MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

FARMED LANDSCAPES RESEARCH CENTRE

Nutrient Management in Farmed Landscapes

33rd Annual FLRC Workshop

This document contains the programme and abstracts of all presentations to the 33rd Annual FLRC Workshop at Massey University on the 11th, 12th and 13th February 2020.

They are printed here in the programme order and may be of assistance to people who wish to search for keywords in the abstracts 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 11th February

0915-1000 Registration and Morning Tea

1000–1015 **WELCOME AND SETTING THE SCENE**
Professor Chris Anderson
Director, Farmed Landscapes Research Centre,
Massey University

1015-1030 **Andrew Kempson, K Green, K Forster** *Invited Speaker*
He Waka Eke Noa – Primary Sector Climate Change Commitment
HE WAKA EKE NOA – GOVERNMENT AND AGRI-FOOD AND AGRI-FIBRE SECTOR JOINT CLIMATE ACTION PLAN

Session 1 : Agricultural Greenhouse Gas Emissions

Chairman: **Professor Surinder Saggar**
Manaaki Whenua – Landcare Research

1030-1100 **Bob Rees** *Keynote Speaker*
AGMARDT FUTURE SHAPERS
Scotland Rural College, Edinburgh, UK
HOW FAR CAN GREENHOUSE GAS MITIGATION TAKE US TOWARDS NET ZERO EMISSIONS IN AGRICULTURE?

1100-1115 **Karl Richards**
Teagasc, Wexford, Ireland
OPTIONS FOR REDUCING GASEOUS EMISSIONS FROM IRISH AGRICULTURE

1115-1130 **Patrick Forrestal and K Richards**
Teagasc, Wexford, Ireland
LONG-TERM EFFECTS OF UREASE AND NITRIFICATION INHIBITOR ENHANCED FERTILISERS

1130-1145 **Bhupinder Pal Singh, P Mehra and S Saggar**
Elizabeth Macarthur Agricultural Institute, NSW Dept of Primary Industries, Australia
NITROUS OXIDE EMISSIONS FROM COW URINE PATCHES AT DIFFERENT SOIL MOISTURE LEVELS IN AN INTENSIVELY MANAGED AUSTRALIAN GRASSLAND

1145-1200 **Donna Giltrap, N Portegys, S Saggar and J Hanly**
Manaaki Whenua - Landcare Research, Palmerston North
WHAT FRACTION OF A URINE PATCH CAN BE INTERCEPTED BY A TARGETED INHIBITOR APPLICATION?.

1200-1215 **Discussion**

1215-1230 **Poster Papers**

Patrick Forrestal, M O'Neil, K Richards, G Bates, D Smith, B Jolly and S Saggar
Teagasc, Wexford, Ireland
PERFORMANCE OF "SPIKEY" IN LOCATING AND DETECTING FRESHLY DEPOSITED URINE PATCHES IN LIVESTOCK GRAZED PASTURE SOILS OF IRELAND

Promil Mehra, BP Singh, B Jolly, G Bates, S Saggar and J Luo
Elizabeth Macarthur Agricultural Institute, NSW Dep of Primary Industries, Australia
PERFORMANCE OF SENSOR TECHNOLOGIES IN DETECTING FRESHLY DEPOSITED URINE PATCHES IN GRAZED PASTURE SOILS OF AUSTRALIA

Kamal Adhikari, S Saggar, J Luo, D Giltrap, P Berben, T Palmada, M Sprosen, S Lindsey and J Dando
Manaaki Whenua - Landcare Research, Palmerston North
NITROUS OXIDE EMISSIONS AND EMISSION FACTORS FROM URINE DEPOSITED 'HOT-SPOTS' IN DAIRY PASTURES – WINTER TRIALS

May Hedges, J Hanly, D Horne and S Saggar
Farmed Landscapes Research Centre, Massey University, Palmerston North
EFFECT OF INCREASING COW URINE PATCH AREA ON AMMONIA EMISSIONS FROM URINE APPLIED TO A PASTURE SOIL

Maria Jimena Rodriguez-Gelos, P Kemp, P Bishop, J Hanly, S Navarrete and D Horne
School of Agriculture and Environment, Massey University, Palmerston North
PLANTAIN SWARD: IS IT EFFECTIVE IN REDUCING N_2O EMISSIONS IN SPRING AND AUTUMN?

Bill Carlson, J Luo, S Lindsey and C de Klein
AgResearch, Hamilton
EFFECT OF PLANTAIN USE ON REDUCTION OF NITROUS OXIDE EMISSIONS FROM A WAIKATO FARM

1230-1330 **Lunch**

Session 2 : Sequestering C to Offset GHG Emissions

Chairman: **Dr James Hanly**
Farmed Landscapes Research Centre, Massey University

1330-1400 **Axel Don** *Keynote Speaker*
Thünen Institute of Climate Smart Agriculture, Germany
DEEP TILLAGE EFFECTS ON SOIL CARBON STOCKS - EVIDENCE FROM LONG-TERM EXPERIMENTS

1400-1410 **Erin Lawrence-Smith, D Curtin, M Beare, S McNally, F Kelliher, R Calvelo Pereira and M Hedley**
Plant and Food Research, Christchurch
THE POTENTIAL FOR FULL INVERSION TILLAGE PASTURE RENEWAL TO BUILD SOIL CARBON IN PERMANENT PASTURES

1410-1420 **Mike Beare, S McNally, R Calvelo Pereira, C Tregurtha, R Gillespie, G van der Klei and M Hedley**
Plant and Food Research, Christchurch
THE AGRONOMIC AND ENVIRONMENTAL BENEFITS AND RISKS OF AUTUMN PASTURE RENEWAL WITH FULL INVERSION TILLAGE

1420-1430 **Roberto Calvelo Pereira, M Hedley, J Hanly, M Osborne, S McNally and M Beare**
School of Agriculture and Environment, Massey University. Palmerston North
THE AGRONOMIC AND ENVIRONMENTAL BENEFITS AND RISKS OF SPRING PASTURE RENEWAL WITH FULL INVERSION TILLAGE

1430-1440 **Sam McNally, G Van der Klei, R Calvelo Pereira, S Thomas, M Beare and M Hedley**
Plant and Food Research, Christchurch
NITROUS OXIDE EMISSIONS FROM FERTILISER AND URINE FOLLOWING FULL INVERSION TILLAGE AUTUMN PASTURE RENEWAL

1440-1450 **Miko Kirschbaum, M Beare, M Hedley, S McNally, R Calvelo Pereira, Erin Lawrence-Smith and Denis Curtin**
Manaaki Whenua - Landcare Research, Palmerston North
WHAT PROCESSES CAN CAUSE SOIL C STOCKS TO INCREASE AFTER FULL INVERSION TILLAGE? A SENSITIVITY ANALYSIS OF POSSIBLE CONTRIBUTING PROCESSES

1450-1505 **Discussion**

1505-1510 **Poster Papers**

Mike Hedley, M Beare, R Calvelo Pereira, S McNally, E Lawrence-Smith, C Tregurtha, M Osborne, R Gillespie, G Van der Klei and S Thomas
School of Agriculture and Environment, Massey University, Palmerston North
WHERE, WHEN AND HOW - PRACTISE GUIDELINES FOR SUCCESSFUL INTRODUCTION OF FULL INVERSION TILLAGE TO INCREASE SOIL CARBON STOCKS UNDER PASTURE

Yajun Peng, J Hanly, P Jeyakumar and R Calvelo Pereira
School of Agriculture and Environment, Massey University, Palmerston North
CAN FULL INVERSION TILLAGE DECREASE SOIL AND PLANT CD CONCENTRATIONS IN TWO CONTRASTING SOILS

1510-1530 **Afternoon Tea**

Session 3 : Management of Emissions

Chairman: Dr Ants Roberts
Ravensdown

1530-1540 **Phil Journeaux and T Kingi**
AgFirst, Hamilton
MITIGATION OF ON-FARM GREENHOUSE GAS EMISSIONS

1540-1550 **Nigel Meads, T Wang, N Jantasila and A Kocher**
Alltech New Zealand, Auckland
THE RELATIONSHIP BETWEEN DIETARY PROXIMATE ANALYSIS AND GREENHOUSE GAS EMISSIONS DETERMINED USING IN VITRO METHODOLOGY

1550-1600 **Lorna McNaughton and P Beatson**
LIC, Hamilton
METHANE INDEXING OUR NEXT GENERATION OF DAIRY SIRES

1600-1610 **David Scobie, R Dynes, Jessica B Faris, A Taylor, B Wright and S Wright**
AgResearch, Christchurch
SHEEP, BEEF AND FORESTRY TO BALANCE CARBON EMISSIONS

1610-1620 **Phil Journeaux, J Wilton, L Archer, S Ford, and G McDonald**
AgFirst, Hamilton
THE VALUE OF NITROGEN FERTILISER TO THE NEW ZEALAND ECONOMY

1620-1630 **Discussion**

1630-1635 **Poster Papers**

Neha Jha, P Bishop, M Camps-Arbestain and B Maddison
School of Agriculture and Environment, Massey University, Palmerston North
ROLE OF SHELTERBELTS IN SEQUESTERING SOIL CARBON IN NEW ZEALAND GRAZED PASTURES

Weiwen Qiu, D Curtin, M Beare and K Lehto
Plant and Food Research, Christchurch
EFFECTS OF LAND USE AND SOIL TYPE ON CARBON AND NITROGEN MINERALIZATION

Nigel Meads, B Smith, T Wang, N Jantasila and A Kocher
Alltech New Zealand, Auckland
SEASONAL CHANGES IN METHANE EMISSION FROM NEW ZEALAND PASTURES A SURVEY USING IN VITRO METHODOLOGY

1635-1730 **Overseer Session**

1730 **Day One concludes**

Wednesday 12th February

Session 4 : Nutrient Attenuation; Edge-of-field Practices (Part one)

Chairman: **Associate Professor Ranvir Singh**
Farmed Landscapes Research Centre, Massey University

0830-0900 **Laura Christianson** *Keynote Speaker*
University of Illinois, USA
SCALING A MOUNTAIN: AN OPPORTUNITY FOR DENITRIFYING BIOREACTORS

0900-0920 **Ian Layden, S Irvine Brown, R Abel and F Manca** *Invited Speaker*
Dept Agriculture and Fisheries (QLD), Australia
MANAGING NITROGEN IN TROPICAL FARMING SYSTEMS: A BUDGETING AND MITIGATION APPROACH

0920-0940 **Rhianna Robinson, I Layden, C Wegscheidl and F Manca** *Invited Speaker*
Dept Agriculture and Fisheries (QLD), Australia
BIOREACTORS IN THE GREAT BARRIER REEF (GBR) CATCHMENTS: IMPLEMENTATION AND NETWORKING

0940-1000 **Chris Tanner** *Invited Speaker*
NIWA, Hamilton
THE SPECTRUM OF EDGE-OF-FIELD TO WATERWAY MITIGATION OPTIONS FOR NUTRIENT MANAGEMENT IN FARMED LANDSCAPES

1000-1015 **Discussion**

1015-1045 **Morning Tea**

Session 5 : Nutrient Attenuation; Edge-of-field Practices (Part two)

Chairman: **Emeritus Professor Mike Hedley**
Farmed Landscapes Research Centre, Massey University

1045-1055 **Greg Barkle, R Stenger, J Clague, A Rivas and B Moorhead**
Land and Water Research Ltd, Hamilton
UNDERSTANDING CONTAMINANT EXPORT PATHWAYS IS PREREQUISITE FOR IMPLEMENTING EFFECTIVE NUTRIENT ATTENUATION OPTIONS

1055-1105 **Aldrin Rivas, G Barkle, B Maxwell, B Moorhead, R Stenger, L Schipper, F Birgand and J Clague**
Lincoln Agritech Ltd, Hamilton
DETERMINING THE SPATIAL VARIABILITY OF NITRATE REMOVAL IN A WOODCHIP BIOREACTOR THROUGH HIGH FREQUENCY MONITORING AT MULTIPLE LOCATIONS

1105-1115 **Lee Burbury, R Mellis, P Abraham, R Sutton, T Sarris, M Finnemore and M Close**
ESR, Christchurch
ASSESSING IF WOODCHIP DENITRIFICATION WALLS ARE A VIABLE EDGE OF FIELD NITRATE MITIGATION PRACTICE IN GRAVEL AQUIFER SETTINGS

1115-1125 **Rupert Craggs, J Park and V Montemezzani**
NIWA, Hamilton
FILAMENTOUS ALGAE NUTRIENT SCRUBBERS FOR TREATMENT AND NUTRIENT RECOVERY FROM AGRICULTURAL DRAINAGE

1125-1135 **Brian Levine, L Burkitt, D Horne, L Condron, C Tanner and J Paterson**
School of Agriculture and Environment, Massey University, Palmerston North
PHOSPHORUS MITIGATION PROJECT: QUANTIFYING THE ABILITY OF DETAINMENT BUNDS TO MITIGATE NUTRIENT LOSSES FROM PASTORAL AGRICULTURE IN THE LAKE ROTORUA WATERSHED

1135-1145 **Brandon Goeller, C Febria, L McKergow, J Harding, F Matheson, C Tanner and A McIntosh**
NIWA, Hamilton
COMBINING TOOLS FROM EDGE-OF-FIELD TO IN-STREAM TO ATTENUATE REACTIVE NITROGEN ALONG SMALL AGRICULTURAL WATERWAYS

1145-1155 **Juliet Milne and J Luttrell**
NIWA, Wellington
REGULATORY BARRIERS TO THE UPTAKE OF EDGE-OF FIELD AND FARM-SCALE DIFFUSE NUTRIENT POLLUTION MITIGATION TECHNOLOGIES

1155-1210 **Discussion**

1210-1230 **Poster Papers**

Aldrin Rivas, R Stenger, S Wilson, J Clague, G Barkle, P Durney and B Moorhead
Lincoln Agritech Ltd, Hamilton
SKYTEM SURVEYS FOR CATCHMENT-SCALE HYDROGEOPHYSICAL EXPLORATION

Kishor Kumar, C Hedley, A El-Naggar, J Ekanayake, J Drewry, D Horne and B Clothier
Landcare Research, Palmerston North
THREE YEARS OF DRAINAGE FLUXMETER MEASUREMENTS UNDER A CENTRE PIVOT – HOW DO THEY RELATE TO SOIL, CLIMATE AND IRRIGATION?

Sarmini Maheswaran, D Burnham, J Millner, L Cranston, D Horne, J Hanly, P Kenyon and P Kemp
School of Agriculture and Environment, Massey University, Palmerston North
NUTRIENT LEACHING UNDER INTENSIVE SHEEP GRAZING: A NEW RESEARCH INITIATIVE

Reid Christianson
University of Illinois at Urbana-Champaign, USA
CONSIDERING PERSISTENCE IN THE LANDSCAPE WHEN TRACKING WATER QUALITY BENEFITS OF CONSERVATION PRACTICES

Lee Burbery, P Abriham, T Sarris and C Tanner
ESR, Christchurch
IN-STREAM WOODCHIP DENITRIFYING BIOREACTOR TRIAL, SOUTH CANTERBURY

Abhiram Gunaratnam, M Grafton, P Jeyakumar, P Bishop, C Davies and M McCurday
School of Agriculture and Environment, Massey University, Palmerston North
STUDY THE INFLUENCE OF SOIL MOISTURE AND PACKING INCREMENTAL LEVEL ON SOIL PHYSICAL AND HYDRAULIC PROPERTIES

1230-1330 **Lunch**

Session 6 : Synergies in Solutions for GHG and Water Quality

Chairman: **Dr Aaron Stafford**
Ballance Agri-Nutrients

1330-1350 **Nanthi Bolan**
Cooperative Research Centre for High Performance Soil (Soil CRC), Australia
BIOCHAR-NUTRIENT INTERACTIONS IN SOIL IN RELATION TO AGRICULTURAL PRODUCTION AND ENVIRONMENTAL PROTECTION

1350-1400 **Robert Ward, R Gentile, J Laubach, J Hunt and A McMillan**
Plant & Food Research, Palmerston North
ASSESSMENT OF THE CARBON AND WATER BALANCES OF SAUVIGNON BLANC GRAPES USING EDDY COVARIANCE

1400-1410 **Brian Ellwood, H Lowe and B Paton**
Lowe Environmental Impact, Palmerston North
CONCEPTUAL FRAMEWORK TO ENABLE COORDINATED SOLUTIONS FOR CLIMATE CHANGE AND WATER QUALITY

1410-1420 **Kathryn Hutchinson, T van der Weerden, A Hutton, M Manning, A Taylor and R Dynes**
AgResearch, Palmerston North
DAIRY AND DRY STOCK: EXPLORING THE BIG LEVERS FOR GHG REDUCTIONS AND IMPLICATIONS FOR WATER QUALITY AND ECONOMICS

1420-1430 **Di Lucas and B Smith**
Lucas-Associates, Christchurch
INTEGRATED FARM PLANS (IFP

1430-1440 **J Rowarth, Ants Roberts and M Manning**
Agri-environment analyst, Tirau
LEARNING FROM THE PAST: A COMPARISON OF FOOD PRODUCTION SYSTEMS FOR MANAGING NUTRIENTS

1440-1450 **Tony Fransen**
LIC, Hamilton
QUANTIFYING ENVIRONMENTAL EFFICIENCY THROUGH GENETIC MERIT (BW

1450-1505 **Discussion**

1505-1515 **Poster Papers**

Georgia O'Brien, L Posthuma and D Bloomer
LandWISE, Hastings
"BACK OF AN ENVELOPE" NUTRIENT BUDGETING

Luke Posthuma, G O'Brien and D Bloomer
LandWISE, Hastings
LIQUID FERTILISER APPLICATION TOOLS FOR NITROGEN MANAGEMENT SUCCESS IN VEGETABLE CROPPING

Vance Fulton, L Burkitt, B Levine, J Paterson and D Horne
BOP Nutrient Management, Papamoa
GROUND TRUTHING OVERSEER FM - MODELLED P LOSSES VERSUS MEASURED P LOSS

Logan Bowler and B Longhurst
Agblution Solutions Ltd, Marton
USING GREEN WATER FOR YARD WASHING: CASE STUDY OF A MANAWATU DAIRY FARM

1515-1545 **Afternoon Tea**

Session 7 : Uncertainty in Measurement and Modelling

Chairman: **Dr Alec Makay**
AgResearch

1545- 1555 **David Wheeler, E Meenken, M Espig, M Sharifi, M Shah and S Finlay-Smits**
AgResearch, Hamilton
UNCERTAINTY – WHAT IS IT?

1555-1605 **Mos Sharifi, E Meenken, B Hall, M Espig, S Finlay-Smits and D Wheeler**
AgResearch, Hamilton
IMPORTANCE OF MEASUREMENT AND DATA UNCERTAINTY IN A DIGITALLY ENABLED AGRICULTURE SYSTEM

1605-1615 **Esther Meenken, D Wheeler, M Espig, J Bryant, H Brown, E Teixeira and C Triggs**
AgResearch, Hamilton
A FRAMEWORK FOR UNCERTAINTY EVALUATION AND ESTIMATION IN AGRICULTURAL BIOPHYSICAL MODELS

1615-1625 **Munir Shah, S Meenken and E Meenken**
AgResearch, Hamilton
AUGMENTING TRIAL DATA WITH OTHER DISPARATE DATA SOURCES AND QUANTIFYING UNCERTAINTY

1625-1635 **Martin Espig, S Finlay-Smits, E Meenken, D Wheeler, M Sharifi and M Shah**
AgResearch, Hamilton
UNDERSTANDING AND COMMUNICATING UNCERTAINTY IN DATA-RICH ENVIRONMENTS: TOWARD A TRANSDISCIPLINARY APPROACH

1635-1645 **Linda Lilburne, J Guo, J Barringer, I Lynn, S Hainsworth, E Teixeira and A Tait**
Manaaki Whenua - Landcare Research, Canterbury
COMPARISON OF USING S-MAP SOIL INFORMATION WITH THE OLDER FUNDAMENTAL SOIL LAYERS

1645-1700 **Discussion**

1700-1715 **Poster Papers**

Nicolaas Portegys, S Saggar, J Hanly, D Giltrap
School of Agriculture and Environment, Massey University, Palmerston North
MEASURING SPATIAL DISTRIBUTION OF DICYANDIAMIDE MOVEMENT IN A WELL-DRAINED AND A POORLY-DRAINED SOIL

Bawatharani Raveendrakumaran, M Grafton, P Jeyakumar, P Bishop and C Davies
School of Agriculture and Environment, Massey University, Palmerston North
COMPARATIVE EVALUATION OF CONTROLLED RELEASE FERTILISERS FOR NITRATE LEACHING BY A LYSIMETRIC EXPERIMENT

Scott Post
Lincoln Agritech, Canterbury
FULL-SCALE HOPPER TESTING OF LIME FLOWABILITY

Themba Matse, P Jeyakumar, P Bishop and C Anderson
School of Agriculture and Environment, Massey University, Palmerston North
EFFECT OF COPPER BIOAVAILABILITY ON NITRIFICATION RATE IN NEW ZEALAND PASTORAL SOILS

Aimee Dawson, C Field, R Hamilton, and A Barlass
Ballance Agri-Nutrients, Upper South Island
STRATEGIC USE OF SOLUBLE MAGNESIUM FERTILISER TO BOOST SPRING DAIRY PASTURES FOR ANIMAL HEALTH OUTCOMES

Nilusha Ubeynarayana, P Jeyakumar, P Bishop, R Calvelo Pereira and C Anderson
Farmed Landscapes Research Centre, Massey University, Palmerston North
COMPLEXATION OF CD WITH ORGANIC ACIDS IN XYLEM FLUID OF CHICORY AND PLANTAIN

Brittany Hill
QCONZ, Hamilton
COMPARING TARARUA DAIRY FARMS ABILITY TO MEET YEAR 20 NITROGEN LEACHING LIMITS USING OVERSEER 5.2.6 AND TABLE 14.2 IN THE ONE PLAN, WITH OVERSEER 6.3.0 AND THE RECALIBRATED TABLE

1715-1800 **Poster Papers on Display**
Informal drinks in the AgHort Lecture Block

1815- **Workshop Dinner at Wharerata**

Thursday 13th February

Session 8 : In-field Mitigation of Nutrient Losses

Chairman: **Dr Roberto Calvelo Pereira**
Farmed Landscapes Research Centre, Massey University

0835-0845 **Adrian and Pauline Ball**
Supreme National Winners, BFEA 2019, Waikato
MANAGING NUTRIENT AND GHG LOSSES WHILE MAINTAINING AN ECONOMIC BUSINESS – DENNLEY FARMS, BFEA WINNERS 2019

0845-0855 **Charlotte Robertson**
DairyNZ, Waikato
DAIRY FARM SYSTEM SOLUTIONS THAT REDUCE NITRATE LEACHING AND THEIR CONSEQUENCES FOR PROFITABILITY

0855-0905 **Pierre Beukes, E Minnee, T Chikazhe and J Edwards**
DairyNZ, Hamilton
OPTIONS AND IMPLICATIONS FOR INCORPORATING PLANTAIN MIXED PASTURES INTO A CANTERBURY DAIRY SYSTEM

0905-0915 **Soledad Navarrete, P Kemp, M Rodriguez, D Horne, J Hanly and M Hedley**
School of Agriculture and Environment, Massey University, Palmerston North
PLANTAIN (*Plantago lanceolata* L.) NITROGEN USE AND EXCRETION BY LACTATING DAIRY COWS

0915-0925 **Maria Jimena Rodriguez-Gelos, P Kemp, S Navarrete, J Hanly, D Horne and P Bishop**
School of Agriculture and Environment, Massey University, Palmerston North
NITROGEN LOSSES FROM PLANTAIN: WHAT CAN WE SAY?

