hr); total N loss from the storage pond (7- 120 days storage); and finally, N loss during the reapplication of the manure to the land.

The results show that NH_3 gas emission from a naturally ventilated barn system is highly dependent on of the fate of urea N contained in the urine and dung (slurry). In the first few hours (2, 4 and 8 h) between excreta deposition and lane scraping NH_3-N emission accounted for 0.05%, 0.34 % and 0.78% of total slurry N. For the 16-32 h of slurry retention in the channel the loss is approximately 0.62% of the slurry N before gravitational flow delivers the slurry to the pond. During storage in the pond, loss of N continues and over 120 days storage this represents up to 24% of total initial N lost. During re-application of slurry to the paddock by tanker using spray or trailing shoe injection NH_3 emissions made up only 2.35% and 1.57% of the total slurry N. Overall NH_3 loss accounted for 27.13% of the urine and dung N deposited in the barn, storage pond and land application. This work clearly identifies that pond storage needs to be minimised or ponds covered if NH_3 losses occurring in manure management are to be reduced.

DAIRY HOUSING METHANE MITIGATION USING GRAZED PASTURE SOILS

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Methane (CH_4) emissions from New Zealand dairy farms are mainly contributed by enteric fermentation. Further intensification of the dairy industry is expected to increase these emissions in future. As an effective way to reduce enteric CH_4 emissions from dairy cattle remains elusive, a range of mitigation options need to be explored to help reduce their emissions.

One potential mitigation option is to pass CH_4–enriched air (~150 ppmv) collected from barns/ animal sheds through the adjacent soil primed with CH_4–eating bacteria, methanotrophs. In this study we are assessing the CH_4 removal potential of four North Island dairy pasture soils contrasting in soil organic matter (2.47 to 9.90 % C). Initially, these soils were primed for two months with four CH_4 concentrations (150, 1200, 2400 and 3600 ppmv) in a laboratory batch study to determine the threshold CH_4 concentration required for the soils to reach high CH_4 removal potential. Results indicated that the ability of soils to oxidise CH_4 increased with an increase in CH_4 input concentration except for the Massey dairy no.1 soil. The soils primed at 2400 and 3600 ppmv CH_4 were then exposed to a lower CH_4 concentration (150 ppmv) typical of that found in barns, for three months to assess the ability of the primed soils to sustain high CH_4 removal at low CH_4 concentrations.

Of all the soils, Taranaki (9.9 % C) consistently removed >80 % of CH_4, whereas Horotiu (4.9 % C) and Massey dairy no. 4 (3.02 % C) went through low and high CH_4 removal stages (~40 to 65 %). On the other hand, the Massey dairy no. 1 soil (2.47 % C) removed between 9 and 30 % CH_4. These results suggest that primed pasture soils high in organic matter have the potential for mitigating low levels of CH_4 emissions from housed animals.

Results of the changes in methanotrophic abundance and diversity during the priming and low CH_4 exposure periods of these soils will also be discussed.

MISCANTHUS (ELEPHANT GRASS) EXHIBITS VERY LOW NITROGEN LEACHING – ANOTHER OPTION FOR THE MITIGATION TOOLBOX?

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Miscanthus is a perennial rhizomatous grass of Asian origin that is grown commercially as a biofuel crop in Europe. It has a very high dry matter yield due to its efficient C_4 photosynthetic pathway. Miscanthus is suited to substituting or co-firing with coal, providing a sustainable fuel source for industrial heat generation and reducing associated greenhouse gas emissions.

Fonterra is interested in miscanthus as a partial fuel substitute in its factories which utilise coal.

Wastewater from Fonterra factories is often utilised in land treatment systems (LTS) where pasture is grown either as part of a dairying operation or exported from the farm as cut and carry silage. These LTS involve several hundred hectares of irrigated land close to each factory which could be utilised for biofuel production.

A two hectare trial plot of Miscanthus was planted on the Fonterra Darfield LTS in 2011 to see how it would perform under wastewater irrigation. Suction cup lysimeters were installed in the plot in 2013. Three seasons of monitoring data have now been collected. The results show that after an initial 'establishment phase' the measured nitrogen leaching is extremely low (< 0.5 kgN/ha/yr). The crops potential as a biofuel crop is discussed, together with potential operational challenges that might need to be overcome.

Miscanthus might also be a suitable candidate to support farm riparian plantings as its deep rooted nature (> 1.2 m) may intercept shallow groundwater thereby improving surface water quality. It is palatable to stock thus could act as a partial feed source. When used as shelter belts it provides numerous ecosystem services[1]. If planted with sufficient width, half of each shelter belt could be harvested annually and the resulting biofuel sold to supplement farm incomes.

WHAT DRIVES CHANGE IN FARMERS' MANAGEMENT PRACTICES?

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Regional council's throughout New Zealand are imposing rules and regulations on land use activities in an effort to reduce the impact of agriculture on freshwater and achieve the limits set in the National Policy Statement for Freshwater Management (NPSFM). The introduction of such regulations is expected to result in farmers making changes to their on-farm management practices, but will it?

Farmers do not farm or make decisions in isolation but are shaped and influenced by a complex web of relationships and influences that include amongst other factors; other farmers, the environment, markets, rural professionals, industry trends, the community, as well as a range of rules and regulations. Farmers are constantly having to adapt and/or change their on-farm management practices in response to those influences, and do so in a variety of ways. Therefore, who or what is actually driving changes in on-farm practice is an important question. For example, is it the regional council's new rules, or is it a change in the supply contract for the meat company that a farmer sells their venison too?

This paper will report on preliminary findings from PhD research undertaken in the Tukituki Catchment of Hawke's Bay which is the first catchment that the Hawke's Bay Regional Council has implemented the NPSFM in. Semi-structured interviews have enabled the development of a more nuanced understanding of how farmers are enabled to adapt and/or change their land management practices – ie. who or what really does enable a farmer to change. This research also seeks to explore the specific role or influence (if any) of the Hawke's Bay Regional Council on such change processes. It is hoped that this case study will help inform the regional council about how they can effectively engage with farmers and establish relationships that encourage and enable farmers to change and adapt their land management practices in order to reduce the impact of agriculture on freshwater quality.

WHOLE FARM TESTING: A FURTHER REVIEW OF DATA

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Whole farm testing, when combined with variable rate application is about applying the right nutrients in the right amount in the right place. Ravensdown has been offering whole farm testing since 2011 allowing farmers to get a clearer picture of the variability of nutrients between paddocks. Intensive soil testing across the whole farm, coupled with the use of technology to develop nutrient management plans and the integration with proof of placement tools will help farmers reduce the variability of nutrient levels between paddocks. ARL provides the soil analysis component of this offering.

A review of the data collated by ARL conducted in 2014 identified over 300 farms that had participated in whole farm testing. Approximately 15% of these farms completing a second round of whole farm soil testing. Current data has seen that figure increase to over 1,000 farms with approximately 27% of these farms completing two or more rounds of testing. This report will review data collated by ARL to determine if the trend identified in 2014 has continued to show a reduction in the variance of fertility as farmers apply their fertiliser at the variable rates as advised in their nutrient management plans.