0925-0935 **Rowland Tsimba**
Genetic Technologies Ltd, Cambridge
QUANTIFICATION OF NITROGEN (N) LEACHING LOSSES UNDER A MAIZE CROPPING SYSTEM

0935-0945 **Chris Rogers, P Back, E Gee, Y Chin, S Linton and A Wark**
School of Agriculture and Environment, Massey University, Palmerston North
PREDICTING NUTRIENT LOSS – WHAT TO DO WITH EQUINE PROPERTIES?

0945-0955 **David Horne, R Singh, P Tozer and D Gray**
School of Agriculture and Environment, Massey University, Palmerston North
SHARING BOTH THE RESPONSIBILITIES AND RESOURCES TO REDUCE N LEACHING: A NEW PARADIGM FOR DAIRY FARMING

0955-1010 **Discussion**

1010-1040 **Morning Tea**

Session 9 : Policy Development and Implementation

Chairman: Dr Lucy Burkitt
Farmed Landscapes Research Centre, Massey University

1040-1050 **Nicholas Kirk**
Manaaki Whenua-Landcare Research, Canterbury
THE BARRIERS TO FRESHWATER POLICY IMPLEMENTATION IN AOTEAROA NEW ZEALAND

1050-1100 **Tom Corser**
Ministry for Primary Industries, Wellington
UPDATE ON THE PROPOSED NATIONAL POLICY STATEMENT FOR HIGHLY PRODUCTIVE LAND

1100-1110 **Selva Selvarajah**
EnviroKnowledge, Dunedin
CENTRAL GOVERNMENT MANAGEMENT OF THE FRESHWATER UNDER THE RESOURCE MANAGEMENT ACT

1110-1120 **Lynette Baish and K Proctor**
Horizons Regional Council, Palmerston North
INNOVATIVE, ADAPTIVE AND ENGAGING POLICY DEVELOPMENT FOR NUTRIENT MANAGEMENT WITHIN INTENSIVE FARMING SYSTEMS: WHERE POLICY, SCIENCE AND AGRICULTURE INTERSECT

1120-1130 **A Brocksopp, Peter Roberts, D Patterson and M Highway**
Living Water Partnership
RESTORING AND RECONNECTING A RURAL FRESHWATER ECOSYSTEM AND SENSITIVE COASTAL ENVIRONMENT USING A COMMUNITY-LED 'MOUNTAINS TO SEA' APPROACH

1130-1140 **Nicole Matheson, S Hayman and E Harris**
Irrigo, Ashburton
IMPLEMENTATION OF AN AUDITED SELF-MANAGEMENT PROGRAMME – A CASE STUDY OF BARRHILL-CHERTSEY A MID-CANTERBURY IRRIGATION SCHEME

1140-1150 **Shane Gilmer**
Hawke's Bay Regional Council, Hastings
FARM PLAN ANALYSIS UNDER THE TUKITUKI CATCHMENT PLAN LUC FRAMEWORK

1150-1205 **Discussion**

1205-1300 **Lunch**

Session 10 : Managing Fertilisers, Trace Elements and Crops

Chairman: **Professor Chris Anderson**
Farmed Landscapes Research Centre, Massey University

1300-1310 **David Nash, R McDowell, L Condron, M McLaughlin**
Soil and Allied Services Pty Ltd, Australia
QUANTIFYING THE DIRECT CONTRIBUTION OF FERTILIZERS TO PHOSPHORUS EXPORTS FROM PASTURES

1310-1320 **David Nash, R McDowell, L Condron, M McLaughlin**
Soil and Allied Services Pty Ltd, Australia
FERTILIZER SELECTION FOR OPTIMAL ENVIRONMENTAL PERFORMANCE

1320-1330 **Hendrik Venter, M Manning, R Christie, A Roberts, M White, A Metherell, W Bodeker, and J Holloway**
Ravensdown, Napier
REVISITING THE WATKINSON DISSOLUTION TEST FOR PREDICTING PHOSPHATE RELEASE FROM DIRECT APPLICATION PHOSPHATE ROCKS

1330-1340 **Dan Bloomer, L Posthuma and G O'Brien**
LandWISE, Hastings
ENGAGING TO CHANGE – IMPROVING NUTRIENT MANAGEMENT PRACTICES WITH VEGETABLE GROWERS THROUGH ON-FARM TRIALS

1340-1350 **Greg Sneath**
Fertiliser Association, Wellington
REVISION OF TIERED FERTILISER MANAGEMENT SYSTEM FOR SOIL CADMIUM

1350-1400 **Gerald Rys**
Cadmium Management Group, MPI, Wellington
A REFRESHED NEW ZEALAND CADMIUM MANAGEMENT STRATEGY

1400-1410 **Gautam Shrestha, R Calvelo Pereira, G Kereszturi, J Jeyakumar, C Anderson and M Poggio**
School of Agriculture and Environment, Massey University, Palmerston North
PREDICTING CADMIUM CONCENTRATION IN NEW ZEALAND AGRICULTURAL SOIL USING MID INFRARED SPECTROSCOPY

1410-1420 **Peter Carey, B Malcolm, S Maley and W Hu**
Lincoln Agritech, Christchurch
NEW TILLAGE TECHNOLOGY TO IMPROVE CATCH CROP OUTCOMES IN SOUTHLAND

1420-1430 **Mitchell Donovan and R Monaghan**
AgResearch Invermay, Mosgiel
MODELLING SPATIAL AND TEMPORAL VARIABILITY IN EROSION RISK FOR WINTER GRAZING MANAGEMENT

1430-1445 **Discussion**

1445-1500 **Closing Remarks**

1500 **Afternoon Tea and depart**

HE WAKA EKE NOA – GOVERNMENT AND AGRI-FOOD AND AGRI-FIBRE SECTOR JOINT CLIMATE ACTION PLAN

Andrew Kempson[1], K Green[2] and K Forster[2]

[1]Fonterra Co-Operative Group, Hamilton
[2]Ministry for Primary Industries, Wellington

In April of 2019, the Interim Climate Change Commission (iCCC) provided advice to Government on ways to reduce emissions from agriculture.
The iCCC concluded that the best way to incentivise farmers to reduce emissions is to price them at farm level, and that pricing needs to be part of a broader policy package that includes tools, support and advice to farmers.

Primary sector leaders acknowledged change is required and shared the Government's aspirations to shift to higher value, more environmentally sustainable farming systems. This includes a commitment to mitigating the primary sector's contribution to climate change through actions that reduce or offset emissions, to contribute to the global effort under the Paris Agreement to limit the global average temperature increase to 1.5° Celsius above pre-industrial levels.

This acknowledgement culminated in 11 primary sector organisations who, represent all of the pastoral farming types in New Zealand, making a collective commitment called He Waka Eke Noa.

The commitment detailed how the primary sector will work in good faith with government and iwi/Māori to design a practical and cost-effective system for reducing emissions at farm level by 2025. The sector committed to working with government to design pricing at farm level system to reduce agricultural methane and nitrous oxide emissions that includes a pricing mechanism building on the principles set out in He Waka Eke Noa. The primary sector's proposed 5-year programme of action was aimed at ensuring farmers and growers are equipped with the knowledge and tools they need to deliver emissions reductions while maintaining profitability.

In October of 2019 in what is a world leading first, farming leaders and the Government announced a plan to formalise this commitment and join forces along with Māori to develop practical and cost-effective ways to measure and price emissions at the farm level by 2025, so that 100 per cent of New Zealand's emissions will be on the path downwards.

The 5-year joint action plan includes:

- Improved tools for estimating and benchmarking emissions on farms
- Integrated farm plans that include a climate module
- Investment in research, development and commercialisation
- Increased farm advisory capacity and capability
- Incentives for early adopters
- Recognition of on-farm mitigation such as small plantings, riparian areas and natural cover

HOW FAR CAN GREENHOUSE GAS MITIGATION TAKE US TOWARDS NET ZERO EMISSIONS IN AGRICULTURE?

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An increasing number of countries have set targets for reducing national greenhouse gas emissions to net zero in the coming decades. Such emission reductions will require a transformation of all sectors of society, but nowhere more so than in agriculture and land use. Using the UK as a case study we outline how changes in agricultural management could contribute to the net zero target. Agriculture in the UK is responsible for 46 Mt CO_{2e} or 10% of UK emissions (2017). In order to reach an overall target of net zero for the UK economy by 2050 it is estimated that agricultural emissions must be reduced by over 50%. It is envisaged that this will be partly achieved by implementing a range of technologies that reduce nitrous oxide emissions (including more efficient use of fertilisers and manures, the use of urease and nitrification inhibitors, more extensive use of legumes, and improved soil management) and methane emissions from livestock (including dietary manipulation, use of improved genetics, and improved animal health). Unlike some other sectors, agricultural emissions cannot be reduced to zero, and the land use sector will play a major role in the removal of residual positive emissions. Biomass energy carbon capture and storage offers the largest opportunity for CO_2 capture, but other approaches such as increased soil carbon sequestration, the use of biochar, mineral weathering, and direct air capture are currently being explored. However, such offsetting mechanisms are also likely to be relied upon by other sectors including aviation in which it is difficult to achieve zero emissions. If offsetting is unable to remove sufficient quantities of GHGs to reach the net zero target, then additional measures (such as improved nutrient use efficiency, carbon sequestration and reduced consumption of dairy, beef and lamb) to reduce emissions from the agriculture sector will be required.

OPTIONS FOR REDUCING GASEOUS EMISSIONS FROM IRISH AGRICULTURE

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A marginal abatement cost analysis was used in order to assess the abatement potential of a range of mitigation measures, as well as their associated costs/benefits on both GHG and ammonia emissions for the period 2020-2030. This analysis was necessitated a) by increases in Irish agricultural output that have occurred post milk-quota removal and as a consequence of the national FoodWise 2025 initiative and b) requirements to achieve national GHG and ammonia reduction targets. Irish dairy production has expanded by over 40% to 7.6 billion litres since the abolition of milk quotas. Irish agriculture accounts for 33% of national greenhouse gas emissions (GHG) and 98% of ammonia emissions. Agricultural emissions of GHG and ammonia have increased by c. 13% since 2011. The Irish governments Climate Action Plan, published in June 2019, has set a target for Irish agriculture to reduce emissions to 17.5 to 19 MT CO_2-e yr^{-1}. In addition agriculture has been tasked to deliver the total LULUCF flexibility allocated to Ireland of 2.68 MT CO_2-e yr^{-1}. How can Irish agriculture reduce emissions? Measures were sub-divided into four different categories: a) Measures with reduced agricultural GHG (i.e. directly reduce methane and nitrous oxide); b) measures that reduced ammonia, c) Measures which enhance CO_2 removals from the atmosphere in terms of land management or Land-Use, Land-Use Change in Forestry (LULUCF), and d) reductions from displacement of fossil fuels via enhanced cultivation of biomass and/or adoption of anaerobic digestion. The total level of GHG abatement of all three categories averaged over the period 2021-2030 was 6.19 MT carbon dioxide equivalents (CO_2-e) per year. The ammonia abatement potential was estimated between 17-21 kT NH_3 yr^{-1} by 2030, with urea substitution, N management, low-emission landspreading of manures and slurry acidification identified as the primary strategies. The GHG related measures have been included in the Irish National Climate Action plan 2019 and the ammonia measures will be included in the forthcoming Code of Good Practice to Reduce Ammonia emissions (DAFM). The challenge now is to encourage widespread adoption of these measures and this will require significant knowledge transfer efforts to practice change.

LONG-TERM EFFECTS OF UREASE AND NITRIFICATION INHIBITOR ENHANCED FERTILISERS

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Fertiliser nitrogen (N) is a cornerstone input in many intensive agricultural systems including those prevalent in Irish temperate grassland. Increased new pressures to meet environmental commitments in addition to achieving agronomic potential economically has brought renewed interest to the subject of fertilizer nitrogen source and enhanced efficiency fertilizers. Field studies often examine the effects of fertilizer nitrogen options over single or a couple of growing seasons due to the nature of funding cycles. The present study examines the effect of a suite of N fertilizers applied to the same plots over the long-term (6 years and continuing). The fertilizers include; calcium ammonium nitrate (CAN), urea, urea + N- (n-butyl) thiophosphoric triamide (NBPT), urea + dicyandiamide (DCD) and urea+NBPT+DCD. This suite of fertilisers has, in previously published research, been shown to differ significantly in terms of gaseous N emissions. However, yield and nitrogen efficiency over single year trials have been more difficult to detect. Evidence of difference in agronomic performance between fertilisers in the current long-term trials is beginning to emerge. Results will be presented. The findings are important because changes in fertilizer practice at farm level occur not just in the short-term but in the long term.

NITROUS OXIDE EMISSIONS FROM COW URINE PATCHES AT DIFFERENT SOIL MOISTURE LEVELS IN AN INTENSIVELY MANAGED AUSTRALIAN GRASSLAND

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In intensively grazed pastures, urine patches deposited during livestock grazing are the hotspots for production of greenhouse gas, nitrous oxide (N_2O), and nitrate leaching. The impacts of spatial and temporal variability in urine N concentration and volume on N_2O emissions required to accurately estimate country-specific N_2O emission factors (EFs) have not been thoroughly evaluated under variable warmer and drier temperate environments (*e.g.,* Menangle, NSW, Australia). Here we quantify and compare N_2O emissions and EFs from a naturally expanding effective area (NEEA), with that from a uniformly wetted area (UWA) of urine application in large *versus* small chambers, respectively.

The results show that over 146 days (early winter to late spring), there was the least cumulative N_2O emissions with low urine-N loading (141–282 kg N ha^{-1}) under NEEA, relative to the urine-N loading of 709 kg N ha^{-1} under UWA. In NEEA, there was no difference in N_2O emissions with different urine volume treatments applied at the below field capacity (BFC) soil moisture condition. In contrast, there was a significant difference in N_2O emissions at the field capacity (FC), for example, 522±64 g N_2O-N ha^{-1} (1.5L urine) *versus* 365±52 g N_2O-N ha^{-1} (1.0L urine). In UWA, the N_2O-N emissions were higher at the FC than BFC. The EF values in NEEA did not vary significantly with urine-N loading and soil moisture conditions, and ranged between 0.07±0.01% to 0.11±0.03% in the BFC, and 0.09±0.02% to 0.16±0.03% in the FC. The EF values in UWA were 0.09±0.02% and 0.26±0.05% in the BFC and FC, respectively. The N_2O EF was higher in UWA than NEEA only at the FC soil moisture condition. The results suggest that the cattle urine-derived EFs for N_2O emissions (over winter to spring) in the drier temperate environment are lower than the country-specific EFs of 0.4 and 1.0% currently used in the Australian and New Zealand inventories, respectively.

WHAT FRACTION OF A URINE PATCH CAN BE INTERCEPTED BY A TARGETED INHIBITOR APPLICATION?

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Urine patches are potential hot spots for N losses via gaseous emissions and leaching in grazed pastures. These losses may be reduced by the application of inhibitors that slow down particular transformations of the urine-N (e.g. urease inhibitors, nitrification inhibitors). Technologies exist that can detect urine patches and target the inhibitor application specifically to the patches, thereby avoiding the need to apply the inhibitor over the entire paddock. In practice, however, there will be some time delay between the grazing event and the inhibitor application. This delay could result in some physical separation between the urine and the inhibitor in the soil, which would limit the potential effectiveness of the inhibitor.

In this study we used the HYDRUS 2D/3D model to simulate the movement and transformation of urine-N down the soil profile for two different soils at two different moisture levels. We then simulated the application of DCD at two different volumes applied 24h after the urine to estimate the proportion of urine-N captured by the DCD. These simulations will be compared with experimental measurements and the results presented at the workshop.

PERFORMANCE OF "SPIKEY" IN LOCATING AND DETECTING FRESHLY DEPOSITED URINE PATCHES IN LIVESTOCK GRAZED PASTURE SOILS OF IRELAND

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Urine deposition by grazing animals can be a major source of nitrous oxide (N_2O) and nitrogen (N) leaching in livestock grazed pastures. Mitigation N loss from urine patches is possible by detecting and subsequently treating affected pasture with nitrification inhibitors, to maintain more N and enhance plant uptake. The objective of this study was to assess the ability of the newly developed Spikey-R for detecting the location, shape and size of urine patches. The Spikey-R was compared with thermal imagery from a handheld camera immediately after urine deposition, and a remotely piloted aircraft system (RPAS) 7 and 14 days after urine application. A field trial was established on a dairy pasture in Teagasc, Johnstown Castle, Ireland. Urine patches were created by applying synthetic urine (1, 2 and 3 l) heated to 40^{o}C at two contrasting soil moisture regimes (below and at field capacity). Spikey-R was able to determine accurately the shape, size and location of urine patches up to 52 hours after urine application. Good agreement was found for urine patch area between the Spikey-R and RPAS techniques (r=0.92) but less so with areas determined by the thermal imagery (r=0.68). Patch areas measured by Spikey-R and RPAS were at least 1.37 and 2.81 times greater than those measured by thermal imagery. This result was likely due to increased diffusion and expansion of the urine patch from when the thermal images were captured (~1 minute) relative to the Spikey-R (2 hours) and RPAS (7 days) techniques. The larger patch areas measured by the RPAS flights likely captured the peripheral pasture growth response surrounding the urine patch. Overall, the study illustrates that Spikey-R and RPAS are effective tools for accurately determining urine patch shape and size in Irish dairy pasture soils. However, Spikey-R was able to detect patches directly after their deposition, whereas the RPAS technique identified urine patches solely based on pasture response.

PERFORMANCE OF SENSOR TECHNOLOGIES IN DETECTING FRESHLY DEPOSITED URINE PATCHES IN GRAZED PASTURE SOILS OF AUSTRALIA

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Grazing is an integral part of Australia's Dairy Industry (3rd largest rural industry) and ~60-65% of dairy cattle feed needs originate through grazing yearly. During grazing, the distribution pattern of ruminants and frequency of urinating events over the grazed paddock are unevenly dispersed. These urine patches act as the hotspots of gaseous and leaching losses of nitrogen (N). Identification of the location and size of urine hotspots is central to mitigating N losses by their targeted management.

This study investigated the potential of sensing technologies such as Spikey-R (a New Zealand designed machine for detecting the location, shape and size of urine patches). This study verified the capability of Spikey-R through its comparison with thermal sensor camera images and aerial images captured through a multispectral camera attached to a remotely piloted aircraft system (RPAS). These technologies were tested by manually creating urine patches with 1, 2 and 3 litres of synthetic urine, heated to ~40^{o}C, over a moderately well-drained soil at different soil moisture levels (below and at field capacity referred as Dry and Wet site, respectively).

The detection of urine patches through Spikey-R, when compared with thermal and RPAS approaches, resulted in 100% position accuracy. Spikey-R precisely detected the patch shape, size and location for up to 48 hours after deposition of urine. The detection of urine patches through RPAS was more evident after 14-day post-application of urine. Comparatively, the mean patch area assessed through thermal and RPAS sensor camera images were 20% and 10.5%, respectively, higher than the area detected through Spikey-R. Irrespective of soil moisture conditions, the trends in the shape of detected urine patches through each sensor were not significantly different from each other.

NITROUS OXIDE EMISSIONS AND EMISSION FACTORS FROM URINE-DEPOSITED 'HOT-SPOTS' IN DAIRY PASTURES – WINTER TRIALS

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In dairy-grazed farm systems, total nitrous oxide (N_2O) emissions could be dominated by relatively large emissions within small areas termed 'hot-spots' – areas with high stocking density resulting in proportionally high excretal nitrogen (N) deposition and soil compaction. The objective of this study was to determine N_2O emissions and emission factors (EF_3) from urine applied to potential hot-spot areas (i.e. water troughs, gateways and raceways) to improve our understanding of N_2O emissions within a dairy-grazed farm. Two field studies were conducted during winter at two typical dairy farms, one on a poorly drained Tokomaru soil (Manawatu) and the other on a well-drained Otorohanga soil (Waikato). Gas sampling chambers were placed at various locations in potential hot-spot areas as well as in the surrounding 'typical' pasture. Soil was either treated with cow urine or remained untreated. Overall, N_2O emissions at the Manawatu site were higher than at the Waikato site. However, there was no clear trend for higher emissions and EF_3 values from applied urine in hot-spot areas compared with those from the typical pasture area at either farm. The winter N_2O emissions measurement results suggest that changes in soil physical and chemical parameters of the areas around the water troughs and gateways, possibly influenced by disproportionate excreta deposition, and soil compaction resulting from stock movements and subsequent elevated water-filled pore space, slightly influenced the total emissions from deposited urine but also affected the background emissions and so had little impact on N_2O EF_3 values when compared with EF_3 values from cattle urine deposited in a typical pasture area.

EFFECT OF INCREASING COW URINE PATCH AREA ON AMMONIA EMISSIONS FROM URINE APPLIED TO A PASTURE SOIL

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Livestock urine patches are a major source of nitrogen (N) gaseous and leaching losses to the wider environment in New Zealand agriculture. This is due to the high application rate of N (typically 400-800 kg N/ha) returned in urine deposited on relatively small areas of pasture during grazing. A typical urination is ~2.5 L deposited on 0.25 m^2 pasture soil area. It has been demonstrated that increasing the spread of dairy cow urine patches has potential to reduce the movement of mineral N below the rootzone, thus, reducing N leaching risk. However, there has been limited research on the effect of urine patch size on NH_3 emissions. Therefore, the objective of this study was to quantify the effect of increasing urine patch area (i.e. decreasing urine application depth) on NH_3 emissions from cow urine applied to a pasture soil during autumn.

A field experiment was conducted on a pasture site near Palmerston North in the early autumn of 2019. The soil at the site is a Manawatu silt loam soil (Weathered Fluvial Recent soil or Dystric Fluventic Eutroichrept). Three urine application depth treatments of 10 mm, 5 mm and 2.5 mm were used, representing the depths that would result from applying 2.5 L of urine to three different patch areas: 0.25 m^2 (i.e. typical patch size), 0.5 m^2 and 1 m^2, respectively. Each treatment was replicated five times. The concentration of total N in applied urine was 4.53 g N L^{-1}. Ammonia measurements were conducted over a period of 20 days using the Dynamic Chamber method. Soil samples were also collected and analysed for soil nitrate, ammonium and pH.

Average cumulative NH_3 emissions increased with increasing urine application depth, but the relationship was not linear. When the NH_3 losses from each application depth treatment were extrapolated to the urine patch areas that they represented, then the highest losses occurred for the 1 m^2 urine patch area (2.5 mm treatment). These results showed that increasing the spread area of a specific volume of urine could increase total NH_3 emissions.

PLANTAIN SWARD: IS IT EFFECTIVE IN REDUCING N_2O EMISSIONS IN SPRING AND AUTUMN?

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Several studies have indicated that the use of novel swards such as plantain (*Plantago lanceolata*) can reduce nitrogen (N) losses from grazed systems to air and water. Relative to perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) swards, cows grazing plantain excrete smaller quantities of N in urine thereby, potentially, lowering N_2O emissions from urine patches. Recently, some studies have also suggested that bioactive compounds in plantain, mainly aucubin, could play a role in inhibiting the nitrification process in the N cycle.

The potential for plantain to decrease N_2O emissions was evaluated at Massey University's Dairy Farm 4 on a Tokomaru silt loam soil by using the static chamber method in two field experiments/different seasons (spring 2017 and autumn/winter 2018). Urine treatments evaluated were, urine from cows grazing plantain, urine from cows grazing ryegrass/white clover and water (as control), which were applied to two sward treatments, plantain and ryegrass/white clover. Each treatment was replicated five times resulting in 15 soil plots for mineral N and moisture content and 15 chambers for N_2O measurements. Urine was applied using a metal ring of 0.5 m diameter at a hydraulic loading rate of 10 L m^{-2}. Soil samples were taken to determine soil mineral N and soil moisture content. In spring, urine treatment did not affect (P= 0.2665) N_2O emissions when the urine N concentration in plantain and ryegrass/white clover urine range between 2.81- 3.18 g L^{-1}. In autumn/winter, N_2O losses from plantain urine were lower (P< 0.003) than from ryegrass/white clover urine when the urine N concentration in the plantain urine (3.85 g L^{-1}) was 22% lower compared to ryegrass/white clover urine (4.99 g L^{-1}). In spring N_2O emissions from the ryegrass/white clover sward were higher (P= 0.0281) than from the plantain sward. However, in autumn/winter, the soil under plantain was wetter (P< 0.05) resulting in the plantain swards producing more (P< 0.0001) N_2O compared to the ryegrass/white clover sward. Therefore, in spring the plantain sward reduced N_2O emissions regardless of the urine treatment, probably due to the bioactivity of aucubin. However, in autumn/winter, N_2O losses from the plantain sward were higher than those from the ryegrass/white clover sward due to greater water filled pore space.

EFFECT OF PLANTAIN USE ON REDUCTION OF NITROUS OXIDE EMISSIONS FROM A WAIKATO FARM

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The objectives of this study were to compare the nitrous oxide (N_2O) emission factors for urine (EF_3, N_2O-N emitted as % of N applied) from animals grazing two pasture types: conventional ryegrass (*Lolium perenne*) /white clover (*Trifolium repens*) (RG/WC) or a mixed sward of 60% plantain (*Plantago lanceolate* L.) and 40% RG/WC (P/RG/WC), and to assess whether any differences in EF_3 were due to a "plant" effect or a "urine composition" effect. This work was carried out on a free-draining alluvial soil near Waharoa in the Waikato region during the winter of 2019. A static chamber method was used to measure N_2O fluxes from urine, collected from cows which had been fed on RG/WC or P/RG/WC diets. EF_3 values were calculated for each urine type applied to each pasture type.

The mean net N_2O emission from the RG/WC urine was 0.57 kg N_2O-N ha^{-1} when applied to the RG/WC pasture and 0.40 kg N_2O-N ha^{-1} when applied to the P/RG/WC pasture. The mean net N_2O emission from the P/RG/WC urine was 0.60 kg N_2O-N ha^{-1} when applied to the RG/WC pasture and 0.41 kg N_2O-N ha^{-1} when applied to the P/RG/WC pasture. Overall, the differences in net N_2O emission between the two urine types were not significant ($P > 0.05$), but the net mean N_2O emissions from the P/RG/WC pasture were lower compared with those from the RG/WC pasture ($P < 0.05$). Accordingly, the EF_3 values were not different when either urine type was applied to either RG/WC soil or P/RG/WC soil, but the EF_3 values for the P/RG/WC sward (0.10-0.12%) were lower than those for the RG/WC sward (0.15-0.17%) ($P < 0.05$). These results indicate that the effect that plantain had on reduction of N_2O emissions was not due to specific compounds in the urine but most likely due to biological nitrification inhibition caused by substances exuded from plantain roots or due to other differences in soil microclimate such as soil moisture levels.

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DEEP TILLAGE EFFECTS ON SOIL CARBON STOCKS – EVIDENCE FROM LONG-TERM EXPERIMENTS

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In most natural ecosystem soil carbon is concentrated at the very top of the soil profile. Thus, large parts of the soil are insufficiently used to store carbon. Tillage facilitates the translocation of soil carbon into deeper parts of the soil and thus can enhance soil carbon.

First evidence that deeper tillage can increase total soil carbon stocks come from study sites in Northern Germany. At these sites the ploughing horizon was deepened from on average 25 cm to 35 cm in the 1960s and 70s. More drastic and deeper tillage (>60 cm depth) is used as a melioration measure to improve soil´s infiltration capacity. Such deep tillage increased soil carbon stocks by more than 40% on long term as observed at different long term experiments. Also soil flipping of grassland using diggers is such a drastic melioration measure. Their effect on soil carbon is large, increasing the total carbon stocks by about 70% and doubling of the subsoil carbon stocks. Translocated topsoil carbon seems be stabilised and preserved in the subsoil. The reasons for this high stability are still not completely understood and will be discussed.

Additionally, deep tillage decreases the carbon content at the soil surface, which stimulates new C sequestration in the topsoil. It takes decades for the topsoil after deep ploughing to reach the initial carbon content. This turns topsoils with deep tillage into a long term C sink.

Not all soils are suitable for deep tillage and also negative effects of deep tillage on soil carbon stocks have been observed (in forest). Based on results of various long-term experiments, I will discuss the magnitude of C sequestration with deep tillage and the mechanisms behind it.

THE POTENTIAL FOR FULL INVERSION TILLAGE PASTURE RENEWAL TO BUILD SOIL CARBON IN PERMANENT PASTURES

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This paper outlines a methodology and the first national estimates of the soil C sequestration potential of full inversion tillage (FIT) pasture renewal in New Zealand.

Soils under permanent pastures have large topsoil C stocks. As such, the scope to accumulate additional C in surface soil is limited. However, because C in pastoral soils declines with depth, there may be potential for subsoil to sequester additional C. Grazed pastures in New Zealand require periodic renewal (re-seeding following shallow cultivation) to mitigate productivity deterioration.

To derive the first national estimates of the soil C sequestration potential of FIT pasture renewal (to a depth of 30 cm) in New Zealand, we conducted a case study using soil C data obtained from 247 continuously grazed pasture sites (5 major soil Orders representing ~80% of the country's improved grassland area), a soil C accumulation and decomposition model and a geographic overlay of land use, slope and soils information.

On average, prior to FIT the C concentration in the 0–15 cm layer across all soil Orders was 1.8 to 2.0 times that in the 15–30 cm layer with the 0–15 cm layer containing around 25–30 t ha^{-1} more C. Estimated changes in C stocks post- hypothetical FIT were considered to be driven by: 1) accumulation of C in the new 0–15 cm layer (inverted subsoil), and 2) decomposition of C in the new 15–30 cm layer. Decomposition was estimated using a two-pool model with decay rate constants (k) of 0.1 y^{-1} for particulate organic C and 0.02 y^{-1} for mineral-associated C. In the 20 years following FIT pasture renewal, the stock of soil C was estimated to increase on average by between 8 (Pallic and Recent soils) and 13 t ha^{-1} (Allophanic soils), assuming that C in the surface 15 cm recovered to 80% of the pre-FIT concentration. Nationally, adoption of FIT for pasture renewal on all suitable FIT-ploughable grasslands was estimated to induce soil C sequestration of 21 Mt over 20 years.

THE AGRONOMIC AND ENVIRONMENTAL BENEFITS AND RISKS OF AUTUMN PASTURE RENEWAL WITH FULL INVERSION TILLAGE

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Developing strategies to increase soil carbon (C) and thereby offset the increase in global GHG emissions is of increasing importance. The one-off (or infrequent) use of full inversion tillage (FIT) for pasture renewal has been identified as a promising option to increase soil C stocks. The process of FIT relies on burying C rich topsoil at depth while C depleted subsoil is brought to the surface, where the C inputs from new pasture production may accelerate C sequestration. Results are reported from two field trials on imperfectly drained Pallic soils in Canterbury and the Manawatu to assess the effects of FIT-renewal in the autumn on soil C, dry matter production, nitrogen losses and agronomic costs. The trials consisted of replicated plots where ryegrass/clover pasture was renewed via FIT, no-tillage (NT) or shallow tillage (ST) compared to continuous pasture (no renewal). Additional treatments at Lincoln included plots sown to a mix of forage oats and Italian ryegrass following either FIT or NT. All treatments were established in March 2018. As expected, FIT resulted in a redistribution of C in the top 30 cm of soil but did not change the total C stock immediately after cultivation or one year after pasture renewal. Total dry matter production during the first 20 month was similar under all three (FIT, NT, ST) pasture-to-pasture renewal treatments, which were, on average, about 3 t/ha higher than the continuous pasture treatment. Total dry matter production in the pasture-to-crop-to-pasture renewal system over the same period was greater for FIT (≈ 36 t/ha) than NT (≈ 32 t/ha), which produced 9-13 t/ha more dry matter than the pasture-to-pasture renewal practice. At both sites, accumulation of mineral N following FIT-renewal increased the risk of NO_3^- leaching losses in winter, but this was partially mitigated at Lincoln in the oat/Italian ryegrass treatment. Our results show that the additional agronomic costs (e.g. tillage, fertiliser) associated with FIT are more than offset by the increase in dry matter production in the first year after renewal. Longer-term maintenance of the pasture renewal treatments is needed to demonstrate the effects of FIT-renewal on soil C stocks.

THE AGRONOMIC AND ENVIRONMENTAL BENEFITS AND RISKS OF SPRING PASTURE RENEWAL WITH FULL INVERSION TILLAGE

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Increasing soil organic carbon (SOC) stocks could offset farm net greenhouse gas emissions by reducing global atmospheric CO_2 concentrations and, thereby, slow climate warming. New Zealand's long-term pastures commonly create topsoils (0–10 cm) rich in SOC but the subsoils (10–30 cm) often contain less than half as much SOC. Lowland farmers are advised to renew their pastures every 7–10 years to improve pasture production. Pasture renewal practices typically involve herbicide spraying in spring or late summer-autumn to (i) directly establish new pasture or (ii) sow a forage crop for summer or winter grazing prior to sowing new pasture. Minimum till or direct drilling maintains the vertical stratification of SOC, limiting the scope to increase SOC under new pasture. Trials have been established to test whether a one-off (or infrequent) use of full inversion tillage prior to pasture renewal (FIT-renewal) could accelerate SOC storage in soils by both exposing low SOC subsoil to carbon inputs from new pasture and transferring carbon-rich topsoil deep into the subsoil (potentially slowing its decomposition).

During 2016–2017, two trials were established, one at Massey University (Pallic soil) and one on a commercial farm in the Taranaki/Whanganui area (Allophanic soil) to assess the effects of spring FIT-renewal on SOC stocks and crop/pasture agronomic performance. In both trials, FIT-renewal involved ploughing to approx. 30 cm depth and sowing a summer *Brassica* crop followed by autumn re-grassing. Other renewal treatments included were no-till (direct drill) and shallow till. Changes in SOC vertical distribution, plant growth, herbage quality (at both sites) and nitrogen leaching (Massey site only) were monitored.

At both sites, FIT effectively buried SOC below 0–10 cm depth and increased crop yield compared to no-till treatment. Pasture production was similar among all treatments. In the Massey trial, N leaching losses were consistently lower under FIT than the other practices. These results highlight the potential agronomic and environmental benefits of FIT-renewal; however, longer-term studies are needed to verify the effects on SOC storage. The benefits of spring FIT-renewal may depend on timely application and the inclusion of a crop phase.

NITROUS OXIDE EMISSIONS FROM FERTILISER AND URINE FOLLOWING FULL INVERSION TILLAGE AUTUMN PASTURE RENEWAL

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Full inversion tillage (FIT) has potential for greenhouse gas mitigation through increasing soil carbon stocks. The soil organic carbon (SOC) stock under long term pasture is typically concentrated at the surface and declines with depth (i.e. stratified). The use of full inversion tillage (FIT) during a pasture renewal event provides an opportunity to manipulate this stratification and provide an opportunity to increase the total SOC stock. However, there is considerable concern that the manipulation of the SOC within the soil profile during and after this tillage will result in increased nitrogen losses.

We assessed the emissions of nitrous oxide (N_2O) following application of urine and fertiliser at two field trials (Lincoln, Canterbury and Palmerston North, Manawatu) established using FIT during pasture renewal. The trial design for both field experiments consisted of autumn pasture renewal following FIT, no tillage (NT) or continuous pasture (CP, no renewal). In each cultivation renewal, subplots were established whereby the N_2O emissions where quantified after application of urine (600 kg N ha^{-1}), fertiliser (50 kg N ha^{-1}) or control (0 N) treatments using sealed gas chambers. Emissions were measured across 2 subsequent years (approximately 4 months and 16 months post FIT renewal). Emission factors (EF) for both years were derived for the urine and fertiliser treatments under the various tillage practices.

A reduction in the N_2O emissions and EF were observed in the first year following FIT when compared to the continuous pasture. The NT treatments had greater losses of N_2O in the first year but these emissions typically reduced to levels similar to the CP treatment in the second year. Overall, N_2O emission factors across both years followed the general trend of FIT≤CP<NT and had varying effects of tillage across the two sites.

WHAT PROCESSES CAN CAUSE SOIL C STOCKS TO INCREASE AFTER FULL INVERSION TILLAGE? A SENSITIVITY ANALYSIS OF POSSIBLE CONTRIBUTING PROCESSES

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There is now good evidence that, at least under some circumstances, a one-off use of full inversion tillage for pasture renewal can lead to an increase in overall soil carbon stocks. However, at this stage, there is no direct evidence to identify the processes responsible for such increases in carbon storage. At the same time, much is known of the various factors that enhance or slow soil-carbon decomposition rates. Factors that are considered to play an important role are:

1) Soil temperature
2) Soil moisture
3) Maximum protective capacity (for soil carbon) of the mineral soil
4) Biological synergistic effects whereby a more active decomposer community also increases the specific decomposition rate of less decomposable material
5) Oxygen concentration / Redox potential

Full inversion tillage changes the exposure of soil carbon to these factors with possible effects on decomposition rates. For instance, upper layers of the soil undergo greater temperature fluctuations than layer deeper within the soil. Similarly, upper soil layers undergo more intense wetting and drying cycles, whereas deeper soil layers are likely to experience less variable and either wetter or drier average conditions.

In this presentation, these factors will be discussed, and some exploratory simulations will estimate what contribution each could make towards enhanced protection of soil organic matter under defined edaphic and climatic conditions.

WHERE, WHEN AND HOW - PRACTISE GUIDELINES FOR SUCCESSFUL INTRODUCTION OF FULL INVERSION TILLAGE TO INCREASE SOIL CARBON STOCKS UNDER PASTURE

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Where: Permanent pastures on dairy and intensive sheep and beef farms in New Zealand reach an equilibrium with topsoils (0-15 cm) rich in but subsoils (15-30+ cm) low in soil organic carbon (SOC). Even pastures renewed regularly with minimum tillage practices retain this strong vertical stratification of SOC. *When:* Practical experience from our research shows that this is time to introduce full inversion tillage (FIT) pasture renewal. FIT increases the depth of SOC, and allows the new grass to build new SOC in the low C subsoil exposed at the surface after tillage. A renewal sequence of FIT applied in spring, followed by a seasonally-active crop before direct drilling new grass is recommended for weed control and to minimise the risk of soil N loss to water. Little or no spray-off period is required with FIT, which reduces mineral N accumulation and N_2O emissions prior to new pasture establishment. Increased crop yields after FIT make it cost neutral compared to no-till pasture renewal.

How: Select a pasture due for renewal that has not been deep (> 15 cm) ploughed in the last 10 years. Take soil cores to 0 - 30 cm, cut and place the topsoil (0 - 7.5 cm) in a separate bag to the sub-soil (7.5 - 30 cm depth). On receiving the soil test results if the SOC value for the topsoil is at least twofold greater than that of the subsoil then proceed with FIT. Lime and fertiliser may be applied after FIT where soil pH, P or K status is in the deficient range for the crop to be sown.

A standard plough fitted with a disc coulter and a trash-burying, skimmer in front of each mouldboard is best suited for burying topsoil in the furrow bottom. The point of the skimmer share should be set at 7.5 cm below the soil surface of the herbicide-treated pasture, with the main share of the mouldboard set to 25 - 35 cm depth depending on the vertical stratification of SOC. Plastic mouldboards or mouldboard slats are best suited to heavy and allophanic soils.

CAN FULL INVERSION TILLAGE DECREASE SOIL AND PLANT CD CONCENTRATIONS IN TWO CONTRASTING SOILS?

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Cadmium (Cd) concentrations in New Zealand pasture soils show a strong vertical stratification, with elevated Cd levels in the topsoil and declining down the soil profile along with organic matter content. Recent studies have demonstrated that the one-off (or infrequent) use of full inversion tillage (FIT) for pasture renewal can provide an opportunity to increase soil organic carbon stocks by altering the vertical distribution of the organic matter. However, the effect of corresponding changes in soil chemical properties (e.g. soil pH and organic matter) and Cd distribution in the redistributed soil, on Cd uptake by plants is not well documented.

Two field trial sites were established in the Manawatū (Pallic soil) and Taranaki (Allophanic soil) regions. The treatments involved the use of either FIT (~25 cm soil depth), shallow tillage (~5 cm soil depth, ST) and no tillage (NT) to cultivate long-term pasture soil. After tillage, all treatment plots were sown with turnip as a summer crop followed by autumn re-grassing (ryegrass/white clover). At both trial sites, soils were core sampled (0–40 cm) before cultivation (pre-tillage) and after five months of turnip growth (post-tillage) to assess changes in total and exchangeable soil Cd concentration with depth at 5 or 10 cm intervals. Herbage samples were collected at selected grazing times for both the turnip crop and new pasture phases to evaluate changes in Cd uptake by plants.

For the Pallic soil, soil Cd concentrations were low (0–5 cm: 0.22 and 0.016 mg Cd/kg for the total and exchangeable fractions, respectively) and were not significantly ($p > 0.05$) affected by tillage treatments. For the Allophanic soil, soil Cd concentrations were moderately high before cultivation (0–5 cm: 0.42 and 0.031 mg Cd/kg for the total and exchangeable fractions, respectively). For this soil, the FIT treatment decreased soil total and exchangeable Cd, compared to the pre-tillage treatment, and subsequently resulted in lower plant Cd uptake, compared to the ST and NT treatments.

MITIGATION OF ON-FARM GREENHOUSE GAS EMISSIONS

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This paper discusses the results from a range of modelling studies carried out over a number of years for the NZ Greenhouse Gas Research Centre (NZAGRC), the Biological Emissions Reference Group (BERG), and individual private farms.

It shows the results of analysis of changing farm systems and/or land use on various farms, as to the impact on GHG emissions, and associated impact on farm profitability. It also discusses the impact of modelling on multi-enterprise farms (i.e. mix of dairy, sheep & beef, forestry) as to "mixing & matching" changes on different farms, as to the impact across the whole enterprise.

As a generalisation, the farm system changes resulted in 2-10% GHG reductions, with variable impacts on farm profitability.

It also discusses horticulture and arable cropping impacts, and the use and issues of forestry as an offset and finishes with a discussion on sector-wide changes, and the impact of this on individual farms, as to meeting the zero-carbon legislation targets.

THE RELATIONSHIP BETWEEN DIETARY PROXIMATE ANALYSIS AND GREENHOUSE GAS EMISSIONS DETERMINED USING IN VITRO METHODOLOGY

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There has been a lot of interest in determining greenhouse gas (GHG) emissions from ruminant feedstuffs, whether individual raw materials or complete rations that include both pasture and supplements.

The enteric production of GHG is determined in part from the fermentation of dietary carbohydrates. The current work looked at 147 rations from lactating dairy herds across New Zealand spanning a period of 12 months which were incubated in a closed *in vitro* gas production system to determine the relationships between proximate analysis measurements and methane production. Rations were collected from lactating commercial herds and included a range from 0% pasture through to 100% pasture in the diet.

In a ruminant diet additivity of the proximate analysis of raw materials is assumed when designing rations, due to the ease of formulation. However, in the dynamic fermentation environment within the rumen, additivity of dietary components is not expected to be linear. For this reason, correlations of methane with fermentation characteristics were determined.

The current study found a weak relationship between methane production from the *in vitro* system and proximate analysis. The correlation coefficients were positive for protein, starch, and total non-fibre carbohydrates, being 0.02, 0.22 and 0.29 respectively, and negative for ash, acid detergent fibre and neutral detergent fibre, being -0.07, -0.29 and -0.48 respectively.

The coefficients were stronger for parameters determined during fermentation. Correlation coefficients were positive for butyrate production, apparent dry matter digestibility (ADMD) and true dry matter digestibility (determined as ADMD less microbial biomass produced) being 0.46, 0.78 and 0.66 respectively. The correlation coefficient was negative for propionate being -0.77.

It is concluded that *in vitro* fermentation parameters provide a better predictor of methane production than proximate analysis.

METHANE INDEXING OUR NEXT GENERATION OF DAIRY SIRES

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Ruminant animals are a significant source of methane, a potent greenhouse gas. Methane is produced in the rumen and belched out. Methane output can be altered by feeding some forages and concentrates, but in general the more an animal eats, the more methane is produced. Genetic variation in methane production has been identified in sheep and cattle. Breeding 'low methane' cattle could assist farmers in meeting their obligations to reduce greenhouse gas emissions.

Livestock Improvement Corporation (LIC) and CRVAmbreed (CRV) are working with the New Zealand Agricultural Greenhouse Gas Research Centre to measure methane output in young dairy bulls. Each year around 300 young bulls are purchased and enter Sire Proving Schemes. Around 80 daughters per sire are generated and the performance of their daughters is used to identify the top bulls which then sire the majority of NZ dairy cattle. Most traits of economic value to dairy production can only be measured in lactating females. However, methane can also be measured in males. A methane ranking can be generated and used to make selection decisions before the bull is used for any inseminations.