For this report we have identified a subset of dairy farms that have completed up to four rounds of whole farm testing. The data has been aggregated across pH, Olsen P, potassium, calcium and magnesium. The overall data set shows promising trends with the spread of results decreasing across all of the components. This suggests that areas lower in fertility have had more fertiliser applied and areas higher in fertility have had less fertiliser applied. As with the data set evaluated in 2014, it is still difficult to draw conclusions due to the small number of farms identified. With just over 850 farms having completed only two rounds of testing to date we can continue to evaluate this data as further testing rounds are completed.

UNDERSTANDING THE INFLUENCE OF SOIL PROPERTIES ON PLANT UPTAKE OF CADMIUM IN NEW ZEALAND AGRICULTURAL SOILS

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The New Zealand economy relies heavily on the primary production sector and the use of phosphate fertilisers. Cadmium (Cd) occurs naturally in the phosphate rock used to produce phosphate fertilisers and is present in fertiliser at varying levels. Different factors influence Cd uptake into plants (and therefore the human food chain) and, to manage the health risks of Cd, we need a better understanding of the soil-plant relationships involved.

To address the lack of New Zealand-specific science on factors influencing plant uptake of cadmium, a two-year project has recently started, primarily funded by the Ministry for Primary Industries and the Fertiliser Association of New Zealand, with additional funding and support from Vegetables New Zealand, Onions New Zealand, Foundation for Arable Research, the New Zealand Flour Millers Association, Baking Industry Research Trust, DairyNZ, Landcare Research and regional councils.

A key focus of this project is to understand the influence of soil properties on Cd uptake in key agricultural crops: leafy greens, potatoes, onions and wheat. As part of this, soil and plant samples were collected from existing industry trials and/or commercial fields in the main commercial growing areas for each crop across New Zealand. Around 20 sites for each of potatoes, wheat or onions were sampled, with plant and soil samples taken from each of three or four replicate plots per crop. A smaller number of sites with spinach and lettuce were assessed. Analyses of the samples showed the main soil properties of interest (pH, total carbon, CEC and soil cadmium) spanned a range of values, providing a good starting point to examine the influence of these properties on plant uptake to be assessed. Field trials to assess the effect of lime and compost additions on minimising Cd uptake in potatoes at three locations (Pukekawa, Manawatu and Canterbury) and wheat (Canterbury only) are being undertaken. This information also provides a baseline assessment of Cd uptake into New Zealand crops, and insight into management practices that can reduce plant uptake of Cd.

This paper provides an overview of the results to date.

INFLUENCE OF FLUCTUATING SOIL MOISTURE ON CADMIUM PHYTOAVAILABILITY AND ACCUMULATION IN PLANTAIN

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A pot trial was undertaken on contrasting Allophanic and Gley soils (total cadmium [Cd] 0.79 and 0.61 mg kg^{-1}, respectively) to explore the effect of fluctuations in soil moisture on soil Cd phytoavailability and Cd accumulation in plantain. Increases in 0.05 *M* $CaCl_2$ soil extractable Cd concentration aligned with increases in soil moisture following periods of soil drainage/drying. However, there was no difference ($P > 0.05$) in soil extractable Cd or plantain Cd concentrations under either continuously-drained or 3-day flooded/11 day drained irrigation regimes, indicating that short-term saturation and the onset of reducing conditions has little influence on soil Cd phytoavailability. Despite the greater total Cd concentration of the Allophanic soil, soil extractable Cd concentrations were much greater in the Gley soil, likely due to its much lower soil pH and organic matter content. Overall, the difference in soil extractable Cd concentrations between soil types was much greater than the fluctuations brought about by changes in soil moisture. These results are discussed in the context of managing Cd accumulation in Cd-sensitive crops.

WHAT DOES CADMIUM IN OUR FORAGE CROPS MEAN FOR OUR LIVESTOCK

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There has been anecdotal evidence for some time that 'weeds' have an ability to accumulate an elevated concentration of trace elements. Much of this relates to the uptake of essential trace elements such as Cu and Zn. However, a paper by Stafford et al. in Geoderma Regional published in 2016 showed that chicory had a Cd concentration approximately 20 times higher than rye grass. The concentration of Cd was also significant elevated in plantain and Lucerne relative to ryegrass.

New Zealand farming systems are today diversified away from stands of rye grass. Forage crops are a common sight on New Zealand farms. Chicory and plantain can have superior nutrient profiles to traditional grass and are more resilient to dry conditions. Lambs are commonly fattened on chicory, plantain and Lucerne, with and without clover. Cadmium accumulation models designed to protect against exceedances of this contaminant in foodstuffs (i.e. offal) are based on rye grass. The question that must be asked is 'what effect does grazing on forage crops with elevated Cd have on the concentration of Cd in the animals' body?'

Research stared in late 2016 aims to quantify the potential impact of forage crops with elevated Cd on the concentration of Cd in the blood and liver of sheep. The findings of this work will provide preliminary data on the potential magnitude of the 'forage crop effect' on the Cd burden of New Zealand's livestock. This paper will explore the context for the work, and report on provisional findings.

SOIL QUALITY AND TRACE ELEMENTS FOR LAND USES IN THE WELLINGTON REGION AND IMPLICATIONS FOR FARM MANAGEMENT

J Drewry, R Parkes and M Taylor

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This paper reports on soil quality indicators for soil nutrients, soil compaction and trace elements from soil quality monitoring undertaken for State of the Environment monitoring in the Wellington region. Selected trace element contaminants (e.g., arsenic, cadmium, chromium, copper, lead, nickel and zinc) indicators for land uses including drystock, dairy, market gardening, cropping, horticulture, exotic forest and native vegetation are presented.

Indicators included anaerobic mineralisable nitrogen, total nitrogen, Olsen P, and organic carbon. Soil physical indicators were bulk density and macroporosity. Indicators not previously reported for this region include hot water extractable carbon and fluorine. Sites with soil quality indicators well outside targets may represent an increased risk of soil erosion and soil nutrient loss from land to water via surface runoff or leaching, or may result in reduced farm production. Trace element concentrations in soil were evaluated relative to draft ecological soil guideline values that were recently developed.

Greater Wellington Regional Council has programmes for assisting farmers with riparian planting, hill country erosion control, and improved farm and nutrient management using farm and environment plans. Recently, the council initiated more resourcing and contestable funding to improve farm and catchment management. In regard to the soil quality results and other catchment information, options for improving soil, farm management and catchment water quality will be discussed.

SCIENCE AND POLICY: SOIL CADMIUM IN THE TARANAKI ENVIRONMENT

Gary Bedford

Director-Environment Quality, Taranaki Regional Council

Management of soil quality includes consideration of the potential risk that various contaminants may alter the physical, chemical or biological condition of the soil, or enter the human or animal food chain via ingestion. Taranaki Regional Council has an ongoing soil monitoring programme that has been running since 1998 (originally part of the national 500 Soils project). For land in agricultural use, the underlying concern is that the widespread application of fertilisers, animal remedies, and/or agrichemicals may lead to diffuse source soil contamination with the passage of time.

Repetitive sampling across a variety of sites within this programme indicates that concentrations of cadmium in the region's productive soils appear to have plateaued at levels that are well below those that might pose a risk to human, animal, or soil health. This is at variance with earlier modelling projections, which may be explained by re-consideration of modelling assumptions and inputs. Other investigations undertaken by the Council across groundwater, river water quality, and river sediments, find no evidence that cadmium is at or near levels of concern in any environmental domain.