Methane output is highly correlated to feed intake, therefore it is essential to measure feed intake at the same time as methane. The proposed trial will involve young bulls being housed in pens in a barn. Methane will be measured using a GreenFeed system (C-Lock Inc.). Methane gas flux is measured by the bull putting their head into the GreenFeed and the animals' breath is analysed for methane. Feed entices the animals to use the GreenFeed and keeps them there long enough to get a stable methane record. Separate feed intake bins SmartFeedPro, (C-Lock Inc.) will record intake of lucerne hay cubes. Methane production per kg of dry matter consumed will be calculated over a three week measurement period. At least 50 records per animal are needed to accurately estimate methane production.

A pilot trial of up to 45 animals will take place in 2020. If successful from 2021 all bulls in the LIC and CRV sire proving schemes will have methane output measured.

SHEEP, BEEF AND FORESTRY TO BALANCE CARBON EMISSIONS

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Sheep and beef farming will need to change to meet greenhouse gas emission targets. A unique farm in South Canterbury was modelled to determine total CO_2 emissions. The farm has 360 effective hectares of pasture and carries around 4500 stock units in an average year. Overseer® (version 6.2.0) modelling estimated 1574640 kg of CO_2 equivalents came from this farm in the 2016-2017 season. The Lincoln University online Farm Carbon Footprint Calculator predicted 56.2 ha of the farm would need to be planted in *Pinus radiata* to balance CO_2 equivalent emissions from ruminant livestock with CO_2 sequestration in trees. Sown with either fodder beet or maize, some cultivatable paddocks have produced more than 20000 kg DM/ha. The farm has no irrigation and has other areas that are not cultivatable which produce less than 4600 kg DM/ha, some as little as 2500 kg/ha. A hypothetical scenario for plantation forestry choosing areas of low pasture production was modelled. Although 56.2 ha is 15.6% of the effective area, this scenario reduced annual pasture dry matter production by 9.44 % and livestock by 499 stock units. Challenging sites generally produce poor-quality pasture that is less palatable, at times of year when the rest of the farm has surplus forage. Note that carbon accumulation by *P. radiata* may also be impaired on poorer soils but only 30% canopy cover is required by the relevant legislation, such that some grazing would be available after trees established. An alternative scenario considered planting native species on riparian areas and forestry on erosion prone slopes, both of which will improve environmental outcomes. This required 63.2 ha and reduced stock units by 613. Thus, there is potential to balance carbon emissions, provide shade, shelter and drought forage reserves while reducing erosion of slopes and riparian areas. Financial incentives to plant trees will help defray some costs of fencing and establishment. On this farm, the owners already have forest, however new drivers provide opportunities to expand forestry and capture the benefits of an integrated system and for the industry to capture more value from the 'story' of 'balanced' food production.

THE VALUE OF NITROGEN FERTILISER TO THE NEW ZEALAND ECONOMY

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Nitrogen fertiliser is an integral component of plant growth and is an important component of New Zealand farming systems, significantly aiding in the economic viability of many of those systems. As a result, usage of nitrogenous fertilisers has been increasing over recent decades.

The environmental impact of New Zealand farming systems is under increasing scrutiny, particularly relating to impacts on water quality. One aspect of this is the use of nitrogenous fertilisers and both the direct and indirect influence this has on nitrate leaching.

This study has analysed the value of nitrogen fertiliser across the pastoral (dairy, sheep and beef), permanent horticulture (i.e. trees/vines), arable cropping, and vegetable growing sectors based on a "with versus without" scenario, as well as a "without + substitutes" scenario. This considered the impact at a farm gate level, as well as extrapolating this to a New Zealand economy level based on the impacts on Gross Output, Value Add (GDP), and employment.

The results showed that the farm gate impact was:

- $1.7 billion if N fertiliser is removed and no substitution is used; or
- $2.1 billion if substitution with other supplementary feeds and legume cover crops are utilised.

At the national level, these impacts would flow through as:

- A drop in gross output by $19.8 billion
- A drop in Value Add (GDP) of $6.7 billion
- A reduction in employment by 73,760

The impact on nitrogen leaching was also modelled using Overseer, showing significant reductions in the dairy models, but minimal change in the other farming systems.

ROLE OF SHELTERBELTS IN SEQUESTERING SOIL CARBON IN NEW ZEALAND GRAZED PASTURES

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Intensive pastoral farming with year-round grazing results in contamination of land and waterways, and leads to greenhouse gas emissions. Planting shelterbelts on grazing farms could be a potential option to combat these environmental issues. Shelterbelts do not only help sequester carbon (C) aboveground but also contribute to build C in the soil close by thus mitigating the emission of carbon dioxide to the atmosphere. Trees also help regulate excessive nutrient flow (such as nitrogen (N)) in surface and sub-surface soil, and thus mitigate N leaching and gaseous losses. Despite their numerous benefits, there is a limited information available on the role of shelterbelts, especially in temperate pastoral systems.

We plan to conduct measurements of total soil organic C in paddocks with and without shelterbelts. Here we have selected 10 farms across North and South Island of New Zealand to undertake these measurements. Currently we are presenting the data on soil C for selected studied sites. This work is part of a larger study where the influence of shelterbelts on C sequestration, N cycle, and animal welfare is investigated.

For the measurement of soil C, we collected three replicated soil cores (D = 4.35 cm, L= 60 cm) from selected paddocks with and without shelterbelts on two dairy farms in the Manawatu region of New Zealand. The soil cores were collected from distance of 1 m, 5 m, 10 m, 20 m, 40 m and 80 m from the shelterbelts or from the boundary of the paddock where there is no shelterbelt. We divided each soil core into 5 segments. These were air dried, ground and sieved to 2 mm. Subsamples were further ground to < 0. 3 mm for total C content measurement using elemental analyzer.

We found that the organic C content decreased in soils as the distance from the shelterbelts (and the sampling depth) increased. Overall the paddocks with shelterbelts have higher soil C content than the paddocks without shelterbelts. We are currently sampling paddocks in additional farms to ensure the results obtained so far are representative of New Zealand pastoral systems.

EFFECTS OF LAND USE AND SOIL TYPE ON CARBON AND NITROGEN MINERALIZATION

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Soil organic matter is an important source of plant-available nutrients, particularly nitrogen. In this study, we evaluated (1) effects of land use and soil type on total and mineralisable organic matter, and (2) the efficacy of hot water extractable organic N as a predictor of mineralisable N in Waikato soils. Soils were collected at two depths (0–10, 20–30 cm) at 15 sites in the Waikato on either Allophanic (8 sites) or Gley (7 sites) soils. At each site, samples were taken under both long-term pasture and in adjacent maize paddocks. The soils were immediately sieved (<4 mm) and, after adjusting soil moisture potential to -10 kPa, they were incubated at 25^{o}C for 14 weeks to measure C and N mineralisation. Using air-dried soil samples, hot water extractable C&N, and total C and N were determined. Total organic matter ranged from very low (5 g C kg^{-1}) to very high (150 g C kg^{-1}). Organic matter content was greater in surface soils but did not differ ($P > 0.05$) between soil types or between the two land uses. Overall, mineralisable C and N were influenced by land use (pasture > maize in topsoil) but not soil type. There was a strong relationship ($R^2 = 0.90$; n = 60) between hot water extractable organic N (HWEON) and mineralisable N, supporting the use of the HWEON test for routine assessment of mineralisable N.

SEASONAL CHANGES IN METHANE EMISSION FROM NEW ZEALAND PASTURES – A SURVEY USING IN VITRO METHODOLOGY

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There is a lot of interest in determining carbon footprints (CFP) of ruminant production systems. Many of the commonly used carbon calculators use a fixed emission factor for the enteric methane that is related to a kilogram of dry matter intake (DMI). DMI is usually estimated from an energy balance model that relates to animal production parameters.

Inherent in this approach is the assumption that all DMI is of equal energy value. Pasture is the key ingredient in ruminant production systems in New Zealand. Pasture energy level varies on several criteria, one of which is digestibility. Digestibility, while being multifactorial in nature, is related to seasonal effects.

A closed *in vitro* gas production system was used to measure enteric methane production from 314 New Zealand pasture samples across a 24-month period that covered two consecutive milking seasons (June 2017-May 2019). Pastures were taken from commercial farms the length of the country.

Across the 24-month period, emissions were determined to range from 9.75 to 32.41 g methane per kilo of dry matter (DM), averaging 21.09 g/kg DM with a standard deviation of 3.92. There were distinct periods between December and May (summer/autumn) in both seasons when the methane emission conspicuously decreased.

Our results confirmed that methane emission per unit of dry matter decreases in autumn, as a result of poorer dry matter digestibility. Furthermore, it is known that in some animal production systems animals also have a lower DMI at this time of year. When recalculating the methane (g/kg DM) to be represented on a digestible basis (g/kg Truly Digestible Dry Matter) the seasonal variation flattened out slightly, confirming the hypothesis that increased digestibility of dry matter results in increased methane production.

The implications of this work are firstly that there is capacity to improve the accuracy of individual farm estimations, and that secondly, the opportunity exists to increase the accuracy of carbon calculator models.

SCALING A MOUNTAIN:

AN OPPORTUNITY FOR DENITRIFYING BIOREACTORS

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Agricultural productivity in the US Midwest is underpinned by more than 19 million ha of subsurface drainage networks which are also a key source of nitrogen (N) transport from fields. A large-scale database of subsurface drainage nutrient loss was used to provide context for nitrate-N loss and establish rationale for the necessity of edge-of-field practices like denitrifying bioreactors. Growers across the region often ask what a “baseline” level of nitrate loss would have been prior to modern agriculture. The database showed nitrate loss from today’s corn-soybean (*Zea mays-Glycine max*) rotation was significantly greater than losses from grass or prairie land uses (i.e., more native land uses) with medians of 22, 19, and 1.6 kg N/ha for corn, soybean, and grass site-years, respectively. Along those lines, there is a misconception that N fertilizer, which is essential for profitable corn production, is the sole culprit for this nitrate loss. However, N losses were not significantly different between corn site-years that did and that did not receive N fertilizer (22 and 21 kg N/ha, respectively) when grouped across the database, possibly due to trade-off effects between drainage nitrate concentration and discharge. The likelihood of meeting water quality goals with in-field practices alone is small given the necessity of artificially improved drainage on soils that are inherently N-rich. Edge-of-field practices like denitrifying woodchip bioreactors provide targeted and cost effective N treatment while allowing growers to maintain in-field production in the face of highly variable cropping markets. Denitrifying bioreactors are a proven N-mitigation technique, but there are also design barriers to their performance. Examples include a limited ability to treat a significant proportion of highly variable drainage flow and nitrate loadings as well as cool water temperatures in the early spring. Several bioreactor design solutions that have been constructed in Illinois to address these challenges will be presented. Tweaking N fertilizer use will not solve N loss challenges in the US Midwest but advances to edge of field practices like denitrifying bioreactors can help fill a significant gap in scaling this water quality mountain.

MANAGING NITROGEN IN TROPICAL FARMING SYSTEMS: A BUDGETING AND MITIGATION APPROACH

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Increasing nitrogen use efficiency (NUE) and minimising nitrogen losses in intensive farming systems presents major challenges for producers and policy makers. These challenges are particularly acute in tropical farming systems that are adjacent to sensitive marine and estuarine ecosystems such as the Great Barrier Reef (GBR) lagoon and Moreton Bay in southeast Queensland. Despite substantial investment over the last fifteen years into increasing the adoption of best management practices (BMPs), there is increasing evidence that the adoption of nutrient management practices has stalled. When practice adoption rates are combined with water quality monitoring data it's clear that relying on current industry BMPs alone will not achieve water quality targets and therefore address the risk posed by agriculture to sensitive ecosystems. However, the reality is that producers and their advisors are being asked to undertake complex nutrient management often in the absence of fit-for-purpose empirical evidence. This evidence base is particularly crucial when farming system changes and environmental outcomes are required. In addition, there has been little to no research into other tools that recognises the difficulties of managing nitrogen losses and would support agronomic efforts. This work presents a nitrogen (N) management approach that seeks to complete the nitrogen cycle for both producers and policy makers. It employs a co-innovation approach that aims to improve our understanding of nitrogen movement and management at farm scales; and that a mix of approaches will be needed to address this wicked problem. It discusses coupling an investigation in pineapple systems via a nitrogen budget with edge-of-field mitigation using woodchip bioreactors. The results demonstrate that even under conservative nitrogen regimes, losses of N can be substantial and that the first woodchip bioreactor wall constructed in Queensland achieved complete removal of nitrate (NO_3^-) in shallow groundwater. This work has led to a rapid improvement in the understanding of BMP efficacy and how woodchip bioreactors are an effective and easily implementable method to mitigate losses from intensive farming systems.

BIOREACTORS IN THE GREAT BARRIER REEF (GBR) CATCHMENTS: IMPLEMENTATION AND NETWORKING

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Intensive agricultural production can have adverse water quality impacts on aquatic ecosystems. Declining water quality associated with land-based run-off has been identified as a key risk for Queensland's World Heritage Listed Great Barrier Reef (GBR). In 2015, the Australian and Queensland governments released the Reef 2050 Long-Term Sustainability Plan (Reef Plan) to provide an overarching framework for managing the GBR. The Australian and Queensland governments have invested in water quality improvement projects and research across the state to reduce sediment, pesticides and nutrients entering the GBR Marine Park. However, despite investment into improved agronomic strategies and adoption of Best Management Practice (BMP); Reef Plan water quality targets for Dissolved Inorganic Nitrogen (DIN) are unlikely to be achieved. This highlights the need to consider the role of edge-of-field mitigation, to reach the ambitious targets for DIN entering the GBR. Denitrifying bioreactors have been identified as a potential treatment system option for reducing nitrate pollution from agriculture in the GBR lagoon. Until pilot research in 2015, bioreactors as an edge-of-field mitigation tool remained relatively unexplored in Australia. Woodchip bioreactors are currently being trialled in a number of GBR catchments. The aim is to test their efficacy in differing climates and agricultural production systems to identify opportunities and constraints for the use of bioreactors. This presentation discusses the management approach of bioreactor installations in GBR catchments and how Queensland has navigated a uniform approach to the design, construction and monitoring of a range of bioreactor installations. It unpacks how a network of seemingly disparate entities have come together to advance bioreactor research in Queensland and raised the profile of bioreactors as a nitrogen mitigation option. In 2020, the Network will produce the first installation and monitoring guidelines for bioreactors in tropical regions, pioneering a coordinated approach to research, development and extension across organisations.

THE SPECTRUM OF EDGE-OF-FIELD TO WATERWAY MITIGATION OPTIONS FOR NUTRIENT MANAGEMENT IN FARMED LANDSCAPES

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The government, regulators, iwi and industry are working together with farmers to address the cumulative environmental impacts of intensive farming practices here in New Zealand, as in many other places around the world. In-field management of diffuse nutrient losses, through improvements in input and output budgeting, fertiliser application and livestock and cropping management are the first place to start. But in some areas such in-field mitigation options are not economically viable or will be insufficient to meet desired discharge limits. We know that all landscapes are not equal in terms of their propensity to retain or leak nutrients, the efficacy of downstream nutrient attenuation processes, or the ecological sensitivity (or resistance) of downstream receiving waters. Some of our interventions to facilitate farming make things worse by increasing connectivity between land and water and/or compromising natural attenuation processes in the landscape. The spectrum of potential edge-of-field to waterway mitigation options available to complement in-field management will be overviewed, with illustrations from applications in New Zealand and Denmark. Options overviewed will include: targeted and engineered riparian buffers, modified drainage systems, detention bunds, natural and constructed wetlands, filamentous algal and macrophyte nutrient scrubbers, bioreactors and reactive filters.

UNDERSTANDING CONTAMINANT EXPORT PATHWAYS IS PREREQUISITE FOR IMPLEMENTING EFFECTIVE NUTRIENT ATTENUATION OPTIONS

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Introduction: Drainage pipe discharge from artificially drained land is often targeted as the "best-bet" when considering edge-of-field attenuation options. This is because artificial drainage allows contaminants to discharge rapidly and un-attenuated through the drainage pipe into receiving waters. The effective implementation of attenuation measures is fundamentally dependent on understanding the importance of the relevant export pathways for the contaminants considered. To address this corresponding knowledge gap, we quantified the contaminant export pathways and the characteristics of such flows at two field sites.

Methods: Drainage flows at two dairy farms (Tatuanui and Waharoa) were monitored, with flow-proportional samples analysed for Nitrogen (N) and Phosphorus (P) over two drainage seasons. Sub-soil investigations permitted the controls on the drainage hydrology to be determined, and shallow wells were used to monitor water table dynamics. Depth profiling allowed monitoring of N and P concentrations and redox status through the shallow groundwater.

Results: Water balances confirmed soil coring results that the Tatuanui site was hydraulically sealed in the subsurface and no vertical recharge and contaminant export was occurring through this pathway. In contrast, Waharoa had approximately equal volumes of discharge occurring vertically into the shallow groundwater and laterally through the artificial drainage system.

Nitrate-N was the predominant form of N in the artificial drainage pathway at both sites (72-86% of total N). The average nitrate-N concentration in the groundwater at both sites was less than 0.2 mg NO_3-N/L, and redox indicators demonstrated the reduced status of the shallow groundwater. Consequently, any nitrate-N recharged into the shallow groundwater is likely to be denitrified.

At the Waharoa site, the ratio of total-N exported in artificial drainage and groundwater was approximately 60:40, however, the N forms in each pathway were substantially different. The concentration of nitrate-N in the artificial drainage increased with flow at both sites, resulting in a two-fold effect on the mass of N requiring treatment in such circumstances.

Conclusion: The subsurface materials and the hydrogeochemical characteristics of the shallow groundwater are important factors for controlling contaminant exports, and therefore the success of edge-of-field attenuation options under poorly or imperfectly drained soils.

***Acknowledgement*:** This work was carried out as part of the MBIE-funded Critical Pathways and Transfer Pathways Programmes

DETERMINING THE SPATIAL VARIABILITY OF NITRATE REMOVAL IN A WOODCHIP BIOREACTOR THROUGH HIGH FREQUENCY MONITORING AT MULTIPLE LOCATIONS

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Woodchip bioreactors have been shown to be effective in removing nitrate from artificial drainage. However, performance assessments were usually based only on nitrate concentrations at the inlet and outlet. Optical nitrate sensors provide an opportunity for cost-effective monitoring of nitrate at multiple locations and at high frequency. Information on the changes in nitrate along the length of the bioreactor provides a deeper understanding of how bioreactors work and can reveal potential areas for improving their performance.

A pilot-scale woodchip bioreactor was constructed on a dairy farm in Waikato. Dissolved oxygen (DO) and nitrate concentrations were monitored with optical sensors at the inlet and outlet and at 19 locations within the bioreactor. DO was measured manually, whereas nitrate was measured at high frequency with a multiplexer sampling system. In this paper, we present the results for four quarter sections of the bioreactor (0-25, 25-50, 50-75 and 75-100% of the bioreactor length) measured later in the drainage season.

In the 2018 season, inlet drainage water was oxic (DO > 4.5 mg/L) but DO concentrations decreased to reducing conditions (< 2 mg/L) within the first quarter of the bioreactor. The highest median removal rate (RR) and removal efficiency (RE) were observed in the second quarter, apparently due to higher nitrate concentrations and reducing conditions coinciding in this section. The lowest RR was observed in the fourth quarter, which is related to nitrate-limited conditions. While incoming nitrate concentrations were highest in the first quarter, nitrate removal was suboptimal due to still partially oxic conditions. This was also reflected in the lowest median RE in this quarter. These results revealed that the latter half of the bioreactor has some spare removal capacity. This suggests that a wider bioreactor configuration with half the length and at least two inflow points may be more effective than the current configuration.

Acknowledgement: This work was carried out under the MBIE-funded programmes "Enhanced Mitigation of Nitrate in Groundwater" of ESR and "Doubling On-farm Diffuse Pollution Mitigation" of NIWA.

ASSESSING IF WOODCHIP DENITRIFICATION WALLS ARE A VIABLE EDGE OF FIELD NITRATE MITIGATION PRACTICE IN GRAVEL AQUIFER SETTINGS

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Woodchip denitrification walls are an *in situ* groundwater nitrate remediation concept that has been successfully demonstrated for shallow sandy aquifer systems. Some of the earliest experimentation was conducted here in New Zealand (NZ), in the Waikato region (e.g. Schipper and Vojvodić-Vuković, 1998). We perceive woodchip denitrification walls to be a potentially useful edge-of-field nitrate-mitigation practice for addressing the challenge of farming within catchment nutrient limits.

Aquifers composed of outwash gravels represent the most common and important groundwater systems in NZ, particularly on the South Island where there are plentiful examples of them having exceeded their capacity to naturally assimilate nitrate leached from intensive land-use. There are no published cases of woodchip denitrification walls ever having been emplaced in gravel aquifer systems. To address this limitation and assess whether woodchip walls are a viable edge-of-field N-mitigation practice, we are undertaking a pilot study of a woodchip denitrification wall applied in a shallow gravel aquifer setting.

The experimental woodchip denitrification wall at Silverstream Reserve, North Canterbury, measures 25 m long x 5 m wide and was built in November 2018. It is entrenched through highly permeable gravel outwash, deposited by the Waimakariri River. Being 3 m deep, it penetrates about 2.5 m below the water table. We estimate that somewhere between 152 and 230 m^3 of groundwater flows through the wall each day, under the natural hydraulic gradient of 0.002. This flux is significantly more than any reported for other woodchip wall studies, hence our wall is ageing faster than other examples and rapid depletion of reactive organic carbon is evident in the time-series water chemistry data we have been collecting. Over its first year, the wall has demonstrated effective nitrate removal of between 93 and 100%, for influent concentrations that have ranged from 6.8 to 7.7 mg NO_3-N/L. It is too early to make reliable predictions of the longevity of the denitrification wall, yet our initial calculations made using findings from our field study tend to suggest that within the suite of known N-mitigation practices, woodchip denitrification walls rank as a relatively cost-effective mitigation option.

FILAMENTOUS ALGAE NUTRIENT SCRUBBERS FOR TREATMENT AND NUTRIENT RECOVERY FROM AGRICULTURAL DRAINAGE

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Filamentous Algae Nutrient Scrubbers (FANS) are a novel agricultural drainage treatment system that grow filamentous algae to recover nutrients for beneficial reuse.

Filamentous algal systems have been used to treat agricultural drainage in the USA, where they have also been used to treat various agricultural effluents and wastewaters.

FANS are gently sloping floways that are covered with attached filamentous algae. The water flows down the floway and over/between the filamentous algae. The water is treated through a combination of algal photosynthesis and growth (nutrient assimilation, oxygenation) and physical filtration (settling, adsorption and precipitation).

This talk will discuss the potential to use FANS systems for agricultural drainage water treatment in New Zealand and ongoing MBIE funded research in this area.

NIWA is currently conducting research on FANS as part of a 5-year MBIE funded programme on agricultural drainage water treatment in which we will develop FANS for NZ conditions using high nutrient affinity NZ species for nutrient recovery.

The programme will also investigate beneficial algae use options that are culturally acceptable to Māori (e.g., fertilizer, animal fodder).

The project is being conducted in consultation with iwi partners who will host field-scale demonstrations in the last two years of the project.

During these field-trials the habitat benefits, particularly for wading birdlife will be also assessed.

PHOSPHORUS MITIGATION PROJECT: QUANTIFYING THE ABILITY OF DETAINMENT BUNDS TO MITIGATE NUTRIENT LOSSES FROM PASTORAL AGRICULTURE IN THE LAKE ROTORUA WATERSHED

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Surface runoff generated on pastures during storm events transport significant proportions of the annual nutrient loads contributing to water quality degradation and eutrophication in Lake Rotorua. The 'Lake Rotorua Nutrient Management Plan' aims to decrease phosphorus (P) loads delivered to the lake by 10 t/yr in order to achieve lake water quality targets.

The Phosphorus Mitigation Project was developed by farmers in the Rotorua lakes catchments to advance the understanding of P mitigation through applied research. Detainment Bunds (DBs) are being investigated as a strategy to mitigate nutrients transported by surface runoff from land used for pastoral agriculture, which covers 48% of the 42,000 ha Lake Rotorua surface area watershed. Detainment Bunds are earthen stormwater retention structures, ~1.5-2 m high m high by 20-80 m long, constructed on pastures across the flow path of targeted low-order ephemeral streams. By impeding stormflow, DBs are capable of temporarily ponding up to 10,000 m^3 of surface runoff which can be rapidly drained via an outlet valve in order to avoid potential negative impacts of prolonged ponding to pasture productivity. The current DB design protocol promotes a minimum pond volume capacity to contributing catchment area ratio of 120 m^3:1 ha.

The 12-month study of 37 ponding events at 2 DB sites in the Lake Rotorua watershed found that annual runoff volumes discharged from the DBs were 30% and 42% lower than annual inflow volumes due to ponded water infiltrating the soil. Correspondingly, annual loads of suspended sediments, and dissolved and total forms of nitrogen and phosphorus discharged from the DB sites were 36% to 61% lower than inflow loads. Additionally, when accounting for the portion of discharged runoff likely to infiltrate the soil downstream of the DB, this strategy prevented 38% to 75% of the annual contaminant loads from reaching connected waterways. Results suggest that in areas with sufficient soil infiltration rates, DBs are able to decrease nutrient loads transported from pastures in surface runoff and could be an effective mitigation strategy available to farmers in the Lake Rotorua watershed.

COMBINING TOOLS FROM EDGE-OF-FIELD TO IN-STREAM TO ATTENUATE REACTIVE NITROGEN ALONG SMALL AGRICULTURAL WATERWAYS

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Reducing excessive reactive nitrogen (N) in agricultural waterways is a major challenge for freshwater managers and landowners. Effective solutions require the use of multiple and combined N- attenuation tools, targeted along small ditches and streams. We present a visual framework to guide novel applications of 'tool-stacking' that include edge-of-field and waterway-based options targeting N-delivery pathways, timing, and reducing fluxes to receiving environments. Implementing tools at multiple locations and scales using a 'toolbox' approach will better leverage key hydrological and biogeochemical processes for N attenuation (e.g., water retention, infiltration and filtering, contact with organic soils and microbes, and denitrification), in addition to enhancing ecological benefits to waterways. Moreover, we encourage scientists and managers to co-develop N-attenuation toolboxes with farmers, since implementation will require tailored fits to local hydrological, social, and productive landscapes.

REGULATORY BARRIERS TO THE UPTAKE OF EDGE-OF-FIELD AND FARM-SCALE DIFFUSE NUTRIENT POLLUTION MITIGATION TECHNOLOGIES

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A growing number of edge-of-field and farm-scale mitigation initiatives are being explored and trialled across rural New Zealand to reduce the impact of intensive land use on fresh water quality. While the evidence base for the technological efficacy of these mitigation initiatives continues to grow, a wide range of social/behavioural, cultural, economic and regulatory barriers may limit their potential adoption by landowners.

In this presentation, we summarise a desk-top review of Regional Plan requirements relevant to the construction, operation and maintenance of edge-of field and farm-scale mitigation technologies, particularly when sited close to or within waterways and drains. The evaluation has focussed primarily on the following edge-of-field mitigations: constructed wetlands, seepage wetlands, riparian buffers, N-bioreactors, P-filters, detainment bunds, two-stage ditches, bank re-battering, silt traps and in-channel remediation works (e.g., wood addition). Such mitigations generally involve activities – such as earthworks, stream diversions, stream bed disturbance and discharges to land or water – that may trigger the need for resource consents in accordance with Regional Plans prepared under the Resource Management Act (RMA) 1991. Although permitted activity rules do exist for many of these activities, these rules vary from region to region and are typically accompanied by lengthy lists of conditions that must be met. Failure to meet one or more of these conditions will trigger the need for resource consent.

The first and most important step is determining whether or not a proposed mitigation will in some way interact with a river or stream, as defined under the RMA (i.e., includes modified rivers and streams). By avoiding construction in, or modification/ disturbance of, the bed or banks of a river, stream, lake or natural wetland, the likelihood of requiring resource consent is much lower. The volume of earthworks, dimensions of structures and amount of water taken are also key factors in determining consent requirements. Some guidance exists to assist landowners with defining watercourses and interpreting permitted activity rules but there appears a clear need to develop guidance for specific mitigation measures in different regions to facilitate greater uptake of mitigation initiatives that will help improve water quality and environmental outcomes.

SKYTEM SURVEYS FOR CATCHMENT-SCALE HYDROGEOPHYSICAL EXPLORATION

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Introduction: The need to understand nutrient transfers into lower-order waterways, i.e. streams operating at the farm to sub-catchment scales, is increasingly being recognised. This requires the relatively shallow and short pathways responsible for these transfers to be unraveled and incorporated into models. While geospatial datasets are widely available for the soil (S-map, FSL) and for the geology (QMAP), there is a scarcity of data for the critical zone in-between, which strongly affects the contaminant transfers at shallow depth (top 20 to 50 m).

Methods: Information on the subsurface has to date largely been derived from point-scale logging during the costly installation of groundwater bores. Airborne transient electromagnetic surveys (e.g. SkyTEM) have the potential to provide related information in much greater spatial resolution in a time-efficient manner. Accordingly, in 2019, we carried out the first SkyTEM surveys in NZ in our Critical Pathways Programme (CPP) catchments, the Piako River headwater catchment (≈100 km^2) on the Hauraki Plains and the Waiotapu Stream catchment (≈300 km^2) on the Central Plateau.

Results: The helicopter surveys covering the catchments in flight lines 200 m apart were completed in 2 days in the Piako and 5 days in the Waiotapu catchment, without any major inconvenience to the local communities (e.g. stock disturbance). The vast amount of electrical resistivity raw data generated required comprehensive automated and manual processing. The extent of data gaps caused by electromagnetic couplings reflected the density of roads, railway and power lines, etc. The reliable depth of investigation ranged from ≈50 m where very low resistivity material occurred near the surface to ≈300 m, with many areas yielding reliable data for ≥200 m.

Conclusion: Sophisticated raw data processing allowed reliable pseudo 3D resistivity models to be created. However, as resistivity is affected by numerous factors (e.g. porosity, pore saturation, salinity), hydraulic conductivity cannot directly be derived from it. Comprehensive ground-truthing, utilising a range of independent data types and data analytics techniques, is required to ensure the 3D resistivity models are interpreted in a manner informative for hydrological modelling.

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THREE YEARS OF DRAINAGE FLUXMETER MEASUREMENTS UNDER A CENTRE PIVOT – HOW DO THEY RELATE TO SOIL, CLIMATE AND IRRIGATION?

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This paper introduces a study conducted at Massey University No. 1 Farm, Palmerston North. The aim of the study was to understand the relationship between predicted drainage volume and the drainage volume measured by passive-wick tension flux meters in the field, and how these volumes relate to soil, climate, and irrigation. The wick was 600 mm long and this established the tension.

The study area has a centre pivot irrigator that is controlled with a variable rate irrigation (VRI) system to ensure optimum use of water resources on two water management zones (i.e. two soil types). The site was cropped with peas, beans, and spring wheat over the 3-year measurement period. In the study area, 24 drainage flux meters were installed around the central pivot. The area for flux meter installation was selected to cover two soil types (Zone 1 and Zone 2). The meters were installed at 60 cm depth and around 3–4 m apart. Zone 1 soil is classed as a Manawatū fine sandy loam and Zone 2 is classed as a Manawatū silt loam. Drainage samples were collected at regular intervals over the 3-year period using a custom-designed pump, and the volumes were measured. The Available Water Holding Capacity (AWC) of the soil was measured in the laboratory using standard methods. Other data collected included climate and crop management information. Results are presented here for the Manawatū fine sandy loam.

The measured drainage was compared with amounts predicted by FAO-56 Penman-Monteith soil water balance, and although both measured and predicted amounts followed the same trends, the measured drainage was found to be significantly greater. We hypothesise that the tension created by the flux meters caused more drainage to be collected than predicted, and that this drainage may have been captured from a larger soil volume than the 'sample' soil volume encased in the flux meter and so we used a least-squares regression model to adjust the measured drainage volumes to fit the predicted values.

The total amount of drainage over the 3-year period was 786 mm. Both rainfall and irrigation had significant effects on the drainage pattern. The wet growing season of the bean crop led to an increase in drainage volume of 29% and 34% compared with the drier growing seasons of the pea and wheat crops. The use of VRI when the soil water deficit falls to 40–50% AWC seemed a sensible recommendation to reduce the drainage volume from Zone 1.

NUTRIENT LEACHING UNDER INTENSIVE SHEEP GRAZING: A NEW RESEARCH INITIATIVE

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Many New Zealand sheep farmers are attempting to increase the amount of home-grown feed, stock performance and profitability. These intensive sheep systems are likely to result in greater nutrient losses in drainage. However, the choice of forage species may help to minimise or mitigate some of these nutrient losses. A large scale, long term field trial, which includes 20 drainage plots (40 m x 20 m each), is currently being carried out at Massy University's Keeble farm to investigate the effect of forage species on the quantity of nitrate-N lost in drainage water. The soil type on the farmlets and plots is Tokomaru silt loam. Each plot is drained by a mole and pipe drainage system, which facilitates the monitoring of drainage volumes and the collection of drainage samples for analysis. The four forage types (treatments) on the plots are; perennial ryegrass/white clover, plantain/white clover, Italian ryegrass/white clover and a turnip/swede rotation. Other parameters being measured include; phosphorus loss, pasture accumulation, estimated ewe intake and ewe performances. This research will provide farmers with information that may potentially help them improve environmental performance while maintaining or improving productivity. Initial results, from the last part of the 2019 drainage season, suggest that leaching losses under sheep on this soil type are relatively small and that the use of alternative forage species may be an effective strategy for reducing the transfer of N from sheep farms to surface waters. The knowledge gained form this study will contribute to a better understanding of how sheep systems can achieve both improved productivity and environmental performance.

CONSIDERING PERSISTENCE IN THE LANDSCAPE WHEN TRACKING WATER QUALITY BENEFITS OF CONSERVATION PRACTICES

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All management activities associated with our land-use choices have various levels of impact on receiving water resources, as well as different life expectancies. This work was done as part of efforts to account for progress being made on conservation practice implementation in the United States Mississippi River Basin towards meeting water quality goals. However, the concept is global, and pertinent wherever water quality initiatives exist. A major part of this work was to determine the persistence of a suite of water-related conservation practices in our landscape by using established design criteria and recommended lifespans. Results show that accounting for persistence could increase our annual estimates of conservation practices area treated by 25 to 30%. Since annual estimates are heavily dependent on the types of practices historically implemented in a given area, regional evaluation of practice lifespan is recommended. Ultimately, accounting for long-lived conservation activities provides a better representation of historical and current efforts to mitigate environmental pollution from agriculture.

IN-STREAM WOODCHIP DENITRIFYING BIOREACTOR TRIAL, SOUTH CANTERBURY

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Woodchip denitrifying bioreactors (WDBs) are an edge-of-field nitrogen mitigation measure that conceivably might be applied to the challenge of farming within nutrient load limits, such as imposed by the National Policy Statement for Freshwater Management. Whether such water treatment systems are a viable nutrient mitigation measure in New Zealand's agricultural landscape however has yet to be properly assessed.

We are trialling an in-stream WDB in an open drain on a dairy farm in South Canterbury. Being conscious that the performance of in-stream WDBs is often compromised by sediment clogging issues, we have incorporated a set of sediment control measures into the bioreactor design. Working within the physical constraints set by the drain geometry and planning rules, we applied stochastic methods to the design problem. Varying a suite of uncertain physico-chemical variables, the metrics of: bioreactor size vs cost vs under/over treatment of water entering the WDB were evaluated, and an optimal design identified.

The 75-m long WDB contains 430 m^3 of 20-50 mm nominal diameter woodchip, processed from virgin *Pinus radiata*. It has been designed to intercept 6 L/s of drain water, containing, on average, 6 mg/L nitrate-N. We predict it should remove about 4,030 kg of nitrogen over what we expect to be a 10-year operational life. This is equivalent to 34% of the total nitrogen load in the farm drain.

When the experimental WDB becomes operational, its performance will be closely monitored. Leaching of dissolved organic carbon, mobilisation of phosphorus from suspended sediment and greenhouse gas production are potential pollution swapping phenomena that will be examined.

STUDY THE INFLUENCE OF SOIL MOISTURE AND PACKING INCREMENTAL LEVEL ON SOIL PHYSICAL AND HYDRAULIC PROPERTIES

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Reconstructed soil packing is an alternative for monolithic soil columns in lysimeter studies. The excavated soil is packed in uniform layers to represent the natural soil conditions. Reconstructed soil packing alters the physical properties, including bulk density and porosity, thus can distort the hydraulic properties of the soil, so consistency of the method used is critical. Therefore, the selection of a suitable packing method becomes decisive. This preliminary study comes under the broad research programme developing and testing new fertilizer formulations in lysimeters.

This work was aimed to study the effect of incremental packing method on the hydraulic properties of soil to select the best combination for testing fertilizers. The selected soil matrix for this lysimeter study was composed of 10 cm topsoil and 30 cm washed builders' sand. For this study, four different soil packing were trialled in lysimeters with the combination of two soil moisture conditions (dry/damp and wet) and two packing depth increments (5 and 10 cm). The flow rate and saturated hydraulic conductivity were measured. Subsequently, several pore volumes of water (around 5 – 6) was allowed to pass through the soil column and the soil subsidence level was measured for each packing method. Both soil moisture condition and increment level have influenced the flow rate and saturated hydraulic conductivity of the soil matrix. The saturated hydraulic conductivity of the dry-5 cm, dry-10 cm, wet-5 cm and wet-10 cm packing were 3.99, 6.70, 3.56 and 6.53 cm hr^{-1}, respectively. Soil subsidence also influenced by both the soil moisture condition and increment level. The highest soil subsidence was exhibited by dry-10 cm packing (13 mm) and lowest by wet-5 cm (2 mm) ($p<0.05$). This preliminary study showed that both moisture condition and increment level influence the soil hydraulic property and compaction level.

Further elaborated study needs to be conducted to evidence the influence of soil moisture and incremental level on other physical and hydraulic properties of soil packing.

BIOCHAR-NUTRIENT INTERACTIONS IN SOIL IN RELATION TO AGRICULTURAL PRODUCTION AND ENVIRONMENTAL PROTECTION

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Biochar application to soil has been shown to enhance carbon sequestration, soil health and remediation of contamination. Biochar application also influences nutrient interactions in soil through various processes that include: (i) by acting as a nutrient source, thereby supplying nutrients; (ii) by acting as a nutrient sink, thereby reducing their mobility and bioavailability; and (iii) by altering soil properties, thereby affecting nutrient reactions and cycling in soil.

As a source, biochar can supply nutrients such as nitrogen, phosphorus, potassium and other trace elements inherently present in the original feedstock used for biochar synthesis. While some of nitrogen and sulphur nutrients in the feedstock materials are lost through gaseous emission, most nutrients are released during the weathering of biochar in soil and becomes available for plant uptake. The nutrient content of biochar depends on the nature of feedstock materials and pyrolysis conditions. Biochars derived from manure- and biosolid-based feedstock materials generally contain higher levels of nitrogen and phosphorus than those derived from wood- and straw-based feedstock materials. While, the nitrogen content decreases with increasing pyrolysis temperature through gaseous emission, the phosphorus and potassium contents increase due an increase in ash content.

As a nutrient sink, biochar can retain nutrients thereby reducing their losses through leaching and gaseous emission. The nutrient retention capacity of biochar depends on its porosity and surface charge (cation and anion exchange capacity) characteristics. It has often been shown that biochar application reduces the loss of nitrogen, phosphorus and potassium through leaching, and nitrogen through nitrous oxide emission. However, the loss of nitrogen through ammonia emission depends mainly on the pH of the biochar.

Biochar application influences various soil properties including pH, bulk density, cation exchange capacity, water retention and biological activity. These changes in soil properties are likely to impact nutrient reactions with soil particles and microbial transformation of nutrients. For example, an increase in cation exchange capacity has been shown to reduce the leaching loss of cationic nutrients such as ammonium nitrogen (NH_4^+) and potassium (K+). This paper provides some case studies involving biochar-nutrient interactions (ammonia volatilization, nitrous oxide emission, and nitrate and phosphate leaching) in relation to promoting sustainable agricultural production and achieving environmental protection.

ASSESSMENT OF THE CARBON AND WATER BALANCES OF SAUVIGNON BLANC GRAPES USING EDDY COVARIANCE

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Eddy covariance (EC) is an established technique for measuring gas flux over a surface, typically carbon dioxide and water vapour. Perennial horticultural systems have the potential to be a carbon sink to help mitigate climate change and EC is potentially a useful tool to quantify this effect. However, there are few overseas studies that use EC in horticultural contexts. We are using the EC technique to continuously measure the net carbon and water flux in two commercial vineyard blocks in the Hawke's Bay. This vineyard is conventionally managed and irrigated, and grows a range of red and white grape varieties. Our aims for this experiment are: (i) to characterise the seasonal variation in carbon and water fluxes; and (ii) to quantify the annual carbon and water balances for a vineyard system.

We are operating two EC towers over a Merlot and a Sauvignon blanc block respectively and have been collecting data since 1 May 2019, however the tower over the Merlot block has suffered an equipment failure and is not currently collecting flux data. Data is processed using standard EC methodologies and we present our preliminary results here.

Preliminary results suggest that over the early growing season, the magnitudes of both the carbon and water fluxes have been increasing and that the vines have been a strong carbon sink. Our results suggest that between 1 May 2019 and 8 January 2020, the vines have sequestered about 300 g C/m^2 of carbon and lost about 400 mm of water due to evapotranspiration.

While we do not have a full year of data collected, our results appear realistic compared with previous studies. The effects of various vineyard management practices and especially harvest on the seasonal and annual carbon and water balances are not yet known. We hope to be able to better answer these questions once an entire year of data are collected. Additionally, we hope to be able to continue running the experiment for multiple years in order to explore the interannual variation, if any, in the carbon and water balances in the vineyard.

CONCEPTUAL FRAMEWORK TO ENABLE COORDINATED SOLUTIONS FOR CLIMATE CHANGE AND WATER QUALITY

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Discussion of a framework that provides the potential for coordinating solutions at a catchment level, to help address both future climate change and water quality issues. The suggested framework uses a coordinated approach and innovative use of spatial data GIS modelling to classify land. The framework allows coordination between landowners to identify areas that could be changed or adapted to improve both water quality outcomes and to protect against future climate change impacts. Based on the outcomes of the GIS special modelling landowners work together to find solutions for the wider catchment. The GIS modelling incorporates layers for climate change impacts, water resource requirements, soil type and leaching potential. Examples of changes that could be made as a result of the framework include crop changes, retirement of land and the sharing of resources. The framework collectively allows landowners to put in place the mechanisms to give confidence to make change or support the change already occurring within the catchment. This paper will explore the opportunities and barriers to such an approach. The approach has applications to achieve improvements in nutrient loss and greenhouse gases, supporting future farming systems and rural communities to become antifragile.

DAIRY AND DRY STOCK: EXPLORING THE BIG LEVERS FOR GHG REDUCTIONS AND IMPLICATIONS FOR WATER QUALITY AND ECONOMICS

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Farmers need practical levers that balance limits on emissions to air and water, and business goals while delivering products to increasingly discerning customers. Agricultural biological GHG emissions are methane (80%), and nitrous oxide (20%), while water quality issues are dominated by nitrates, phosphates and microbes. Opportunity arises from the link between the biological N and carbon cycles that enables levers within farm systems to result in lower emissions to both air and water. Systems changes that reduce feed inputs and stocking rate, decrease replacement rates or include alternate low methane feed [currently limited options] have the biggest impact on GHG footprint, and these may also deliver to water quality.

LUDF has employed enhanced technologies in irrigation and effluent management, e.g. soil moisture monitoring has reduced modelled N loss by 14%, the addition of ClearTech® to increase available effluent storage reduced N loss by a further 2% and initial upgrades of the irrigation infrastructure reduced N loss by another 9%. Additionally, LUDF reduced N fertiliser (from between 250-350 to 178 kg/ha) and feed supplements then matched stocking rate (decreased from 3.9 to 3.4 cows/ha) to feed supply giving a further reduction in both nitrate leaching (18%) and GHG emissions (13%). Potential still exists to further upgrade irrigation infrastructure to provide another 8% reduction in N loss on LUDF, impacts on GHG require further analysis.

Sheep and beef farms face real challenges in reducing GHG footprint [excluding offset potential], since emissions increase as stocking rate increases, which is driven by existing natural and capital assets. Most have few options to change inputs to reduce emissions, but opportunity exists for more product from a similar footprint. Highlands in South Canterbury has increased pasture consumed and product by 30% since 1991 with N leaching less than 20 kg/ha and a 10% increase in GHG emissions/ha, although stocking policies to manage drought resulted in significant reductions in that year. Trees on this farm deliver both offset potential and water quality benefits. A survey of 100 farms with similar emissions to Highlands found animal product per hectare varied from 100 to 350 kg/ha, indicating opportunities across the industry for efficiency gains.

Low input, efficient systems have potential to maintain production while reducing losses to air and water, but this is only the first step, and one many businesses have already adopted. A range of new 'technologies' and management practices will be essential for businesses to have suitable options to drive future reductions in emissions.

INTEGRATED FARM PLANS (IFP)

Di Lucas and B Smith

Lucas-Associates, Christchurch

Integrated Farm Planning involves working with individual farmers and applying landscape planning and farm management modelling to produce their farm plan addressing environmental issues for the property's next 30+ years.