In the light of these findings, the Taranaki Regional Council finds no justification to pursue regulatory intervention in the management of land use (ie fertiliser application and its consequences) in the region. There is no evidence of an actual or potential risk to human, soil, or ecological health that is not being adequately addressed already through on-going soil monitoring, voluntary controls by industry and users, advocacy, participation in research, and guidance and education. The Council's policy is therefore one of maintaining active monitoring programmes and encouraging farmers and the fertiliser industry to adhere to the national cadmium management strategy.

INVESTIGATING THE CADMIUM STATUS OF A WAIKATO DAIRY FARM

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A 102 ha Waikato dairy farm on an Allophanic soil (average Olsen P 44, pH 6.3) near Morrinsville with a long history of superphosphate use was selected to carry out all-paddock sampling for soil (at 75 and 150 mm sampling depth) and plant cadmium (Cd). In November 2011, soil Cd levels in each paddock averaged 1.36 ppm (range 0.67 - 2.05 ppm) at 75 mm depth and 0.85 ppm (0.54 - 1.33 ppm) at 150 mm depth. This represented a 38% reduction in soil Cd levels from the deeper sampling. At 150 mm depth in August 2013, soil Cd levels averaged 0.79 ppm and ranged from 0.29 to 1.38 ppm. For the screening exercise at 0 - 75 mm sampling depth, the farm, having a mean soil Cd level above 1 ppm would be categorised as requiring further "definitive" sampling at 0 – 150 mm depth. Sampling at 0 – 150 mm depth placed the average farm soil Cd in Tier 1 of the Total Fertiliser Management System (TFMS). There was a moderately strong relationship (r^2 = 0.48) between soil Cd levels sampled at 75 and 150 mm depth. This relationship supported the screening of paddocks for soil Cd at 75 mm depth as part of the "screening" sampling for soil nutrient levels to determine whether further sampling was required at 0 – 150 mm depth.

There was a very weak relationship (r^2 = 0.05) between soil Cd sampled to 150 mm and plant Cd (12 -198 ppm) in November 2011. In August 2013, soil Cd at 150 mm depth was moderately strongly related (r^2 = 0.50) to soil total P (mean 1597 ppm, range 616 – 3976 ppm) but weakly related (r^2 = 0.02) to soil Olsen P (mean 31 µg/ml, range 14 – 112 µg/ml).

In four paddocks, mean soil Cd levels declined from 1.30 ppm at 0-100 mm sampling depth to 1.18 ppm at 0-300 mm to 0.47 ppm at 0-500 mm.

CURRENT STATE AND TREND OF CADMIUM LEVELS IN SOIL, FRESHWATER AND SEDIMENTS ACROSS THE WAIKATO REGION

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The Waikato Regional Council has monitored cadmium in soils, groundwater and the Waikato river and carried out numerous investigations in aquatic sediment. Soil cadmium monitoring shows a decreasing trend in concentration of cadmium for the average of 150 soil quality monitoring sites since 2007, although 3% of samples remained above Tier 2 levels (1.4 mg/kg). According to the TFMS, sites above Tier 0 require some form of phosphate fertiliser management to ensure that cadmium contamination is kept below concentrations of concern for the next 100 years. Fertiliser industry soil monitoring showed similar results. Cadmium was detected in 16% of the groundwater samples with the highest cadmium concentration 50% of the drinking water standard limit value of 4 µg/L. These samples tended to be from high intensity farming areas. Results for the Waikato River samples were all below the detection limit (0.01 µg/L). Cadmium was enriched in peat lake sediments compared with background soil concentrations, while the estuarine and marine sediments within the Lower Firth of Thames were enriched compared with the west coast estuaries. In all cases, cadmium concentrations were below the ANZECC sediment low guideline for protection of aquatic ecosystems (1.5 mg/kg).

A reduction in fertiliser cadmium levels compared to levels pre-1990's and the more efficient use of fertiliser are thought to contribute significantly to the reduced accumulation of soil cadmium. However, mineral P fertilisers continue to be an important source of contaminant cadmium to agricultural soils. Despite fertiliser industry driven reductions in fertiliser cadmium levels, cadmium is still being applied to land. If this cadmium is not accumulating in soil surface, it is being transferred to plants and the food chain, and moving deeper into the soil profile and/or the wider environment. Although current cadmium levels in New Zealand soil and the current rates of application, do not, and are not likely, to have a significant adverse effect on the environment, monitoring must continue to provide warning should the situation change. Ongoing implementation of the Cadmium Management Strategy is likely to ensure that there remains minimal risk to human health and the environment over the foreseeable future. The fertiliser industry are encouraged to seek ways to further reduce cadmium loading in agricultural soils, including the potential for use of alternative raw materials, utilising recycled P.

COST-BENEFIT ANALYSIS OF CADMIUM MANAGEMENT IN NEW ZEALAND'S HORTICULTURAL SOILS

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Horticulture in New Zealand is a rapidly expanding industry, with exports recently growing to reach a record $4.3 billion. However, risks to this sector exist in the form of cadmium (Cd) accumulation within productive soils due to the Cd content of phosphate fertilisers and their widespread repeated application. Exclusion from international markets can occur when agricultural food products exceed food safety guidelines for the maximum residue level of Cd as a result of production on Cd contaminated soils. New Zealand's current system for managing soil Cd, the Tiered Fertiliser Management System, fails to account for variances in Cd plant uptake. Hence the establishment of risk based guidelines which cater to New Zealand's diversifying range of horticultural environments is needed. As soil pH and organic matter content are the two primary soil properties controlling Cd bioavailability, manipulating these variables using lime and compost amendments can have beneficial effects by limiting Cd plant uptake. A cost-benefit analysis has been conducted in order to determine whether the use of these soil amendments to manipulate soil properties – as has been commissioned within current New Zealand field trials – can effectively regulate plant uptake of Cd and is therefore a worthwhile solution to soil Cd contamination problems in horticultural soils. As a result, adequate risk based guidelines can be developed for New Zealand's horticultural soils that can uphold the premium standards of this key national industry.

MITIGATING ELEVATED TOPSOIL CADMIUM WITH TOPSOIL INVERSION TILLAGE

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A number of published soil surveys on permanent pasture soils have identified elevated cadmium (Cd) concentrations associated with intensively managed pastures in Taranaki and Waikato regions. A recent industry survey (Abraham et al. 2016- FLRC workshop) indicated that 20% of farms in these regions have reached the Tier 2 Cd management threshold topsoil concentration (> 1 mg Cd kg^{-1} soil) and will need to undertake phosphorus fertiliser management practices to decrease the rate of Cd accumulation in the soil. More detailed soil 'Cd profiling' (e.g. Loganathan and Hedley, 1997; Zanders et al., 1999 and Stafford et al., 2017) indicates a sharp stratification of Cd concentration with soil depth.

Cadmium distribution in the soil profile is strongly related to organic carbon (OC) content. In dairy pasture soils highly fertilised with superphosphate up to 90% of the added soil Cd load remains within the top 15 cm. Where top soil Cd concentrations exceed the Tier 2 trigger values (1-1.4 mg Cd kg^{-1} soil) it is likely that land use would be constrained to permanent grazed pasture or to crops that do introduce Cd into the human food basket.

Land use change to vegetable and cereal production will require decreasing soil Cd bioavailability if edible parts of root, tuber and leafy vegetable crops are to stay below the FSANZ standard of 0.1 mg Cd kg^{-1} . One potential management strategy is topsoil inversion during deep mouldboard ploughing. To achieve topsoil inversion a small skimmer mouldboard is placed before the main mouldboard on a conventional plough. The small skimmer mouldboard places the topsoil (0-5 cm) Cd contaminant load at the 25-30 cm depth in the bottom of a 30 cm deep furrow. An example shows reduction of the 0-15 cm Cd concentration from an average of 1.2 mg Cd kg^{-1} soil to 0.67 mg Cd kg^{-1} soil, compared to 0.82 mg Cd kg^{-1} soil with conventional mouldboard plough. In some previously uncultivated soils with a strong vertical stratification of Cd, topsoil inversion tillage can move a soil from the Tier 3 management trigger (1.4 to <1.8 mg Cd kg^{-1} soil) to Tier 1 (< 0.6 mg Cd kg^{-1} soil).

EFFECTS OF SOIL PROPERTIES ON BIOAVAILABILITY OF FLUORINE TO MICROORGANISMS

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The frequent application of phosphate fertilisers increases the soil fluorine (F) concentration in New Zealand agricultural soils. Increased soil F concentrations have the potential to harm soil microorganisms which are vital to soil functions. Information on soil properties that influence a soils' exchangeable and total soil F concentration, coupled with an ability to explain the relationship between soil chemistry and soil microbial activity, will be important to help develop soil management practices that will minimise the negative effects of increased soil F concentrations.

Soils were collected from seven different agriculture land use sites to represent major soil orders in New Zealand. Soil pH, acid ammonium oxalate extractable Fe and Al, total soil F, $CaCl_2$-extractable and water-extractable F concentrations were measured to provide information on soil properties that influence total and exchangeable F. Soil microbial biomass C was measured to quantify soil microbial activity.

$CaCl_2$-extractable and water-extractable F concentrations ranged from 6.85 to 1.39 and 6.35 to 1.38 mg/kg soil respectively, and were two orders of magnitude lower than the total soil F concentrations. The total soil F concentration correlated significantly ($p<0.05$) with acid ammonium oxalate extractable Fe ($r = 0.79$) and Al ($r = 0.92$). Correlation between total soil F concentration and $CaCl_2$-extractable F concentration was non-significant ($p>0.05$). Soil pH significantly ($p<0.05$) influenced the $CaCl_2$-extractable F concentration. The correlation between total soil F and microbial biomass C was not significant ($p>0.05$). However, $CaCl_2$-extractable F was significantly ($p<0.05$) correlated ($r=-0.69$) with microbial biomass C. Low microbial activity (BMC = 451 µC/g soil) was recorded in soil which had low soil pH (5.12).

Soil pH is a key factor that influences exchangeable and water-soluble fluorine. The effect of F on microbial activity could therefore be minimized by promoting soil management practices which can alter the soil pH.

REMEDIATION AND RECOVERY TECHNIQUES FOR VOLCANIC ASH-AFFECTED PASTURE SOILS OF NEW ZEALAND

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The value of exports from NZ's land-based primary production is around $34 billion per annum. Soils are the key resource that drives this primary productive sector. Soils are also the fragile skin of our Earth, and the host of many essential ecosystem services. These ecosystem services operate on a delicate balance, which is easily disrupted by impacts from natural hazard events, particularly the widespread dispersal of volcanic ash. Once soils are disturbed in this way, their provision of vital soil functions is rapidly diminished. Volcanic activity represents a major natural hazard that could strike this production sector at any time.

Research to date on volcanic ash impacts on agriculture has been limited to direct impacts of ash killing plants, acidifying water and soil surfaces, and causing health issues for animals and plants, with some work focussed on mitigation techniques for short term fertility and production recovery. Very little information is available on remediating the ash-affected soil.

The research proposed here aims to define the ideal remediation strategies for pastoral systems in the North Island of New Zealand (and by comparison agricultural systems elsewhere) following large-scale ash deposition. This project will employ a mixture of social-science research, agricultural experiments and economic modelling. This research will help in determining the best remediation technique suitable for effective recovery of pasture and pasture soil post heavy ash fall, in terms of economic feasibility and recovery time. This will be achieved by interviewing local farmers in two study regions and, based on their feedback, analysing selected remediation techniques through field and laboratory studies. The study will be undertaken in two different regions of New Zealand that are susceptible to serious ash fall in the future, namely *Waikato* and *Taranaki*.

THE MEASUREMENT OF EXTRACTABLE ORGANIC SULFUR BY NEAR-INFRARED SPECTROSCOPY

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Extractable Organic Sulfur (EOS) is an estimate of the available sulfur pool in soil. It is an alternative to the widely used sulfate test, but does not suffer the same in-field variability that sulfate does. Sulfate is often elevated by dung and urine events, and has high temporal and spatial variation. While EOS does not suffer the same in-field variation, it traditionally suffers high analytical measurement variation.

Extractable Organic Sulfur (EOS), is typically determined from a potassium phosphate extraction, and taking the difference between the total extracted sulfur (TES) and the sulfate extracted. The total extracted fraction is typically measured by an Inductively Coupled-Plasma Optical Emission Spectroscopy (ICP-OES) instrument, and the sulfate by ion chromatography. As the EOS measurement is the difference, the uncertainty in the measurement is coupled to the measurements of the other two. As typical with analytical measurements, there is a component of error associated to the concentration of the individual analytes, thus when sulfate (and therefore TES) is high, the uncertainty associated to this, is also high in absolute terms (though still low in relative terms). This means that for high TES or sulfate values, the analytical error in the EOS method can be very high, to the point of making the result meaningless.

Near-Infrared (NIR) has been used for many years to measure some other soil constituents at Hill Laboratories particularly those associated with the organic fraction in soil. It has been recently found that a successful calibration for EOS can be also constructed. Although, the NIR measurement is most probably an indirect measure of the EOS through the vibrations associated to the organic matter fraction, the error associated to the measurement does not scale with TES or sulfate concentration. Thus the NIR method for EOS is typically more accurate than the reference method for soils with high sulfate.

THE LEACHING AND RUNOFF OF NUTRIENTS FROM VINEYARDS

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To assess nutrient losses in New Zealand's major viticultural regions, we carried out a comprehensive and comparative national study of nutrient leaching and runoff, using detailed weather and soils information with an appropriate set of viticultural practices. We have used our mechanistic Soil Plant Atmosphere Simulation Model (SPASMO) to provide these simulations. We carried out SPASMO simulations on 89 viticultural soil-types across the six viticultural regions of New Zealand - Gisborne, Hawke's Bay, Martinborough, Marlborough, Nelson and Central Otago. Our modelling covered 95% of New Zealand's vineyards.