The farm context and multi-factor site data are identified, recorded and mapped to provide the baseline for the farm planning to comprehensively address rural environmental issues. Production systems, nutrient management, GHG emissions, natural ecosystems and landscapes are addressed. The landscape resource involves natural, cultural and social diversity, with past and present regimes recognised in looking toward the future. Using internationally certified lifecycle carbon emissions' analyses the IFP team have developed a model and a framework that applies multi-skilled best practice, knowledge and data.

Staged plans are developed which include identifying spatially the land management changes needed to achieve improved environmental management. The plans provide staging that transitions each farm toward net carbon neutral, through mitigating and in setting emissions within the property, whilst also transitioning to low nutrient loss and healthy freshwater ecosystems.

Using the IFP, the multi-skilled team provides a blueprint for transitioning to sustainability through planning and strategic monitoring. They seek to find community support for future generations of Aotearoa NZ's primary industry producers.

LEARNING FROM THE PAST: A COMPARISON OF FOOD PRODUCTION SYSTEMS FOR MANAGING NUTRIENTS

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Many solutions are being offered for ensuring that food production does not impact upon the environment. The spectrum being practiced in New Zealand ranges from Biodynamic to Organic, Ecological, Regenerative, Conventional and Industrial, with proponents of some systems suggesting that New Zealand farmers can change to another system, generally one nearer the beginning of the list, for the better – that is, do 'better' by the environment and make more money, even without attracting a premium for the product.
Some of them can, but one size never fits all.

Part of the difficulty in the debate is differences in starting points, goals, and resources available to achieve those goals. In particular for New Zealand is the difference in a goal to minimise environmental impact per unit of production, thereby sparing land from agricultural production, and the goal of minimising impact per hectare. The latter is the focus in Europe and agricultural subsidies offsetting opportunity cost have been increasing in recent years. There has, however, been little positive effect in decreasing environmental impact. The OECD nutrient balance figures suggest nitrogen losses are increasing again.

This paper considers the production and environmental aspects of organic and conventional systems, as well as other systems where research results are available. It presents information on yield and nutrient losses, including greenhouse gases, both per kg of production and per hectare. It also considers the economic aspects, bringing in recent research for credence factors.

New Zealand farmers, unsupported and unconstrained by government subsidies, are in the fortunate position of having options. They generally choose the farming approach that suits their farm (soil, topography, climate, location), values and inclination. Imposing 'systems' based on belief rather than analysis, however well-meaning, could result in unintended environmental consequences. It could also have a negative impact on the economy.

QUANTIFYING ENVIRONMENTAL EFFICIENCY THROUGH GENETIC MERIT (BW)

Tony Fransen

LIC, Hamilton

Nitrogen loss associated with cow urine patches and methane emissions from cow burps are demanding more attention due to their environmental effects, media interest, and regulatory change.

LIC has always focused on breeding and selecting for cows which efficiently convert the food they eat into milk production, while maintaining important attributes needed to maximise the productive life of the cow.

Since its inception as the national dairy animal evaluation system in 1996, Breeding Worth (BW) has been, and still is, a great indicator of environmental efficiency. It's a strong assumption then, that when it comes to improving both nitrogen and methane efficiency of cows, a key driver would be the animal's ability to maximise production output per kilogram of feed eaten.

The analysis indicates that BW shows a good relationship with how much urinary nitrogen and enteric methane is produced by an animal per kilogram of milksolid produced.

For production within a single lactation every $10BW increase, there was 1.0g less urinary nitrogen produced per kilogram milksolid. Similarly 1.1g less enteric methane is produced per kilogram milksolid. These results align with the DairyNZ research, with high BW and low BW cows in metabolic stalls comparing intake, output, and partitioning. High BW cows showed greater nitrogen efficiency, higher levels of nitrogen being in milk protein and lower amounts of nitrogen in urine.

The environmental efficiency of LIC's Daughter Proven Premier Sires team (including Friesian, Jersey and KiwiCross®) has improved over time. Using the weighted average from the number of straws sold each year, the urinary nitrogen calculated per kilogram of milksolid has progressively decreased by 0.34% per year (10% over 30 years) as has calculated enteric methane per kilogram of milksolid by 0.23% per year (7% over 30 years).

These improvements in environmental efficiency have been made through BW being a sound measure of overall efficiency of a dairy animal. So when making recommendations, remember that BW is a key measure of the overall efficiency of the animal, including environmental efficiency.

“BACK OF AN ENVELOPE” NUTRIENT BUDGETING

Georgia O’Brien, L Posthuma and D Bloomer

LandWISE, Hastings

Gisborne District Council's Tairawhiti Resource Management Plan (TRMP) includes rules for farms with more than 1 hectare of vegetable or maize crops. Under this, cropping farmers in Gisborne are required to make and submit a Farm Environment Plan by 1 May 2021.

Fertilisers must be applied according to the Fertiliser Association’s Code of Practice for Nutrient Management. Growers have sought support for preparation of nutrient budgets that incorporate industry good practice for intensive cropping. For vegetables, “Nutrient Management for Vegetable Crops in New Zealand” by JB Reid & JD Morton published by Horticulture NZ provides recognised guidelines.

To help growers incorporate these guidelines into crop by crop nutrient budgets a simple, easy to follow one-page nutrient budget has been developed with reference to lead growers and industry experts. The poster shows how this simple tool has been developed for and tested by growers to engage them in the Nutrient Management mindset.

LIQUID FERTILISER APPLICATION TOOLS FOR NITROGEN MANAGEMENT SUCCESS IN VEGETABLE CROPPING

Luke Posthuma, G O'Brien and D Bloomer

LandWISE, Hastings

As part of "Future Proofing Vegetable Production" we have been testing the use of liquid fertilisers for nitrogen application to vegetable crops. Some growers have tried spray application and suffered crop damage from leaf burn so are understandably cautious. However liquid application appears to offer benefits, so alternatives are being found and tested.

The poster presents results from early trials of soil applied liquid nitrogen fertiliser on broccoli and sweetcorn and describes an experiment on soil and canopy applied liquid fertiliser on potatoes. Information supporting the use of "Y-drop" and "Stream Bar" applicators to enable more frequent Nitrogen applications to Vegetable Crops in Winter is presented.

GROUND TRUTHING OVERSEER FM –
MODELLED P LOSSES VERSUS MEASURED P LOSS

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Surface runoff water quality inflow and outflow from three Detainment Bunds (DBs) in the Lake Rotorua Catchment, was monitored from Dec 2017 to Dec 2018 as part of the Phosphorus Mitigation Project Inc. Two of the DBs were located on dairy farms and one was on a beef/sheep/deer farm. The catchment areas delivering surface runoff to the inflow point of the DBs (i.e. before ponding treatment) ranged from 6 to 47 ha in size. This present study was able to 'value add' to the larger water quality monitoring project, by comparing OverseerFM predictions of surface P losses with measured inflow surface water quality.

Farm scale OverseerFM nutrient budget models were constructed for each farm, and areas within the DB catchment were blocked separately, in order to identify P loss from the DB catchment area. Areas within the DB catchment were blocked in more detail than typical OverserFM blocking (up to 11 blocks within the DB catchment), to account for different management, soil and topographical features, in order to model P loss accurately. These blocks were also soil sampled separately to identify differences in soil P and anion storage capacity (ASC). S-map digital soil data was available for all 3 farms, however, S-map indicated that two farms had podzols, whereas the ASC results and ground truthing indicated that these two farms were more accurately described as allophanic soils in OverseerFM.

When accurate soil information was used, the OverseerFM's predictions of P loss/ha was in good agreement with those measured during the one-year water quality study in the catchments, with measured losses of 1.7, 0.9 and 0.4 kg P/ha verses modelled losses of 1.9, 0.8, 0.7 kg P/ha. In contrast, when the S-map soils were used for all 3 catchments, modelled losses were 1.9, 2.7 and 2.3 kg P/ha. This highlights the importance of using accurate farm scale soil type information when using OverseerFM.

USING GREEN WATER FOR YARD WASHING:
CASE STUDY OF A MANAWATU DAIRY FARM

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The water used for cleaning holding yards on dairy farms does not have to be of the highest quality. Effluent management systems that reduce the volume of water used will also reduce the amount of effluent generated at the farm dairy and subsequently reduce the volume of effluent storage needed. Recycling pond effluent (green water) for washing down holding yards is an option for farmers to consider.

A study was undertaken on green water usage on a 210-cow System 3 dairy farm in the Manawatu over two lactations (2016/17 & 2017/18). Effluent samples were collected from the point of entry onto the holding yard and analysed for solids content, major nutrients and *Escherichia coli.*

Water usage was found to average 30L/cow/day, far below the industry average of 70L/cow/day. Median nutrient concentrations in green water (n=100) of potassium (0.345 kg K/m^3) and phosphorus (0.041 kg P/m^3) were higher than the concentrations typically found for pond effluent (0.290 kg K/m^3 and 0.030 kg P/m^3, respectively) while nitrogen concentrations (0.205 kg N/m^3) were similar (0.190 kg N/m^3). Median *Escherichia coli* populations (n=49) were 4.0 x 10^5 MPN/100 mL, a level within the normal pond effluent range.

UNCERTAINTY – WHAT IS IT?

David Wheeler, E Meenken, M Espig, M Sharifi, M Shah and S Finlay-Smits

AgResearch, Hamilton

All knowledge on which decisions is shrouded with uncertainty of different types and degrees. Addressing uncertainties in data-rich environments is complex and no discipline can do it all, hence interdisciplinary approaches are crucial. Digitalisation in agriculture provides more and increasingly real-time data from smart on-animal and on-farm sensors and IoT devices, but there are uncertainties associated with this. Simulation models can turn this data into actionable knowledge for decision-making but are accompanied by uncertainties. These might concern how the data is collected, the modelling itself, assumptions and social aspects around the model. The model or its outputs are used in a wider context, where uncertainty related to ambiguity, probably or vagueness become important. Uncertainty is thus a fuzzy term that describes a plethora of quantitative and qualitative aspect of limited knowledge. This paper summarises research to bring more certainty to uncertainty.

IMPORTANCE OF MEASUREMENT AND DATA UNCERTAINTY IN A DIGITALLY ENABLED AGRICULTURE SYSTEM

Mos Sharifi[1], E Meenken[1], B Hall[2], M Espig[1], S Finlay-Smits[1] and D Wheeler[1]

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In a digital agriculture system, large number of sensors enabled by real-time connectivity of Internet of Things – IoT technologies, generating farm data including measurements related to environmental, soil, plant, and animal status. Farm models (statistical, verbal, visual, deterministic, etc) transform these data to actionable farm knowledge and information. Sensor measurement data is always associated with uncertainty caused from difference sources such as measurement error. It is essential to identify, assess, quantify, manage and meaningfully communicate this type of uncertainty around agricultural decision-support systems where possible. The likelihood of undesirable decision outcomes can only be manged when the accuracy of available information is known. In this talk, we review the influence of sensor data and measurement uncertainty as part of a broader research programme around uncertainty in decision making systems in a digitally enabled agriculture system.

A FRAMEWORK FOR UNCERTAINTY EVALUATION AND ESTIMATION IN AGRICULTURAL BIOPHYSICAL MODELS

Esther Meenken, D Wheeler, M Espig, J Bryant, H Brown,
E Teixeira and C Triggs

AgResearch, Hamilton

We present an uncertainty evaluation framework that facilitates exploration of how the components of a model contribute together to the overall model output uncertainty. A key aspect of the framework is an unambiguous state-space structure that classifies the types of uncertainty that can be introduced by each model component. A clear compartmentalisation of the model into its components, $r = f(Z_t, \theta, E_t, C_t, \varepsilon)$, is defined such that the real world target quantity ***r*** is predicted to behave as function ***f*** of state equations Z_t, input parameters ***ϑ***, calibration and environmental data C_t and E_t, and residual uncertainty ***ε***. This framework enables us to carry out hybrid analytics that leverages both process-based models and voluminous data via a Bayesian framework to provide real-time, calibrated simulations complete with confidence intervals.

AUGMENTING TRIAL DATA WITH OTHER DISPARATE DATA SOURCES AND QUANTIFYING UNCERTAINTY

Munir Shah, S Meenken and E Meenken

AgResearch, Hamilton

Grass grub is one of the major pests in New Zealand dairy farm systems and have huge economic consequences. In this paper, we used traditional trial data and augmented it with other disparate data sources such as typology and remote sensing data. Using this disparate data we developed a model to predict the presence of grass grub. One of biggest challenge in using disparate datasets is the quantification of uncertainty. We will share our experiences and challenges working with disparate data sets and some potential techniques to quantify uncertainty.

UNDERSTANDING AND COMMUNICATING UNCERTAINTY IN DATA-RICH ENVIRONMENTS: TOWARDS A TRANSDISCIPLINARY APPROACH

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Decision making in farming operations and the environmental regulation of agricultural systems are increasingly dependent on information derived from data-rich, digital sources. Simulation models can help to interpret the growing amount of data and to manage the complex uncertainties that accompany decision making in these contexts. While simulation models may reduce some of these uncertainties, they cannot address others and might even introduce new uncertainties. Modellers and users make frequent reference to uncertainties, but it is often unclear which specific aspects of a model are discussed or whether the uncertainties in question are even concern the model itself. As a result, discourses concerning modelling uncertainty can promote a plethora of meanings. Communication around uncertainty within decision-making processes can therefore remain vague and ineffective unless these diverse meanings are understood by all parties. Drawing on interdisciplinary research in the agricultural sector, we propose a framework to facilitate meaningful communication around modelling uncertainties.

Our framework builds on recent scholarship that distinguishes between the *direct* uncertainty associated with a specific simulation model, including irreduciable uncertainties (e.g. aleatory uncertainty), and *indirect* uncertainties, which concerns the quality or underlying knowledge or users' trust. We expand this useful distinction by adding a third layer of *contextual* uncertainties that emerge from the wider social, political and economic setting within which models are embedded. Additionally, we draw attention to the processes of data generation and model building themselves, which are also influenced by contextual factors (e.g. political priorities).

We propose that framing uncertainty in this way is useful for several reasons. First, it helps to identify different types of uncertainties involved in the building, communication and use of simulation models. This, secondly, allows interdisciplinary research teams to delineate work areas and establish productive collaboration in order to recognise leverage points for uncertainty reduction. Third, the framework facilitates meaningful developer-user dialogue around models' strengths and limitations in addressing complex uncertainties, which is a crucial part of expectation management and model improvement. Fourth, this understanding can form the foundation for a more comprehensive decision-making framework for contexts where a lot of information and uncertainty emerge from data-rich, digital sources.

COMPARISON OF USING S-MAP SOIL INFORMATION WITH THE OLDER FUNDAMENTAL SOIL LAYERS

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Managing land resources at broader scales usually requires spatial soil information, along with data on terrain, climate, vegetation, land cover and land use. These data are used in a range of models. In New Zealand there are two options for the source of soil information to use in models: the Fundamental Soil Layers (FSL), derived from the Land Resource Inventory, and the more modern S-map. The former is complete for New Zealand, whereas the more accurate S-map only covers 34% of New Zealand (as at December 2019). This study compares the two soil data options. First, differences in data definition and data capture are explained, then two soil properties are spatially compared (soil order and profile-available water [PAW]), and finally the implications of using the two soil datasets in three models (highly productive land, droughtiness, and crop suitability) are compared. Differences vary spatially and in significance. For example, in 42% of the area covered by both FSL and S-map, PAW differs by more than 50 mm. Most of this is in the North Island. Soils from the Pumice soil order are more generally in agreement between the two sources of soil data than those from the Gley, Allophanic or Recent soil orders. Differences in Land Use Capability class between the two soil data sources equate to a difference of almost 100,000 ha of highly productive land in Canterbury. The maps of modelled droughtiness in a catchment in Hawke's Bay are quite different, whereas suitability for growing maize in Hawke's Bay is less sensitive to differences in the soil data. Users of soil information are advised to understand the limitations of the different soil data and ensure they use them appropriately, as determined by their particular purpose.

MEASURING SPATIAL DISTRIBUTION OF DICYANDIAMIDE MOVEMENT IN A WELL-DRAINED AND A POORLY-DRAINED SOIL

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Nitrogen (N) losses from urine patches can be significant contributors to greenhouse gas emissions and water quality issues. Nitrification inhibitors may reduce these losses by slowing down the transformation of urine-N to nitrate. Technologies exist that can detect urine patches and target inhibitor applications specifically to the patch area, thereby avoiding the need to apply the inhibitor over the entire paddock. However, the potential time delay between the grazing event and the inhibitor application, and the small volumes of inhibitor used could result in only partial interception of the urine by the inhibitor in the soil. This would limit the potential effectiveness of the inhibitor.

This study was undertaken to determine the movement and interception of the nitrification inhibitor dicyandiamide (DCD). Two volumes of DCD (the equivalent of 10 and 20kg DCD/ha) were sprayed using the Spikey® spray unit onto urine (2 L volume) patches created within 80 cm diameter chambers in two soils of contrasting drainage at two different moisture levels.

On average, 40 and 26% of the DCD applied at 10 and 20 kg/ha levels, respectively was recovered from the soil. Of this, on average 69% was present in the 0-2 cm, 8% in 2-5 cm and 24% in 5-10 cm soil depths. DCD concentrations in the top 2 cm varied greatly and average concentrations of 15.5 and 11.4 mg DCD/kg soil were measured for 10 and 20 kg/ha DCD application rates. There was little difference in DCD (1.45 mg DCD/kg soil) measured below 2 cm between application rates. More DCD was recovered from the poorly-drained soil (38%) compared to the well-drained soil (27%).

After five days, following 24 mm rainfall, DCD recovery remained the same but its distribution and concentrations among the soil depths changed indicating its downward movement. About half of the recovered DCD remained in the 0-2 cm soil, one-third accumulated in 2-5 cm depth and the remainder was in 5-10 cm depth. The findings will be presented and discussed at the workshop.

COMPARATIVE EVALUATION OF CONTROLLED RELEASE FERTILISERS FOR NITRATE LEACHING BY A LYSIMETRIC EXPERIMENT

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The leaching of nitrate from horticultural activities in particular market gardens is a major concern both in terms of surface and ground water contamination. A preliminary trial was carried out to evaluate the leaching behaviour of different fertilisers in spinach production growth on a Manawatu sandy soil. The objectives of this study were to evaluate the effect of different types and rates of controlled release fertilisers on nitrate leaching losses and net crop yield. Fifty lysimeters were filled with 10.78 kg of Manawatu sandy soils and treated with urea, two controlled release fertilisers namely ‘g’and ‘SmartN’ at the rates of 50 kg N/ha (50N), 100 kg N/ha (100N) and 200 kg N/ha (200N). The 200 kg N/ha urea application was made in 10 split doses at a rate of 20 kg N/ha in 7-day intervals, whereas 200N application of ‘g’ and ‘SmartN’ were made twice at a rate of 100 kg N/ha at the time of planting and six weeks after planting. The control treatment did not receive any fertiliser application (0 N). All treatments were replicated five times and spinach seedlings were planted at 5cm depth in each lysimeter. Leachate samples were collected when the rainfall exceeded 18mm.

The application of Urea and ‘g’ at all rates except ‘g’-50N produced significantly higher nitrate leaching losses (19.8 to 27.7 kgN/ha) compared to the control (9.1 kgN/ha), while SmartN at all rates produced no significant increase in nitrate leaching. The highest yields were obtained by urea and ‘g’ greater than or equal to100N, while for SmartN, the maximum yield was obtained at 200N. The total nitrate leached per ton of dry matter production was significantly reduced by the application of N fertilisers compared to the control (135.1 kgNO_3^--N/MgDM). On an average, 16.4 kg NO_3^--N/MgDM was leached from the fertilised treatments. Dry matter production increased at 200N application rates with all three fertilisers, but urea-200N produced highest dry matter yield of 2377 kg/ha. In conclusion, frequent split applications of urea (urea - 200N) increased dry matter yield thereby significantly reduced nitrate leaching.

FULL-SCALE HOPPER TESTING OF LIME FLOWABILITY

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The Civil Aviation Authority (CAA) requires that topdressing aircraft are capable of jettisoning 80% of the aeroplane's maximum hopper load within five seconds of the pilot initiating the jettison action. Three different devices were tested for their ability to assess flowability of 13 samples of lime from different quarries. Overall the 3 test devices (tilting cylinder, upright cylinder with trap door, scale hopper) provided a conservative measure of flowability, in that the lime would get stuck in these devices before flowability in the full-scale hopper testing started to degrade. It was found the compressibility of dried lime correlated with its flowability. As the moisture content of the lime is increased, its compressibility also increases. The average compressibility of the lime samples at flow failure was 20%, which agrees with previously published criteria for good flowability. In order to validate the sampling devices which used 2-5 kg of lime, comparison testing was performed on two full scale aircraft hoppers, holding 1.2-2.0 tonne of aerial grade lime. Full-scale hopper testing was not able to reproduce bridging and lime holding up in the hopper, but did show a decrease in flowability as more water was added to the lime. Measurements of the 3-axis vibrations in topdressing aircraft in normal operations were recorded. RMS vibration amplitudes of approximately half the acceleration due to gravity were recorded during take-off from a rough airstrip. It is believed that bridging of lime in the full-scale hopper tests was not obtained even with 9% moisture content because the hoppers were not shaken to the same level of vibrations seen in practice.

EFFECT OF COPPER BIOAVAILABILITY ON NITRIFICATION RATE IN NEW ZEALAND PRODUCTIVE SOILS

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A higher percentage of the applied nitrogen is lost through various forms such as ammonia (NH_3) volatilisation, nitrate (NO_3^-) leaching and nitrous oxide (N_2O) emissions from soil. To mitigate the environmental impacts of N losses from agriculture systems, different approaches such as control release N fertilisers and urease inhibitors have been applied. In New Zealand, commercially available urease inhibitors such as 3,4-dimethylpyrazole phosphate (ENTEC Ravensdown) are in current use, while dicyandiamide (DCD) have been with-drawn from the market. These products also have no CODEX and thus no safe maximum residue levels for dairy hence, any detection is not allowed. Therefore, exploring alternative strategies in reducing detrimental environmental effects due to N loss is greatly recommended. In recent studies, a strong positive correlation has been observed between copper (Cu) in NZ productive soils and nitrification rate. This indicates a potential new approach in controlling nitrification by manipulating the bioavailable Cu in soils. Heavy molecular weight organic acids (HMWOAs) has been reported to consist of functional groups that can form metal-organic acids complexes with Cu^{2+}, thus reducing Cu bioavailability in the soil. This study aims to evaluate (1) the application of HMWOAs on reducing Cu bioavailability in soils; (2) the effect of Cu bioavailability on nitrification rate, and (3) the effect of Cu and HMWOAs interaction on soil microbial community. Soil incubation and pot experiments will be conducted to evaluate the efficiency of these HMWOAs on reduction of Cu bioavailability in soil and subsequent effect on nitrification rate. Further, DNA and RNA extracts from soil samples will be subjected to 'Illumina Mi Seq' sequencing analysis. Knowledge gained from this research will provide a new sustainable approach to NZ agriculture systems in reducing N losses to the environment.