We considered the impact of four irrigation scenarios in Marlborough. These were no irrigation, regulated deficit irrigation, managed irrigation and calendar irrigation. We have shown through modelling using the Wairau silt loam that most irrigation regimes, except for calendar irrigation, which applies an excessive amount of water, would provide sustainable consumption of water by irrigation abstraction, drainage recharge, and nutrient losses. The nitrate loads are between 10 and 15 kg N-NO_3/ha/y, and phosphorus losses are between 0.1 and 0.2 kg P/ha/y. The lack of difference in nitrate leaching between irrigation regimes highlights that soil-water dynamics play a lesser role in controlling leaching, than do soil-nitrogen dynamics. Irrigation does affect drainage recharge, but to a much lesser extent the leaching of nitrate.

We then carried out simulations across all six viticultural regions of New Zealand only considering the regulated deficit irrigation scenario (RDI). For this regional comparison, within all but the Gisborne region we could geo-reference viticultural production with specific soil types so that we could provide an areally weighted average for each region. To obtain a representative average for the whole of New Zealand, we weighted the regional averages by the respective areas of grapes grown in the six regions.

The national average load of nitrate quitting the rootzones of New Zealand's vineyards is just 8 kg N-NO_3/ha/y, and the average concentration is 7.9 mg/L.

Whereas irrigation regime had only a minor effect on nitrate leaching, the role of the soil, and in particular its carbon to nitrogen ration (C/N), plays a dominant role in determining nitrate leaching.

ROOTZONE REALITY — A NETWORK OF FLUXMETERS MEASURING NUTRIENT LOSSES UNDER CROPPING ROTATIONS SUMMARY OF YEAR 2 RESULTS

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Between August 2014 and May 2015 a network of passive-wick drainage fluxmeters (DFMs) were installed on commercial cropping farms in the Canterbury, Manawatu, Hawke's Bay and Waikato/Auckland regions to quantify the amount of nitrogen (N) and phosphorus (P) in drainage water leaving the root zone. Results from this study are providing growers and regional authorities with measured nutrient losses from cropping farms across a range of sites and seasons and will provide a platform for the discussion and implementation of good management practices. The experimental design across the DFM network includes three sites across the four monitor regions, and uses 12 fluxmeters per site. Individual sites were chosen to provide a range of cropping systems, soil types, climatic conditions and management practices relevant to each region.

Across the DFM network, measured drainage ranged from 0.3 to 611 mm and from 0 to 411 mm over the respective Year 1 (October 2014 to September 2015) and Year 2 (October 2015 to September 2016) monitoring periods. In general, most drainage (60–100%) was captured over the mid-autumn to early spring period (April to September). Measured N losses ranged from 0 to 226 kg N/ha in Year 1 and from 0 to 118 kg N/ha in Year 2, while measured P losses ranged from 0 to 0.56 kg P/ha and from 0 to 0.27 kg P/ha respectively. Nitrate-N was the dominant form of N loss while most P was lost as dissolved reactive phosphate. Variability in N and P losses between sites reflect the wide range of climate, management and soil characteristics and efforts are ongoing with growers to identify how to reduce nutrient losses.

MONITORING THE SOIL WATER BALANCE AND DRAINAGE LOSSES FROM KIWIFRUIT ORCHARDS IN THE BAY OF PLENTY REGION

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The National Policy Statement for Freshwater Management (NPS-FM 2014) directs all regional councils to undertake catchment level regulation of parameters affecting water quality, including nutrient discharge and water allocation limits for all land uses. The Bay of Plenty Regional Council are in the process of developing a freshwater management plan in response to the NPS-FM.

The New Zealand kiwifruit industry faces the prospect of limits being imposed, on the use of water for irrigation and nutrient discharges (particularly nitrogen ("N") to the environment. Currently there is almost no data available to assess drainage losses of nitrogen below the root-zone of kiwifruit orchards. To fill this knowledge gap, ZESPRI has contracted Plant and Food Research (PFR) to undertake a series of field studies to quantify the water balance and nutrient (nitrogen) drainage losses below the root zone.

PFR has installed instrumentation (flow meters for irrigation volumes, time-domain reflectometry sensors (TDR) for soil water contents, passive-wick flux meters (DFM) for drainage, weather stations for local microclimate) on seven kiwifruit orchards across the Bay of Plenty. Our sites cover a range of representative kiwifruit orchards including the two main kiwifruit varieties (Hayward and Gold3), the two predominant soil types (allophanic and pumice), and different irrigation management including some non-irrigated orchards. This instrumentation was set up shortly after harvest, May 2016, to obtain direct measurements of drainage losses.

Our Project is expected to develop the first comprehensive dataset comprising quantified seasonal water balance and nutrient discharge data. This underlying data will enable robust development and validation of models with which nitrogen discharge limits will be determined. Having good models will also allow better management of N use and water consumption on orchards. In this presentation we will describe the field set-up and present preliminary data on the soil water balance.

JUST-IN-CASE TO JUSTIFIED IRRIGATION: IMPROVING WATER USE EFFICIENCY IN IRRIGATED DAIRY FARMS

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Irrigations scheduled before significant rainfall events result in the loss of water and nutrients via drainage and/or overland flow. In the absence of accessible, reliable weather forecast, and the ability to respond to changes in (forecast) weather conditions, farmers seldom schedule irrigation and nutrient applications based on rainfall. NIWA is piloting a study in the Waimakariri Irrigation Scheme to test a co-innovation based approach in using weather forecast for irrigation scheduling. As part of the study, a selection of farmers in the scheme are being provided with farm-specific observed data on current rainfall, soil moisture, soil temperature and drainage, and estimated evapotranspiration, and region-specific 2-, 6- and 15-day rainfall forecasts. Based on these data, farmers may make informed irrigation and nutrient application decisions.

The co-innovation approach means involving a range of stakeholders in the co-development of solutions. Annually, the selected farmers, irrigation scheme managers, researchers, and other relevant stakeholders (e.g. members of local zone committee, farmers and scheme managers from neighbouring irrigation schemes, industry representatives and regulatory agencies) gather for a workshop to review rainfall, irrigation and drainage data from each season and discuss irrigation decisions made during the season. These workshops act as a forum for sharing and discussing ideas, as well as reviewing and refining information provided.

Our four years of observations thus-far highlight that changes to irrigation practices are not mere changing the technology to irrigation scheduling but changing the mindset and behaviour towards irrigation practices. In addition to biophysical data that provide evidence to gains from alternative irrigation practices, continued education and training are critical to behaviour change. Trust built between stakeholders, benefits (economic and environmental) derived from alternative practices and a guided pathway to change are key enablers to behaviour and practice.

MANY TO ONE: HOW CAN DATA BE AGGREGATED TO TELL THE STORY OF INDIVIDUAL FARMER CHANGES TO THEIR COMMUNITIES

Bridgit Hawkins

Regen Ltd, Wellington

Environmental management, sustainability, consent conditions and water quality are all terms today's farmers are becoming increasingly conversant in. Knowledge in these areas is now just as important as traditional farming knowledge like animal health and fencing. These topics are all part of the new digital era of measurement and compliance. As regulations come into effect to ensure standards of water quality are met a lot of data is being recorded in many formats by many parties to meet these new regulations. Some data is gathered automatically, some manually, some once, some multiple times. Some data is easily accessible once gathered, some is not.

New Zealand society is also interested in environmental management, sustainability, consent conditions and water quality, but for different reasons. That interest is more about what is happening in catchments and regions, rather than individual farms, and they are more interested in the outcomes of compliance rather than the process of compliance.