STRATEGIC USE OF SOLUBLE MAGNESIUM FERTILISER TO BOOST SPRING DAIRY PASTURES FOR ANIMAL HEALTH OUTCOMES

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Magnesium supplementation of spring pastures is imperative for animal health outcomes on dairy farms. Traditionally supplementation via dusting or direct to animal has been used. A small plot trial was used to investigate the use of the soluble magnesium fertiliser, kieserite (magnesium sulphate), to boost pasture magnesium contents to animal health levels. Two application timings and three rates of kieserite were applied to autumn saved pasture. Herbage testing was completed monthly during spring to determine uptake of magnesium and soil tests were taken to determine changes in soil magnesium.

COMPLEXATION OF CD WITH ORGANIC ACIDS IN XYLEM FLUID OF CHICORY AND PLANTAIN

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Recent studies indicate that elevated levels of Cd in New Zealand agricultural soils can lead to high Cd accumulation in forage species such as chicory (*Cichorium intybus* L.) and plantain (*Plantago lanceolata* L.). These studies suggest the different abilities of pastoral species to either absorb Cd by roots or to translocate it from roots to shoots. Hence, it is important to determine the Cd translocation mechanism in these forage species. Plants produce Low Molecular Weight Organic acids (LMWOAs), which are involved in heavy metal translocation in plant xylem fluid. Therefore, a hydroponic experiment was conducted to evaluate the influence of increasing Cd concentrations on the production of LMWOAs in chicory and plantain xylem fluid. Germinated seedlings were separately grown in six different concentrations of Cd solutions (0, 0.01, 0.1, 0.5, 2.5 and 5 mg Cd/L) for 12 weeks and the LMWOAs concentrations in xylem fluid were analysed using High-Performance Liquid Chromatography. The results showed that oxalic, fumaric and citric acids in chicory, and oxalic and fumaric acids in plantain were the major LMWOAs in xylem fluids for all treatments. The fumaric and oxalic acid concentrations in chicory significantly increased ($p<0.05$) at 2.5 and 5 mg Cd/L, respectively. The respective percentage increases were 95% and 108% compared to control. The oxalic acid concentration in plantain nominally varied up to 0.1 mg Cd/L treatment and significantly ($p<0.05$) decreased by 26% at 0.5 mg Cd/L treatment relative to control. The citric acid concentration in chicory and fumaric acid concentration in plantain were independent of the increasing Cd levels in the solution. The fumaric acid concentration in chicory was significantly and positively correlated ($p<0.05$, $R= 0.99$) with the xylem fluid Cd concentration in chicory, while LMWOAs in plantain did not show any correlation with xylem fluid Cd concentration. In conclusion, it can be suggested that the translocation of Cd^{2+} in chicory can be facilitated by complexation with fumaric acid in xylem sap. However, further research is needed to confirm the findings of this study.

COMPARING TARARUA DAIRY FARMS ABILITY TO MEET YEAR 20 NITROGEN LEACHING LIMITS USING OVERSEER 5.2.6 AND TABLE 14.2 IN THE ONE PLAN, WITH OVERSEER 6.3.0 AND THE RECALIBRATED TABLE

Brittany Hill

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After adopting the OnePlan in 2007 Horizons Regional Council face the challenge of using outdated Overseer technology to grant or deny nutrient management consents. The nitrogen leaching values set out in the OnePlan were calculated using Overseer version 5.2.6 but version Overseer 6.3.0 is now used to create nitrogen leaching profiles for consent applications. As a result of this, a recalibrated table was created to align Table 14.2 with the updated version of Overseer. However, due to legal obligations the OnePlan is not able to be updated due to the view that "increasing the table will allow farmers to increase the amount of nitrogen leached and therefore more farms will be granted consents".

This presentation investigates the differences in nitrogen leaching figures (kg N/ha) between Overseer versions 5.2.6 and 6.3.0. It also assesses how the different nitrogen leaching figures from the two different Overseer versions effect the proportion of farms able to meet their Year 20 nitrogen leaching targets as set by Horizons Regional Council in the OnePlan and the recalibrated table.

Evidence from this study suggests that recalibrating table 14.2 of the One Plan using Overseer 6.3.0 will mean that farms will have higher nitrogen leaching figures but, the number of farms that can meet the new table will be similar to the number of farms that could meet the existing table using Overseer version 5.2.6. Farm parameters have remained the same between versions to show how these models have calculated nitrogen leaching differently.

The increase in nitrogen leaching between versions suggests that older Overseer versions may have underestimated the amount of nitrogen being lost from farming systems. By adopting the numbers set out in the recalibrated table, it will mean that farms which were considered low leachers under the old table, will again be considered low leachers under the new table and therefore will be able to be granted an intensive land use consent from Horizons Regional Council.

MANAGING NUTRIENT AND GHG LOSSES WHILE MAINTAINING AN ECONOMIC BUSINESS – DENNLEY FARMS, BFEA WINNERS 2019

Adrian and Pauline Ball

Dennley Farms, Waikato

Adrian and Pauline Ball, owners and operators of Dennley Farms Ltd, were the 2019 recipients of the Gordon Stephenson Trophy, as National winners of the Ballance Farm Environment Awards.

Dennley Farms' strong environmental, social and economic sustainability was a stand-out for the National Judging Panel. The business' tagline is 'creating value inside the farm gate,' and the farm team is active in the creation of meaningful industry change and driven to improve consumer perception of the sector.

Aspiring to model low input, low footprint, high animal welfare values, the Balls have achieved best practice agronomy to optimise crop and animal yields without compromising environmental health.

Pauline runs the dairy beef unit which is part of their closed, low-input system where forage crops are home-grown and stocking rates are adjusted accordingly. An innovative approach to managing staff rosters makes Dennley Farms a great place to work.

The couple's early adoption of technology demonstrates an active intention to run a business that has science, logic and progressive innovation at its heart. Long-term plans are to fine-tune farm-grown feed requirements, trial crops and practices that reduce the farm's footprint further year-on-year, introduce more energy-saving and cost-effective infrastructure to the asset base, and maintain growth across the dairy platform and beef breeding enterprise.

Dennley Farms is a showcase for New Zealand farming and growing, with 1.7km fenced and riparian planting along the Waihou River. Adrian continues to be actively engaged in sowing the seeds of change within both Fonterra and the dairy sector.

In this session, Adrian and Pauline will discuss how they have been able to manage nutrient loss along with the conflict this brings in reducing GHG's per unit of meat and milk produced, while maintaining an economic farm business.

DAIRY FARM SYSTEM SOLUTIONS THAT REDUCE NITRATE LEACHING AND THEIR CONSEQUENCES FOR PROFITABILITY

Charlotte Robertson

DairyNZ, Waikato

Dairy products provide nutrition, energy and income for much of the world. It is currently necessary to continue their supply albeit in a more environmentally sustainable manner. Excess nitrate (NO_3^-) from dairy cow urine patches can leach from soils with significant consequences for receiving waters.

Prescribed management practices for reducing NO_3^- leaching by 20%, whilst maintaining profitability were tested for a south Canterbury case study dairy farm. The Baseline was the existing farm management for the 2017/2018 season. Nitrate leaching and profitability were estimated using the models FARMAX Dairy and OVERSEER® Nutrient Budgets. Prescribed management practices from the Forages for Reduced Nitrate Leaching (FRNL) programme were modelled. The practices adopted were: (i) reducing nitrogen (N) in cows' diets through low-N feed (fodder beet), (ii) recapturing N from soils through catch crops (oats) and (iii) diluting urinary N (through ingested plantain). Two crop treatments were applied to the Baseline to address (i) and (ii). Plantain was included in pastures to address (iii). A number of key assumptions were made about plantain's efficacy for reducing NO_3^- leaching. Plantain was not expected to persist in pasture swards without active management and so a persistence curve and maintenance treatments were incorporated. A sensitivity analysis investigated the influence of soil type and poorer persistence of plantain on treatment success.

Most treatments reduced NO_3^- leaching, but substantial management inputs were required to achieve a 20% reduction from the Baseline. Plantain was identified as the key forage for reducing NO_3^- leaching. When plantain was included in pasture swards and undersown every second year to increase its presence, NO_3^- leaching could be reduced by 21-24%, however, profitability was reduced by 5-10%. Fodder beet and oats had little impact on NO_3^- leaching because the crop area was small in comparison to the rest of the farm (4%). There were no treatments that achieved a 20% reduction in NO_3^- leaching and maintained profitability. The implications of this modelling study for real-life application are that if plantain can be maintained in the pasture sward at high enough levels NO_3^- leaching can be substantially reduced, though this would likely result in a loss of profit.

OPTIONS AND IMPLICATIONS FOR INCORPORATING PLANTAIN MIXED PASTURES INTO A CANTERBURY DAIRY SYSTEM

Pierre Beukes, E Minnee, T Chikazhe and J Edwards

DairyNZ, Hamilton

A modelling study was designed for a Canterbury dairy farm to investigate options for incorporating plantain mixed pastures into the system. These options included 28% of the milking platform in a 25%-plantain sward, 56% of the platform in a 25%-plantain sward, 28% of the platform in a 50%-plantain sward, a scenario feeding plantain silage sourced from the support block to lactating cows, and a scenario with 100% of both platform and support pastures consisting of 50% plantain mix. Scenarios were simulated for different drainage years and included economics, such as costs for maintaining plantain pastures, as obtained from the actual case study farm. The modelling reflected plantain's effect on herbage quality and urinary N concentration, but not soil processes. The 100% of pasture area in 50%-plantain resulted in 10 kg N/ha leaching reduction (16%) on the platform pasture area, which was diluted to 5 kg N/ha (7.5%) reduction from all hectares counted including the support and crop blocks. However, the most practical scenario defined by the farm owner for N leaching reduction was 28% of the platform in 50%-plantain sward, resulting in a 1 kg/ha (1.5%) reduction from all hectares counted. This scenario only achieved an average annual plantain intake of around 11%, which is not enough to make a sufficient impact on urinary N amount and concentration to affect N leaching. Reasons for the low impact on N leaching include the large amount of supplements fed on this farm (20+%), and therefore less pasture fed per animal; assumed yield for plantain mixed pastures being the same as standard pasture, therefore the same assumed dry matter intake per hectare; using data from a recent Canterbury study showing difference in crude protein and dry matter percentage between standard pasture and plantain mixed pastures being smaller than in previous studies. Plantain silage carted from the support block to the milking platform had no effect on N leaching because differences in crude protein and dry matter between the silage and the supplements it replaced in autumn were too small. Milk production and profitability were not negatively affected by any of the plantain scenarios.

PLANTAIN (*Plantago lanceolata* L.) NITROGEN USE AND EXCRETION BY LACTATING DAIRY COWS

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The incorporation of plantain (*Plantago lanceolata*) in cows' diets can reduce the urinary N concentration (UNc) and potentially reduce dairying's environmental footprint. However, to provide farmers with confidence in using plantain based swards, research needs to demonstrate that these environmental benefits are not at the expense of milk production and farm profit. This research examined the effect of grazing plantain on milk production and urine-N excretion by cows in an experiment conducted at Massey University's Dairy 4 Farm throughout two lactation seasons (2017-2018 and 2018-2019). Three mobs of 20 cows were matched for age, weight and milk production, and assigned to graze three pasture treatments: (i) plantain, (ii) plantain-clovers mix, (plantain, red [*Trifolium pratense*] and white clover [*T. repens*]), or (iii) ryegrass (*Lolium perenne*)-white clover (wc). The pastures were established (1 December 2016) in a complete randomised design with five replicate plots (800 m^2) for each treatment and which were grazed from spring (September) to autumn (May). Cows were acclimatised to each pasture treatment for 6 days (adaptation period) before grazing the experimental plots (4 cows/plot) for 2 days (experimental period). Pasture intake, diet quality, and animal N (milk, urine and faeces) were measured during the experimental period in spring (September 2017, December 2017/18), summer (February 2018/19), and autumn (March 2018, May 2019) for both lactations. Cows grazing the plantain and plantain-clover mix pastures produced the same quantity of milk solids ($P>0.05$) as cows grazing ryegrass-wc pasture throughout both lactation seasons. Both plantain and the plantain-clover mix reduced ($P<0.01$) the UNc by 36 and 40% in the summer and autumn 2017-18, respectively when compared with ryegrass-wc. However, the UNc in cows grazing plantain was 10 and 21% lower ($P<0.01$) during the summer and autumn 2018-19, respectively when compared to those grazing the plantain-clover mix and ryegrass-wc pastures. The results demonstrate that plantain pastures do not diminish milk solids production from cows and the lower UNc from summer to autumn could reduce N being lost to the environment.

NITROGEN LOSSES FROM PLANTAIN: WHAT CAN WE SAY?

Maria Jimena Rodriguez, P Kemp, S Navarrete, J Hanly, D Horne and P Bishop

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Losses of nitrogen (N) from urine patches as nitrate (NO_3^-) leaching, and nitrous oxide (N_2O) and ammonia (NH_3) emissions are important contributors to the degradation of the environment. Plantain *(Plantago lanceolata*) pastures can reduce N concentrations in cow urine and modify the soil N cycle by inhibiting nitrification. The main goal of the research presented in this paper was to provide a comprehensive understanding of N losses from pure plantain pasture compared to a standard ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture.

Nitrogen losses from plantain pastures, and associated mechanisms, have been studied in a major field trial and a lysimeter experiment. Three pasture treatments were established in December 2016 at Massey University's Dairy 4 farm including; a standard ryegrass/white clover sward, a plantain pasture, and a pasture mix of 70% plantain and 30% red and white clover. Each treatment was replicated five times. Each treatment plot (~800 m^2) had an isolated mole-pipe drain system that allowed for the quantification of NO_3^- leaching. The pastures were grazed by lactating cows over a 10-day period on March and April 2017, and over a 8-day period from September 2017 until June 2018 and from September 2018 until May 2019. Nitrous oxide emissions were evaluated during two season, spring and autumn/winter. In this paper, focuses on the results from the pure plantain and ryegrass /white clover treatments. In addition, a lysimeter study was also conducted to determine the effect of aucubin, a secondary metabolite produced by plantain, on N_2O emissions and NO_3^- leaching. The treatments evaluated in the lysimeters were two forage types (ryegrass/white clover and plantain), two aucubin rates (0 and 10 mg g^{-1} DM plantain) and two urine treatments (urine from cows grazing ryegrass/white clover (583 kg N ha^{-1}) and water as a control).

In 2017 and 2018, NO_3^- leaching was lower from plantain field plots compared to ryegrass/white clover. However, in 2019, NO_3^- leaching losses were similar for both pastures. The N_2O losses from the field experiment are discussed in an associated poster. The lysimeter experiment shows that plantain pastures reduced N_2O emissions and that aucubin had an inhibitor effect on N_2O emissions for the first 20 days after application. However, NO_3^- leaching was variable and the effect of aucubin was not clear.

QUANTIFICATION OF NITROGEN (N) LEACHING LOSSES UNDER A MAIZE CROPPING SYSTEM

Rowland Tsimba

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Nitrogen (N) leaching into ground water sources is one of the main contributors to environmental contamination. Maize, an important crop for dairy and cropping farmers has a deep rooting system which has allowed it to be used as a mitigation strategy in reducing on-farm N-losses in Europe. It has been shown to be an effective sink for dairy shed effluent in NZ. Best practice maize crop management will allow farmers to minimize N losses from maize crops.

A maize-catch crop experiment utilizing a series of lysimeters and suction cups has been established on a long term maize paddock in the Waikato to quantify N losses in a typical maize silage cropping system. Three catch crop options (annual ryegrass, oats and annual ryegrass-oat mix) are being evaluated on their effectiveness in mopping up left over N after maize silage is harvested in a cut and carry system.

During the 2017/18 and 2018/19 maize growing seasons about 500 kg N/ha was made available to the maize crop through soil residual N or additional fertiliser. This was to allow for some left over soil N after maize harvest to simulate high N input systems. On average, maize extracted 330kg N/ha during the growing season whereas an average of 210 kg N/ha was removed by the catch crop over winter. The ryegrass option significantly outyielded oats by 1.5t DM/ha. Even though the ryegrass-oat option yielded 5% more biomass yield (drymatter) than a sole ryegrass treatment, the later extracted 42kg N/tDM compared to 38kg N/t DM for the mix.

Using a series of suction cups and lysimeters, N leaching losses were measured at the 120cm soil depth every time there was drainage to that depth. Between June and October 2019 fallow plots (control) drained 2,330m^3/ha vs. 2,170m^3/ha for plots with a catch crop treatment. Whereas control plots leached 64kg N/ha below 120cm, use of a catch crop reduced leaching by 90%. A comparison between suction cups inserted at 60cm vs. 120cm soil depth showed that on average, N leaching losses from the former were 3.5 times higher than those at 120cm.

PREDICTING NUTRIENT LOSS – WHAT TO DO WITH EQUINE PROPERTIES?

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The majority of the commercial Thoroughbred production occurs within the catchment area for the Waikato Regional council, on large breeding farms ranging from 20 ha to 526 ha in size, managing up to 370 mares during the breeding season. As notified, the Waikato Regional Council's Healthy Rivers Plan Change 1 (PC1) requires large scale farming operations to calculate a nitrogen loss baseline using OVERSEER®. As at early 2020, it remains uncertain if the equine industry will need to calculate baseline N losses, whether under changes to PC1 or the NES-FW. At present, a number of assumptions are made about horses and equine farms systems within the Overseer nutrient management package. This paper describes some of the work completed, and proposed, to provide estimates of input parameters required to permit quantification of nutrient loss on large-scale equine properties.

At an animal level the horse is a monogastric hindgut fermenter rather than a ruminant, which has implications for voluntary feed intake, and the digestibility and utilisation of dietary protein. On commercial stud farms broodmares are managed at pasture year-round, and pasture forms the basis of the diet and the major source of dietary N. This dependence on pasture is in stark contrast to management systems in many countries.

Prospective data collected on commercial farms and data sourced from the published literature were used within a deterministic model and identified that the faecal N loss remained consistent (20-25%) across a variety of diets, whereas urinary N loss increased with daily N intake and percentage of pasture in the diet. Total N excreted by a Thoroughbred broodmare was estimated to be 0.48 g N / kg bodyweight. In contrast, assuming an average BWT of adult dairy cattle, beef cattle, and sheep are 600 kg, 500 kg, and 65 kg respectively, the N excreted would be 0.52 g/kg BWT, 0.40 g/kg BWT and 0.62 g/ kg BWT.

In contrast to ruminants horses are selective browsers, effectively utilising only 70% of the pasture on offer. The remaining 30% of the pasture are "roughs" or latrine areas, and this percentage of pasture as latrine area appears consistent across different equine livestock classes and production systems. At present we lack data on the concentration of N captured in faecal piles within the latrine areas, or the N leaching potential of the faecal piles. Under commercial management systems the stocking rate during spring and summer doubles to 2 mares / ha (1,000 kg live weight / ha) and the impact of these changes in stocking density on N leaching have not yet been modelled.

Thus, to be able use Overseer effectively for Thoroughbred stud operations, further estimation of equine specific parameters is essential.

SHARING BOTH THE RESPONSIBILITIES AND RESOURCES TO REDUCE N LEACHING: A NEW PARADIGM FOR DAIRY FARMING

David Horne, R Singh, P Tozer and D Gray

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In order to improve surface water quality in 'sensitive' catchments in the Horizon region, each dairy farmer is prescribed a unique, nitrogen (N) leaching allocation. This value is determined by the mix of LUC classes on the farm which is only one of the many factors that affect current N loads to rivers. As is reasonably well understood, there are many features of a dairy farm that impact on N leaching, not least of all; climate, soils types, productivity, and the extent of 'in-field' mitigation measures in place. Furthermore, there is both natural and built attenuation at the field edge and beyond.

This paper explores the possibility that there may be mutual benefits to dairy farmers to share their responsibilities to reduce N leaching, and to pool their soil, mitigation and attenuation resources. While this obviously represents a paradigm shift or transformative approach to landuse and farm management, it may allow rural industries to meet their environmental obligations in a more efficient manner. Using a case study approach, this paper explores the potential to manage the dairy landscape, at both the large and small scale, in a coordinated manner for improved environmental outcomes.

THE BARRIERS TO FRESHWATER POLICY IMPLEMENTATION IN AOTEAROA NEW ZEALAND

Nicholas Kirk

Manaaki Whenua - Landcare Research, Canterbury

New Zealanders have illustrated growing concern about the quality of freshwater resources over the last two decades. In response, New Zealand's government has issued new policies – such as the National Policy Statements for Freshwater Management – which instruct regional councils and unitary authorities to set enforceable water quality and quantity limits for freshwater bodies. This presentation examines the barriers local governments face in implementing this new freshwater policy.

Six regional councils and four unitary authorities were interviewed on their experiences implementing freshwater policy. Following a thematic analysis, the author identified four overarching barriers to freshwater policy implementation identified in these conversations: difficulty aligning local policy with national policy, a lack of local government and community capacity, mismatch between local issues and national priorities, as well as some barriers specific to unitary authorities. The presentation concludes with recommendations on how to overcome these barriers.

UPDATE ON THE PROPOSED NATIONAL POLICY STATEMENT FOR HIGHLY PRODUCTIVE LAND

Tom Corser

Ministry for Primary Industries, Wellington

The Ministry for Primary Industries and the Ministry for the Environment have been developing the proposed National Policy Statement for Highly Productive Land (NPS-HPL).

The Our Land 2018 and Environment Aotearoa 2019 reports, published by the Ministry for the Environment and Stats NZ, highlighted a number of issues facing our land and soils. The NPS-HPL addresses the urban expansion and fragmentation issues these reports found to be facing our most productive land.
The overall purpose of the proposed NPS-HPL is to improve the way highly-productive land is managed under the Resource Management Act 1991 (RMA) to:

- recognise the full range of values and benefits associated with its use for primary production;
- maintain its availability for primary production for future generations; and
- protect it from inappropriate subdivision, use, and development.

Public consultation closed on 10 October 2019 and we received around 250 submissions. This followed meetings held across New Zealand as a part of the roadshow outlining the NPS-HPL and four other proposals from the Ministry for the Environment and the Ministry for Housing and Urban Development.

Engagement on the NPS-HPL was broadly positive and supportive, and there was general agreement on the intent of the NPS-HPL, the three objectives and the use of a national policy statement to achieve this. However, as expected there were a number of issues were raised during the roadshow and in submissions. The project team is now engaging with key stakeholders to help address these issues and undertake further analysis. We are working towards seeking Cabinet approval by mid-2020, with the NPS coming into force soon after.

CENTRAL GOVERNMENT MANAGEMENT OF THE FRESHWATER UNDER THE RESOURCE MANAGEMENT ACT

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The Resource Management Act (RMA) has been New Zealand's key environmental legislation since its enactment in 1991. It accorded wide ranging functions and powers to regional councils and the Minister for the Environment to manage natural and physical resources. To date, under the RMA freshwater quality, flow, volume, allocation and monitoring have been regulated and managed by 16 regional councils under their respective regional policy statements and plans with hands-off sparse, weak and ad hoc national instrument usage by the central government. Whilst freshwater quality has been reported as improving in some polluted catchments, overall, there have been concerns about declining water quality and increasing water allocation/use owing to intensifying urban and rural activities.