The technologies and scientific skills now available related to big data, the cloud, data analytics and visualisation have created the potential to enable new insights to be created and, most importantly, communicated to a broad range of audiences with different lenses on the same subject. If an insight isn't understood and isn't compelling, no one will act on it and *no change will occur*.

Bringing these technology solutions together to meet community's need to be engaged and farmer's need to be compliant and acknowledged for that is the objective of NEWMS; Nutrient, Environment and Water Management system. The underpinning 'technology' is storytelling. Data storytelling is a structured approach for communicating data insights, and it involves a combination of three key elements: *data*, *visuals*, and *narrative*.

COMPLEXITIES ASSOCIATED WITH INDUSTRIAL RESOURCE CONSENTS FOR LAND TREATMENT SYSTEMS WHERE SPECIFIC LIMITS ARE SET WITH OVERSEER

Jeff Brown

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Fonterra operate sixteen wastewater land treatment systems (LTS) under resource consents restricting nutrient loadings and requiring significant monitoring programmes of soil, surface water and groundwater quality. The farming systems complement the wastewater irrigation activities. New or upgraded systems have typically been destocked to < 1.5 dairy cows/ha and excess grass silage exported. Full Cut & Carry systems with minor drystock exist at several sites.

Previous consents contained nitrogen loading limits, but newer ones now include nitrogen leaching rate restrictions. Specific numerical Overseer based nitrogen leaching allowances (NLA) exist at six Fonterra LTS sites, which add considerable complexity to ensuring compliance, primarily due to frequent Overseer upgrades. Additionally, the LTS potentially operate at the limits of Overseer's predictive capability as daily wastewater volumes of 2,000-15,000 m^3/day dictate irrigation in August to May/June, as full storage and deficit irrigation of such high daily volumes is impractical. Overseer upgrades often significantly increase predicted leaching rates, creating a risk of non-compliance. While consents at three LTS allow for the NLA to be reviewed when Overseer changes, this involves a considerable amount of work. Also the 3-5 year rolling NLA averaging period, while necessary, requires updating of 3-5 Overseer files per farm to the new model and Data Input Standards changes.

The recently expanded Pahiatua factory LTS provides a case study to investigate these issues. Pre-consenting investigations in 2012 used Ovr 5.4.11, with the consent application and decision used Ovr 6.0. Since then there have been a further eight Overseer versions. The consented average NLA has increased 36% from 28 to 38 kgN/ha/yr, but the gap to Horizons One Plan requirements (not revised for Overseer changes) continues to grow, hinting at potential future complexities. After five seasons the NLA compliance can be formally assessed and will involve 20 Overseer files (5 yrs x 4 farms). However interim compliance tracking will see all existing files updated for each new Overseer version. Added to this are the four original NLA setting files, plus four nutrient management plan forecasting files, resulting in 28 files being updated every six months.

In some Horizons catchments and in the Waikato in future, farming landuse consents complete with NLAs will be required. It is imperative these be consistent with any industrial wastewater irrigation consents and have similar consent terms.

IRRIGATION MANAGEMENT WITH SALINE GROUNDWATER OF DATE PALM CULTIVARS IN THE HYPER-ARID UNITED ARAB EMIRATES

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We are investigating the combined effect of irrigation management and water salinity on the crop yield of dates and their fruit quality. Our experiments are assessing the impact of two different levels of water salinity (5 dS/m and 15 dS/m) on palm-tree water use, irrigation need and date production.

We show how different varieties of date palm respond to altered irrigation volumes and salinity levels for the three varieties of date palms: Lulu, Khalas & Shahlah. These 3 varieties were selected from a long-term date experiment at ICBA involving 18 varieties for they represent a range of salt-tolerances. Baseline results were established during 2015 using the current irrigation practices.

Superimposed on these two salinity treatments are four irrigation treatments, so that we can use these results to minimise the use of irrigation water, yet maintain a salt-leaching fraction to flush excess salts from the rootzone in order to maintain date production. The irrigation treatments are set in relation to the date palms' water use, ETc, and are 2.5 ETc which is the current practice, plus 2 ETc, 1.75 ETc and 1.5 ETc. A SCADA-controlled irrigation system was installed, and the treatments were initiated during January 2016. Heat-pulse sapflow sensors have been inserted into the trees to monitor tree water-use. Time domain reflectometer (TDR) probes have been installed in the soil surrounding the trees, both within the irrigation bund and beyond, to monitor the changing pattern of soil water content in the rootzone. As well, electrical conductivity (EC) sensors have been placed in the soil within the irrigation bund to monitor the changing pattern of soil salinity. Regular monitoring of the trees' canopy areas are being carried out using a new device we have developed called the 'light-stick' A full year's set of results was obtained during 2016.

The knowledge from the results are being used to guide policy development for the use of groundwater to irrigated date palms.

INCENTIVES, OPTIONS AND ENABLERS: INTEGRATIVE SCIENCE TO ACHIEVE THE OUR LAND AND WATER NATIONAL SCIENCE CHALLENGE MISSION

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The national science challenges were set up to address "complex, long-term, national scale issues for New Zealand", and each has a specific mission. Our Land and Water's is to *enhance primary sector production and productivity while maintaining and improving our land and water quality for future generations.*

Delivering on this mission requires science that is transformational. This means a number of things in terms of both the subject of the research and the way it is delivered. Underlying the challenge logic is the recognition that to move beyond incremental change will require the juxtaposition of three elements: incentives, options, and enablers. The interplay between these elements is reflected in the thematic structure of the challenge.

There are three interdependent themes, which taken together explore specific research questions targeting the way value from primary production is enhanced when land use opportunities are informed by the full range of community values, and explored through collaborative processes which emphasise co-innovation and shared learning.

The transformation asked of the Challenge in terms of land use requires fundamental shifts in the attitude and behaviours of land users, informed by a menu of new options. Beyond that, however, knowledge transfer and implementation will depend on the accessibility and relevance of the research. Consequently, the Challenge emphasises co-innovation and co-design, in which end users are actively involved in the framing of research questions, study design and science delivery. Not only must scientists collaborate with each other, but they must also establish a meaningful discourse with their communities. That also requires shifting from a multi-disciplinary research perspective to a cross-disciplinary one, in which the complexities of the whole programme are embraced by researchers.

Cross-disciplinary science represents both an opportunity and a "challenge" for researchers in the way they work with stakeholders across government agencies, industry, communities and NGOs, and with Māori partners, to provide knowledge that underpins policy and behavioural changes in support of achieving the mission.

INTEGRATING VALUE CHAINS TO REWARD SUSTAINABLE LAND USE PRACTICES

Caroline Saunders, Paul Dalziel and Alan Renwick*

Lincoln University, Canterbury
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The vision of the Our Land and Water National Science Challenge is that "New Zealand is world-renowned for integrated and successful land-based primary production systems, supported by healthy land and water and capable people". This workshop addresses a key aspect of that vision; the contribution of our presentation is to present evidence on whether successful achievement of a "world-renowned" reputation will allow New Zealand producers and processors to capture higher returns for their agri-food exports. This is a major theme of the Our Land and Water challenge, which has adopted as one of its aspirational impacts that the New Zealand primary sector will sustain higher economic growth through participation in global value chains that are generating new products, services and market segments that are aligned with and validated against stakeholder environmental, social and cultural values.