Last year, central government proposed sweeping legislative changes under "Essential Freshwater: Health Water, Fairly Allocated". The proposed changes appeared to have been developed in haste and have been inundated with rule based National Environmental Standards (NES), some of which could be counterproductive to the costly water pollution mitigation work carried out at enormous cost to date. Why did it take so long for the central government to use powerful national instruments such as NESs to manage freshwater resources? Would the proposed legislative changes be effective in achieving the desired outcomes for our freshwater resources?

In this policy research paper, the author who has been implementing the RMA since its enactment assesses the performance of the central government since the enactment of the Act and the effectiveness of the recently proposed legislative changes in managing freshwater resources.

INNOVATIVE, ADAPTIVE AND ENGAGING POLICY DEVELOPMENT FOR NUTRIENT MANAGEMENT WITHIN INTENSIVE FARMING SYSTEMS: WHERE POLICY, SCIENCE AND AGRICULTURE INTERSECT

Lynette Baish and K Proctor

Horizons Regional Council, Palmerston North

The impacts of diffuse sources of contaminants generated from various activities, including farm systems, are managed via regional planning instruments. Plan change processes themselves are slow and unwieldy, begging the question, how can plan making and policy development be more agile and adaptive? Horizons applied two innovative approaches within the development and submissions phases of Plan Change 2 – *Existing Intensive Farming Land Uses*. Firstly, an innovative scenario based workshop to test example consents against a set of draft nutrient management policies. This provided an insight into the practicability and impact of the draft provisions. And secondly, a 'friend of the submitter' service, which was available to potential submitters wanting independent support to engage in the plan change process.

A scenario based workshop to see how the provisions might work in practice.
Farm scenarios were developed based on real farm inputs and data. Application drafting and processing teams, including planners, agricultural and science advisors, were allocated to each scenario. The teams were provided with information to undertake the roles allocated to them in their particular field of expertise, with one week to liaise with co-participants. A plenary workshop was held to work through the consenting outcomes. Also in attendance were a number of observers (passive participants) from iwi, industry and NGO's. The scenario testing enabled Horizons to trial the draft provisions in a "laboratory" setting, and provided a platform for engagement and exchange between experts and stakeholders.

The Friend of the Submitter
During the submissions period of Plan Change 2, Horizons appointed an independent 'Friend of the Submitter' to assist stakeholders in understanding the submission process, and in writing a clear and comprehensive submission. It was anticipated this service would be especially helpful to individual farmers and members of the communities. This was a new initiative for Council, with the intent of breaking down barriers to making a submission, and making the process more accessible.

Approaches like the practical workshop can be risky. However, the benefits, in this case the level of engagement attained, and the added robustness gained in respect of refining policy provisions, can make it a risk well worth taking. We want to continue to try innovative ways to engage affected stakeholders and encourage them to have their say.

RESTORING AND RECONNECTING A RURAL FRESHWATER ECOSYSTEM AND SENSITIVE COASTAL ENVIRONMENT USING A COMMUNITY-LED 'MOUNTAINS TO SEA' APPROACH

A Brocksopp[3], Peter Roberts[2], D Patterson[1] and M Highway[1]

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Living Water's mountains to sea project objective is to implement catchment scale freshwater management that demonstrates the restoration of a lowland threatened ecosystems. The focus is on catchment management that will lead to enhancement of the Pūkorokoro Miranda estuarine environment and RAMSAR wetland. Potential benefits of this programme include biodiversity enhancement (especially the benefits to migratory birds), benefits to farmers and benefits to the Firth of Thames (including improved water quality outcomes).

To achieve this goal, Living Water is working with the Western Firth Catchment Group Trust (WFCGT) to develop processes, tools and activities designed to enhance landowners' engagement in catchment activities, build on the initial foundations of catchment group activity and accelerate positive environmental change.

The presentation will report on the progress made to date, focussing on the activities undertaken, including challenges/barriers and future support needed to ensure success.

IMPLEMENTATION OF AN AUDITED SELF-MANAGEMENT PROGRAMME – A CASE STUDY OF BARRHILL-CHERTSEY A MID-CANTERBURY IRRIGATION SCHEME

Nicole Matheson, S Hayman and E Harris

Irrigo Centre Ltd, Ashburton

Barrhill Chertsey Irrigation Limited (BCI) is a mid-Canterbury, farmer owned co-operative irrigation scheme, which first delivered water in the 2010-11 season. BCI has now grown to irrigate approximately 24,210 ha between the Rangitata and Rakaia Rivers, with a Farm Environmental Plan (FEP) managed area of 60,207 ha over 227 properties.

A key aspect of our scheme is to ensure our farmer shareholders operate a Good Environmental Management Practice through an Audited Self Management (ASM) Progamme to ensure BCI complies with consented nitrogen loss limits. We support and encourage shareholders to improve their environmental management by ensuring every farmer shareholder has a farm environment plan which is reviewed and updated annually, coordinating independent audits of these farm plans, monitor intensification and providing professional support and advice.

As a result of our ASM programme, we have seen a significant uptake of Good Management Practices since our programme began. For instance, we have doubled the number of shareholders implementing effective irrigation practices and reduced the proportion of poorer performing farms by 90%.

We have found the most effective tools to improve practice has been to develop relationships with our shareholders and truly understand their motivations and needs, as well as encourage peer discussion groups and competition.

The least effective tools we have found to improve environmental performance have been reporting of annual N losses through Overseer nutrient budgets.

From our experience, uptake of GMPs by farmers to improve water quality have largely been due to an emphasis on developing relationships with our farmer shareholders, and education of resource use efficiency rather than enforcement of strict property N loss limits.

FARM PLAN ANALYSIS UNDER THE TUKITUKI CATCHMENT PLAN LUC FRAMEWORK

Shane Gilmer

Hawke's Bay Regional Council, Hastings

In Hawke’s Bay, the first catchment plan become operative in 2015, and encompassed the Tukituki River and associated sub catchments. The catchment plan stipulated that all primary production landscape larger than 4ha must have a farm environmental management plan (FEMP). The FEMP framework required that critical source areas be identified for each property and proposed mitigations applied within a specified timeline to reduce all on farm contaminant risk, to ground and surface water. Mitigations included the adoption of industry good management practises (GMP). Farms greater than 10 ha must use the Overseer™ nutrient model as part of the nitrogen analysis.

The Land Use Classification (LUC) system and the Overseer™ nutrient model were used to generate a nitrogen leachate limit table. The framework assessed and categorised the nitrogen compliance of individual properties into, either *Permitted Activity status*, *Restricted Discretionary* or *Non-Complying activity*. In addition to the nutrient modelling framework, instream DIN levels are measured and all sub catchments must comply with a 5-year mean of 0.8 mg/L.

More than 1,000 farm plans were submitted to the Hawke’s Bay Regional Council between 2016-2019 and FEMP data was analysed to estimate the nitrogen load contribution at the farm and sub catchment scale. Estimated loads were compared that against the LUC framework and instream nutrient concentrations.

Analysis of FEMP data has indicated that sub catchments could be under or over the total sub catchment LUC allocation with varying compliance with the instream DIN limit.

Future analysis will include the number GMP adopted by farms across each sub catchment and restoration metrics such as riparian fencing length and trees planted.

QUANTIFYING THE DIRECT CONTRIBUTION OF FERTILIZERS TO PHOSPHORUS EXPORTS FROM PASTURES

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Phosphorus exports from grazed pastures can adversely affect down-stream water resources. Recently applied fertilizers can account for ~80% of total phosphorus exports. In practice, is that likely? We examine recent mathematical modelling that suggests for pastures in Australasia where overland flow (i.e. surface runoff) predominates, <10% of total P exports are attributable to recently applied fertilizer.

Phosphorus exports can be considered to have "systematic" (i.e., base or background) and "incidental" (i.e., management related) components. Fertilizer application and grazing are two of the most important incidental factors.

Field monitoring of rainfed and border-check irrigation systems suggests that the effects of fertilizer application and grazing on phosphorus exports decay with time in near-exponential fashion (i.e. very quickly). For example, the initial half-life of fertilizer impact (i.e., the number of days since fertilizing to decrease the total phosphorus concentration in overland flow by half) has been estimated to be ~3 to 4 d, with 95% confidence intervals of ~3 to 8 d. Presumably, phosphorus from water-soluble fertilizers quickly moves into the soil, away from the surface, and this, along with other soil processes, results in that phosphorus rapidly becoming less accessible to overland flow.

When the equations describing the effects of fertilizer application are combined with fertilizer distribution data and the probably of overland flow occurring in subsequent days, it is apparent that for the study areas, most fertilizers were applied at times of the year when phosphorus exports are unlikely. Interestingly, these analyses suggest grazing makes a bigger contribution to total phosphorus exports than fertilizer. While such findings need to be viewed with caution, they are plausible. Grazing increases water-available phosphorus in soil-plant systems and grazing occurs more often at times of the year when overland flow might be expected (e.g., during the irrigation season and late winter and early spring in many rainfed systems).

FERTILIZER SELECTION FOR OPTIMAL ENVIRONMENTAL PERFORMANCE

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Phosphorus exports from grazed pastures can adversely affect down-stream water resources and can be considered to have “systematic” (i.e., base or background) and “incidental” (i.e., management related) components. Mineral (i.e., inorganic) fertilizers may contribute directly to “incidental” P exports soon after their application. Consistent with 4R Nutrient Stewardship (i.e. apply the Right Source of nutrients), we demonstrate the principles for selection of fertilizers that minimize phosphorus exports for three farming systems

In overland flow–dominated systems with seasonal rainfall, basal (i.e., annual) applications of phosphorus fertilizers should be undertaken when the probability of overland flow is minimal, allowing soil processes to lower phosphorus availability at the soil surface (e.g., <5 mm), from where most phosphorus is mobilized. In that case fertilizer selection should be based on agronomic efficiency.

Booster products are sometimes needed when overland flow might reasonably be expected. In these instances, well-timed application of common water-soluble fertilizers are probably appropriate as their phosphorus readily moves from the granule into soil, and soil processes quickly lower its availability to overland flow. Further, the required root zone phosphorus concentration can be achieved at the lowest total phosphorus loading, minimizing legacy effects (i.e., background exports).

In subsurface flow–dominated systems, phosphorus exports depend on the ability of the soil to remove phosphorus in transit. Where flow in soil pores >0.08 mm (i.e. macropores) dominates, water-borne phosphorus can by-pass the soil, especially where artificial drainage systems intercept vertical macropore flow and convey it to waterways. If water drains through the soil fabric (i.e. matrix flow), phosphorus exports depend on the soil sorption capacity. Where agronomically viable alternatives are available, water-soluble fertilizers are probably inappropriate for many sub-surface flow dominated systems.

In border-check irrigation water traverses initially dry soil with a high infiltration rate that declines rapidly behind the wetting front. While land managers control water inflows and outflows, some drainage (i.e., tailwater) from bays and farms is inevitable. It follows that agronomic efficiency and water management are of paramount importance in selecting fertilizers so the required response (i.e. root-zone phosphorus concentration) can be achieved at the lowest total phosphorus loading and associated legacy effects.

REVISITING THE WATKINSON DISSOLUTION TEST FOR PREDICTING PHOSPHATE RELEASE FROM DIRECT APPLICATION PHOSPHATE ROCKS

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Interest in New Zealand in direct application phosphate rock started in the 1980's when rock from a range of sources was available and evaluated. Ultimately the more reactive rocks, those from Sechura and North Carolina were favoured, and Reactive Phosphate Rock was defined as containing not less than 10 % P of which at least 30% is soluble in 2% citric acid. These guidelines are still valid although the flagship RPR's, Sechura and North Carolina, are no longer available. With Sechura containing too high cadmium levels and export of North Carolina rock terminated for strategic reasons.

Since the availability of RPR meeting the 30% citric soluble P threshold is limited, the use of "RPR" terminology should be re-considered in favour of "direct application phosphate rock". Although there is a demand for unadulterated phosphate rock in the marketplace, none of the existing qualification criteria provides any indication on the amount of P that will become available over time. Back in 1994, John Watkinson developed a dissolution rate function (DRF) expressing the amount of P dissolved over time that can be used to describe the reactivity of phosphate rocks for direct application. In this model total P content, particle size distribution, density, mean diffusion coefficient based on soil and climatic properties and dissolution of P into a simulated soil solution factors are used to estimate the amount of P released per year.

In the absence of any other method it is suggested that the Watkinson model be used to describe the reactivity of direct application phosphate rock in parallel with the other existing defining parameters.

ENGAGING TO CHANGE – IMPROVING NUTRIENT MANAGEMENT PRACTICES WITH VEGETABLE GROWERS THROUGH ON-FARM TRIALS

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Growers in Horowhenua and Gisborne have made significant change in nutrient management practices as part of Future Proofing Vegetable Production.

With support from MPI SFF, Horizons Regional Council, Gisborne District Council, Ballance AgriNutrients and Potatoes New Zealand, LandWISE has been working with vegetable growers in Levin and Gisborne to review their nutrient management practices. Focusing primarily on nitrogen we have seen significant changes as growers receive and are supported to use new information.

"Nutrient Management for Vegetable Crops in New Zealand" by Reid and Morton provides guidelines based on the best current experimental evidence. The guidelines, the Nitrate Quick Test and FAR's "Quick Test Mass Balance Tool & User Guide are enabling reduced nutrient wastage.

To support growers, LandWISE has been delivering workshops and field events and running collaborative on-farm trials. Presentations have covered soil sampling and nutrient management, the nitrate quick test, alternative application technologies, fertiliser applicator calibration, and efficient irrigation. These give growers new and updated information, but do not necessarily drive on-farm change.

One-on-one interaction is supporting growers to make actual management changes. Reviewing soil test results, fertiliser recommendations, the guideline recommendations and helping pull it all together is providing the deeper discussion, farm and crop-specific tailoring and confidence building that is necessary.

On-farm trials are comparing growers' historic practices with something new. Trials are kept simple, testing one thing against the other with randomisation and four replicates. In part, they are to continue the conversation, in part to introduce growers to better trial practices, and in part to check that the new management practice does not have negative consequences.

While it was thought trials would compare grower practice with the new nutrient guidelines supported by quick testing, many growers had already adopted them. Some were already applying lower rates than in the guidelines. So, some trials are looking at alternative fertilisers, alternative application methods, different rates of starter and side-dressing and whether biologicals can reduce nutrient requirements.

REVISION OF TIERED FERTILISER MANAGEMENT SYSTEM FOR SOIL CADMIUM

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The Tiered Fertiliser Management System (TFMS) is a component of the "Strategy for Long Term Risk Management of Cadmium and New Zealand Agriculture and Horticulture". The TFMS is intended to manage accumulation of cadmium due to the application of phosphate fertilisers to agricultural soils. In response to recommendations arising from a formal, external review of the Cadmium Management Strategy, the TFMS has been revised. The changes to the TFMS further reduce the very gradual soil cadmium loading to ensure soil cadmium concentrations remain at acceptable levels in New Zealand's agricultural soils over the very long term.

Key recommendations specific to the TFMS, as a component of the Strategy were to: revise the soil Cd trigger points to further reduce cadmium input from phosphate fertiliser, make the link between soil Tier values and fertiliser cadmium levels more explicit and in light of international initiatives and limits, consideration be given to labelling of fertilisers for Cd content. Some changes introduced in response to feedback by the Cadmium Management Group are that the TFMS is no longer limited to just those applications greater than 30kg P/ha/yr, the documented recommendations for agronomic good management practices which are known to reduce plant uptake of soil cadmium are to be presented in a separate document and the principle purpose of the TFMS is brought to the fore.

A REFRESHED NEW ZEALAND CADMIUM MANAGEMENT STRATEGY

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This paper sets out the Cadmium Management Groups (CMG) refreshed strategy for managing cadmium in New Zealand agriculture over the long term. The refreshed strategy is intended to stand until it is reviewed again in 2026. We will also comment on the independent review of the Cadmium Management Strategy that led to its refreshing.

The CMG is a multi-stakeholder group of Regional Councils, primary sectors and Central Government convened by MPI to manage cadmium in the primary sector.

Cadmium is a naturally occurring heavy metal in the earth's rocks, soils, water and air. Cadmium is only acutely toxic at high levels of intake (mostly from accidental industrial exposure), but it can accumulate in kidneys and livers which can lead to chronic toxicity problems.

Current dietary surveys for New Zealander's indicate that the daily intake of cadmium is well below the World Health Organisation (WHO) tolerable monthly intake guidelines. It is unlikely that at current levels of cadmium in food there are adverse health implications for the New Zealand population. However, there is a need for continued vigilance.

Phosphate fertiliser is the primary source of gradual cadmium accumulation in agricultural soils, and the fertiliser industry has enacted a voluntary limit on the levels of cadmium in fertilisers as well as a Tiered Fertiliser Management System for managing cadmium inputs that has also been refreshed.

The refreshed Cadmium Strategy Objective is to *"ensure that cadmium in rural production poses minimal risks to health, trade, land use flexibility and the environment over the next 100 years".*

The refreshed strategy approach is to focus on research, monitoring, education and supporting practices which enable food standards to be met and that control soil cadmium accumulation to:

- Maintain trade access and a vibrant productive primary sector;
- Protect human health;
- Maintain flexibility in land use options; and
- Protect the environment.

PREDICTING CADMIUM CONCENTRATION IN NEW ZEALAND AGRICULTURAL SOILS USING MID INFRARED SPECTROSCOPY

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Spectroscopy based soil analysis have gained popularity over traditional wet chemistry methods in the recent years. Wet chemistry techniques are precise, but highly technical and expensive while being time consuming. Spectroscopy based analysis techniques are cheap, fast and easy to use while maintaining reasonable accuracy. In the context of increased concern of soil cadmium (Cd) level in New Zealand agricultural soils requiring regular monitoring, this research used mid-infrared (MIR: 7498 to 600 cm^{-1}) spectroscopy to develop a robust statistical model to accurately predict agricultural soil Cd.

Eighty-seven topsoil (0-15 cm depth) samples obtained from 30 dairy farms were scanned using MIR spectroscopy; soil characterisation was also done through traditional wet chemistry methods. Data were used to develop spectroscopy-based statistical models to predict soil Cd concentration. Two spectroscopic data transformation techniques including first derivative with Savitzky-Golay smoothing and continuum removal, and two machine learning algorithms including partial least square (PLS) and random forest (RF) regression were tested to generate meaningful calibration and validation models.

Soil Cd concentration ranged between 0.10 and 2.03 mg Cd/ kg soil, and higher Cd values were characteristically found in allophanic soils (0.76 mg Cd/kg) than non-allophanic soils (0.35 mg Cd/kg). Soil total Cd was significantly positive in correlation (r = 0.77) with total phosphorus (P). Spectral data pre-processing using first derivative transformation with Savitzky-Golay smoothing improved the outcome of both regression models than continuum removal. PLS regression validation model predicted total soil Cd variations with relatively high coefficient of determination (R^2_{Val}=0.72) and ratio of performance to inter quartile distance (RPD_{Val} = 1.81) and relatively low root mean square error ($RMSE_{Val}$=0.12 mg Cd/kg). RF-based validation model showed less ideal performance (R^2_{Val}=0.64, RPD_{Val} = 1.60, and $RMSE_{Val}$= 0.14 mg Cd/kg). These results indicated that MIR spectroscopy-based soil Cd dry analysis can help agricultural soil Cd monitoring cheap and fast contributing to the effective management.

NEW TILLAGE TECHNOLOGY TO IMPROVE CATCH CROP OUTCOMES IN SOUTHLAND

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Sowing a catch crop (e.g. oats) after winter forage grazing is recognised as a means to limit nitrate leaching losses, by removing much of the surplus soil mineral-N remaining after winter grazing. For these to be effective they need to be sown as soon as practicable after the cattle have finished grazing, and before the spring, when significant rainfall might reduce their effectiveness.

In the second year (2019) of a three-year Sustainable Farming Fund project in Canterbury and Southland to examine the effectiveness and practicalities of incorporating catch crops in commercial dairy wintering operations, it is the Southland region that presents the greatest challenge. Winter soil conditions in Southland are some of the most problematic in the country to manage, with heavy silt loams common, wet soil conditions and cool temperatures. Consequently, it is often too difficult to cultivate or prepare these soils for drilling until mid-to-late spring at best. However, a new piece of tillage technology we have been trialling has enabled us to drill a catch crop over a period when this would have been near impossible under normal practice. The tillage machinery in this case is the Farmax Rapide 300 spader (or soil inversion plough), working in combination with an integrated Kongskilde drill (“spader-drill”), and represents a new generation of tillage machinery that appears to offer some real opportunities for Southland farmers.

We report the dry-matter yield, N uptake and soil physical condition data from two years of Southland catch crop trials using the spader-drill, compared with conventional tillage, and the potential environmental, efficiency and profitability gains possible in Southland dairy wintering operations.

MODELLING SPATIAL AND TEMPORAL VARIABILITY IN EROSION RISK FOR WINTER GRAZING MANAGEMENT

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Intensive grazing practices in New Zealand have received increasing attention as a potential cause of significant land degradation in the form of soil damage, accelerated rates of erosion and nutrient losses, and reduced plant yields (Drewry *et al.*, 2008; Laurenson *et al.*, 2018; McDowell *et al.*, 2003; Monaghan *et al.*, 2017). Field studies demonstrate pasture grazing can increase soil losses by up to 25%, while intensive-winter increased soil losses by up to 350-550% relative to ungrazed equivalents (Cournane *et al.*, 2011; Laurenson *et al.*, 2018; McDowell *et al.*, 2003; Monaghan *et al.*, 2017). Often, losses could be mitigated if critical source areas (CSAs) were avoided by grazing locations with relatively low susceptibility to surface erosion and soil loss (McDowell, 2006; Monaghan *et al.*, 2017). In order to help meet economic targets (e.g., dairy, beef, and sheep production) and sustainably manage environmental impacts (e.g., water quality, land preservation, greenhouse gas emissions), national efforts are aiming to mitigate sediment and contaminant losses from agricultural activity (Our Land and Water, 2018). In support of this effort, we evaluate land-use suitability (i.e., susceptibility to soil loss and degradation) for sheep and cattle grazing for 4 watersheds in Southland, New Zealand. In addition, we evaluate the contribution of sheep and cattle grazing to soil loss at watershed and regional scales for New Zealand. We develop a model to capture grazing's effect on soil physical properties and ground cover that can be integrated with the Revised Universal Soil Loss Equation (RUSLE). Initial modelling soil loss results are similar to those from field studies, with pasture grazing and intensive winter-grazing respectively increasing soil losses from plots on the order of 10-20% and 100-300%.