Consequently the Agribusiness and Economics Research Unit (AERU) at Lincoln University has been commissioned to head a major research programme beginning 1 January 2017 to answer the following research question validated by an OLW Workshop on 29 September: How can value chains better share value (economic, environmental, social and cultural) from consumer to producer and incentivise land use practices that relieve tensions between national and international drivers? The research team includes participants from GNS Science, Lincoln University, Massey University, PwC New Zealand, Scion, The Agribusiness Group, Thought Strategy, the University of Auckland and a private consultant, Dr John Reid.

This presentation will present results from a related programme (2012-2016) by the AERU on Maximising Export Returns, funded by the Ministry of Business, Innovation and Employment. This programme included original research in five export markets for New Zealand agri-food products (China, India, Indonesia, Japan and the United Kingdom), showing how consumers in these markets value credence attributes such as environmental sustainability, and how capturing price premiums for these attributes can provide increased returns to New Zealand producers.

A FRAMEWORK FOR UNDERSTANDING THE LINKAGES BETWEEN LAND AND WATER QUALITY IMPACTS

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Different soils, landscapes and water pathways vary at a range of scales in their propensity to yield, convey and attenuate contaminants. This affects the land's suitability for various types and intensities of land use. For instance, one national-scale study has found that on average around 55% of N and P lost from productive land uses in New Zealand are attenuated as they make their way through catchments to the sea, but proportions attenuated vary widely across and between landscapes. Limits being set on land uses by regulators under the NPS-FM to safeguard the life-supporting capacity of freshwaters and the associated health of people and communities need to take into account these differences in attenuation between contaminant sources and sites where water quality attributes are set. The Sources & Flows programme in the Our Land & Water National Science Challenge aims to develop a framework that will synthesise our existing knowledge of contaminant sources and pathways to predict the spatial effect of these attenuating factors. This will build on existing frameworks that operate at smaller scales e.g. the farm dairy effluent Risk framework. This framework will be supported by a national scale "source-delivery-attenuation" analysis that will identify where our current knowledge (with existing models) is unable to explain measured stream loads. We will also investigate the use of indirect methods, such as hydrograph and pollutograph analysis and tracers, to verify contaminant pathways to support the framework or for extrapolation of the framework into areas with less base-line data. With appropriate knowledge, productive enterprises will have the opportunity to adapt and tailor their land use and management practices to work within the natural and built attenuation capacity of their landscape.

SHIFTING FROM LAND-USE CAPABILITY TO LAND-USE SUITABILITY IN THE OUR LAND & WATER NATIONAL SCIENCE CHALLENGE

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The needs for better primary sector productivity and better environmental performance are driving changes in land and water policy and management in New Zealand. The primary intent of these changes is sustainable productivity within the limits of land and water resources. Implementing these changes will require a shift from the traditional focus on land-use capability for production, to a broader view that accounts for land-use effects on environmental, social, cultural and economic values at whole-catchment scales. We call this broader view 'land-use suitability' (LUS). Our premise is that incorporating LUS in land assessment, land-use choices and land-use planning can reduce the degradation of values and increase resilience. The LUS programme in the Our Land & Water National Science Challenge (OLW NSC) will develop tools needed for effective LUS assessment and planning. These tools will have three properties that ensure their utility: 1) spatially explicit links between source areas of land-use pressures and receiving environments (surface water, groundwater, soil) where responses to pressures occur; 2) incorporation of ecological, economic, social and cultural resilience; 3) consideration of interventions that increase resilience, and risks incurred by interventions. In the first phase of the LUS programme, we will develop a classification-based tool called LUS Spatial Explorer that uses national environmental datasets and pressure-response models to categorise relationships between source areas and receiving environments. The LUS Spatial Explorer will be tested in Southland, with the OLW NSC Sources & Flows Programme, Mana Whenua and the Southland Regional Council.

THE COLLABORATION LAB: THE TRANSFORMATIVE ROLE OF COLLABORATION IN MANAGING OUR LAND AND WATER

Melissa Robson, Jeff Foote, Philip Barker, Glen Lauder, Graeme Nicholas, Suzie Greenhalgh, Bruce Small, Roger Williams, Ra Smith, Tina von Pein, George Haremate and Gabriele Bammer

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The Collaboration Lab research programme is focussed on the 'Our' part of Our Land and Water. Adversarial processes have dominated allocation and consent applications, leading to stalemate and inaction (Small et al., 2013). Land and water regulations are based on linear science into policy (Weible et al., 2004, OECD, 2009) and take a decide and defend approach to resource management planning (Robson, 2014). The magnitude and complexity of land and water challenges facing New Zealand require science and society to work together in new ways via New Zealand-appropriate models of engagement and science-society interaction.

The value of collaboration has begun to be recognised in New Zealand. Social science research over the past twenty years has emphasised the importance of collaboration for achieving successful outcomes in complex systems. However there are still gaps in our understanding; there is insufficient long-term evaluation of collaborative approaches, there is a paucity of studies on how researchers undertake interdisciplinary research, translating concepts of collaboration into practice has proven very difficult, and there is a lack of important information about Māori participation in collaborative processes.. The research in the Collaboration Lab programme will help to address these gaps. This paper describes the programme's three research projects, which commenced in late 2016.

Project one will use practitioner insights about how the use of collaborative processes enables new practices, ways of organising and social relations that support decision-making and practice change. Project two will survey participants of seven current limit-setting processes and the wider community. These surveys are designed to evaluate both the collaborative process and the outcomes of the collaboration. Project three will examine collaboration case studies using the Integration and Implementation Science (I2S) framework (Bammer 2013). This is to understand if using the I2S framework could lead to improved outcomes in land and water management through improved researcher practice.

Together these projects will build an enhanced understanding of collaborative practice, weaving together centuries of focused practice in Māori tikanga and the leading innovative edge of current collaborative practice from multiple fields to form new mātauranga, or practical wisdom.

NEXT GENERATION SYSTEMS;

A FRAMEWORK FOR PRIORITISING INNOVATION

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There is increasing recognition that the land-based sectors will need new primary production systems to break the lock-step relationship between profitability and production on one hand and environmental footprint on the other. Business as usual will not be sufficient to deliver more value with a lower footprint across NZ and create step rather than incremental change. These next generation systems may include development or redesign of existing land-based systems, as well as systems based on new genetic material, novel integration and new technologies.

Assessment of candidate next-generation farm systems and analysis of their comparative ability to deliver value – financial, environmental and social/cultural – is, however, critically lacking. A framework using multi-criteria decision making (MCDM) was developed because it provides the ability to simultaneously consider multiple domains where selection of best alternatives is highly complex. The approach described here recognises that for land owners and managers, while this assessment is primarily a business decision, it is also influenced by other factors. The aim is to use the framework with land owners and managers to firstly explore opportunities for next generation systems for their business and secondly to identify gaps in knowledge concerning the systems that will require research investment. The MCDM was developed based on published literature and has been refined following feedback from industry representatives, consultants and rural entrepreneurs.

A model system was selected to illustrate the framework. Sheep milking in Canterbury was chosen as it is an emerging industry currently being evaluated by rural entrepreneurs. The example highlights how the various dimensions (financial, environmental, social/cultural) of the decision problem are weighted, how the system performs across these dimensions and the gaps that exist in our current understanding of the system.

EAST ASHBURTON GROUND WATER QUALITY
– A COMMUNITY APPROACH

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The Ashburton Zone Implementation plan identifies ground water quality as a key priority. This project is monitoring 50 randomly selected wells to identify the variability in nitrate levels in ground water throughout an area east of State Highway 1 and bounded by the Ashburton and Rakaia Rivers. Based on this data, farmers in the region will be better informed of the high risk zones, how the nitrate levels in water vary seasonally, sub-regionally, by depth and over time. This will enable the farmers to engage with ECan and the Ashburton Zone Committee with constructive dialogue to develop outcomes that meet the environmental, economic and social needs of farmers and the community. The wells were monitored quarterly in 2016 and monitoring will continue until the end of 2018. Results from the first season showed no seasonal change in average nitrate levels and no obvious differences by well depth. There was a trend to increasing nitrate concentrations closer to the coast. Five wells exceeded the Maximum Acceptable Level for safe drinking water at one or more sampling time. The project was initiated by farmers in the area and all farmers in the area can contribute financially to the project. It is also supported by MPI SFF, industry organisations, regional government and private companies. This whole community approach may be applicable to groups engaged in water quality work in other areas.

CASE STUDY IN COLLECTIVE NUTRIENT MANAGEMENT

Eva Harris

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Barrhill Chertsey Irrigation Limited (BCI) is a developing mid-Canterbury irrigation scheme, which first delivered water in the 2010-11 season. BCI is a joint venture, owned by it's 180 shareholders and a local lines company. BCI has now grown to irrigate approximately 23,000 ha between the Rangitata and Rakaia Rivers, with hopes to expand to 40,000 ha.

In 2015, BCI started a programme to collectively manage nutrient losses as a nitrogen loading cap came into effect for the scheme. The programme is one of the first of it's kind in Canterbury and in New Zealand. Shareholders are contractually obliged to participate in our nutrient management programme and risk losing access to their water and, eventually, their shares, if they fail to make improvements over time.

We require all shareholders to prepare, and regularly update, a Farm Environment Plan (FEP), which details what they currently do and what they need to do to achieve Good Management Practice (GMP). All FEPs are audited and shareholders have access to one on one support, as well as workshops targeting GMPs not commonly achieved, such as irrigation system calibration. We are also required to report on scheme nutrient losses annually, using the sum of shareholder N losses calculated using OVERSEER.

We found using OVERSEER to calculate the scheme N losses has been costly and ineffectual in managing N losses due to the inconsistency of the preparation of the budgets, limitations of the model (particularly for the arable properties) and ensuring they are completed within the same version. Many shareholders are sceptical of the information provided in the budgets and are not yet confident in using this information for making improvements in their farming practices.

Greatest engagement with shareholders was achieved with one on ones and the FEP audits. The workshops have been particularly helpful in facilitating peer-peer learning, which normalises the practices we are advocating.

In summary, uptake of GMPs by shareholders to date have largely been due to an emphasis on education of resource use efficiency as opposed to avoiding N loss based on OVERSEER nutrient budgets.

FARM ENVIRONMENT PLANS AS A COMPONENT OF INDUSTRY AUDITED SELF-MANAGEMENT

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The Waikato Regional Plan Change 1 – Waikato and Waipa River Catchments, which was recently publically notified has been written using an innovative Collaborative Stakeholder Process. This process has sought to engage with the widest cross section of society possible to help determine the most palatable policy approach to achieving the vision and strategy of the Waikato and Waipa Rivers.

This collaborative process identified tailored Farm Environment Plans (FEP) as a key approach to achieve the objectives of the plan change by managing the effects of four key contaminants; Nitrogen, Phosphorus, Sediment and Microbial Pathogens. The requirement of FEP's has been included in the proposed plan change policy mix.

The plan change policy mix also includes two different frameworks that govern the activity status of farms that have undertaken a FEP. Farming activities with an FEP under a Certified Industry Scheme will have a Permitted Activity status, and farming activities with an FEP that sit outside a Certified Industry Scheme will have a Controlled Activity status. A certified industry scheme allows the Waikato Regional Council to have a formal agreement with an Industry Body, and then this Industry Body has individual agreements with the landowners for the provision and delivery of FEP's.

Fonterra participated in a joint project with Federated Farmers (FF) and AgFirst Consultants. FF and AgFirst concentrated their FEP's on farms outside of a Certified Scheme, whilst Fonterra delivered FEP's to shareholding dairy farmers to test the delivery and content of FEP's, and the viability and operation of a Certified Industry Scheme.

The proposed presentation to the Fertiliser and Lime Research Centre workshop will present Fonterra's approach to the delivery of FEP's from the joint project, the challenges in identifying and managing the four key contaminants, the lessons learnt from FEP delivery during the joint project and the alignment between FEP's and other Fonterra Sustainable Dairying initiatives or the Sustainable Dairying Water Accord.

THE EVOLUTION AND DEVOLUTION OF IMPLEMENTATION

Nathan Heath

Hawkes Bay Regional Council, Napier

The theme for this year's FLRC conference is "Science and Policy: nutrient management challenges for the next generation". I question the assumption that it is through science and policy alone that we are going to address the challenges of nutrient and sediment management and their impact on water quality into the future.

Instead I argue that perhaps it is through a growing sophistication to our approaches to "implementation" both locally and nationally where potentially the greatest gains could be achieved to meet this challenge.

THE SUCCESS STORY OF DAIRYING AND THE ENVIRONMENT IN 2042 - HOW IT WAS ACHIEVED

Russ Tillman

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It is the year 2042 and, although dairying is still a major land use and export earner, water quality in New Zealand is improving year by year. It is now considerably better than it was 25 years earlier (in 2017). This paper looks back over how this has been achieved.

In 2042, improved environmental management on dairy farms is just one example of a much broader national strategy to brand New Zealand as a world leader in sustainable economic management. And within dairying, minimising impacts on water quality are again just part of a larger quality brand that has resulted in improved market access and premiums being paid for New Zealand products. Other components of the brand include greenhouse gas footprints, animal welfare, food safety, working conditions for farm staff, and the "back-story" behind inputs such as fertilisers and supplementary feeds.

The reduced impact of dairy farming on water quality in 2042 has resulted from three major innovations. Firstly, strong financial incentives are in place to encourage dairy farmers to reduce their environmental impacts. These incentives operate through the taxation and rating systems, and also through the payout price. Secondly, the presence of the financial incentives to achieve good environmental performance has enabled a simplification of water quality legislation. The approach of assigning arbitrary limits to water quality and nutrient loss from farms has been abandoned. In its place is a simple requirement for farmers to take all reasonably practicable steps to reduce their environmental impact, with the aim of returning water quality as close as practically possible to its pristine state. And thirdly, by linking the benchmarks for good environmental performance (and corresponding financial reward) to what the "best" farmers are achieving, the bar is continually being lifted.

The paper gives a brief overview of events leading to the current (2042) situation, provides some examples of the financial incentives, and describes typical dairy farming systems in 2042.