Nutrient Loss Mitigations for Compliance in Agriculture

32nd Annual FLRC Workshop

This document contains the programme and abstracts of all presentations to the 32nd Annual FLRC Workshop at Massey University on the 12th, 13th and 14th February 2019.

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 12th February

0915-1000 Registration and Morning Tea

1000–1015 **WELCOME**
Professor Chris Anderson
Acting Director, Fertilizer & Lime Research Centre, Massey University

Session 1 : International Frontiers

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

1015-1025 **Chairman's introduction**

1025-1050 **Jenny Deakin** *Invited Speaker*
Environmental Protection Agency, Ireland
THE KEY WATER QUALITY ISSUES IN IRELAND AND THE IRISH RIVER BASIN MANAGEMENT PLAN

AGMARDT ENABLING TRANSFORMATIONAL INNOVATION

1050-1115 **Flemming Gertz** *Invited Speaker*
SEGES, Denmark
ENGAGING FARMERS IN ENVIRONMENTAL MANAGEMENT IN DENMARK

1115-1130 **Peter Thorburn, P Fitch, Y Zhang, Y Shendryk, T Webster, J Biggs, M Mooij, C Ticehurst, M Vilas and S Fielke**
CSIRO Agriculture and Food, Brisbane, Australia
"DIGITAL AGRICULTURE" HELPING FARMERS REDUCE IMPACTS OF CROPPING ON THE GREAT BARRIER REEF

1130-1145 **Alessandro Aduso and S Ledgard**
Ministry for Primary Industries, Wellington
LEAP – A GLOBAL TOOL TO SUPPORT NEW ZEALAND SUSTAINABILITY

1145-1200 **Discussion**

1200-1300 **Lunch**

Session 2 : Environmental Challenges for Agriculture

Chairman: **Dr Alec Mackay**
AgResearch, Palmerston North

1300-1320 **Lee Matheson** *Invited Speaker*
Perrin Ag Consultants, Rotorua
WHAT ENVIRONMENT MANAGEMENT CHALLENGES ARE FACING NORTH ISLAND PASTORAL FARMERS?

1320-1340 **Andy Macfarlane** *Invited Speaker*
Macfarlane Rural Business, Ashburton
ENVIRONMENT MANAGEMENT CHALLENGES FACING SOUTH ISLAND FARMERS

1340-1400 **Dan Bloomer, P McVeagh and G O'Brien** *Invited Speaker*
Page Bloomer Associates, Hastings
ENVIRONMENT MANAGEMENT CHALLENGES FACING INTENSIVE HORTICULTURE

1400-1420 **Rich McDowell** *Invited Speaker*
Our Land & Water National Science Challenge, AgResearch, Lincoln
CURRENT AND FUTURE CHALLENGES IN LAND AND WATER SCIENCE

1420-1435 **Discussion**

1435-1445 **Poster Papers**

Margaret Keegan and N Meehan
Local Authority Waters Programme, Ireland
A NEW COLLABORATIVE APPROACH TO DELIVERING WATER QUALITY IMPROVEMENTS IN IRELAND

Hendrik Venter
Analytical Research Laboratories,Napier
WHOLE FARM SOIL TESTING: SOIL FERTILITY TRENDS OVER TIME

Miles Grafton, T Kaul, A S Palmer and P A Bishop
School of Agriculture & Environment, Massey University
USING PROXIMAL HYPERSPECTRAL SENSING TO MEASURE SOIL OLSEN P AND pH

Jonas Rolighed, G J Heckrath, G.H Rubæk, E M P M van Boekel, P Groenendijk, O .F Schoumans and H .E Andersen
Department of Bioscience, Aarhus University, Denmark
IDENTIFYING PHOSPHORUS LEACHING SOILS USING A SIMPLE LANGMUIR-BASED MODEL

Ian Ferguson
Viable Agriculture Ltd, Ashburton
MEASUREMENT OF SOIL MOISTURE AND NUTRIENTS UNDER WINTER GREEN FEED CROPS IN A TYPICAL DAIRY SUPPORT OPERATION ON LISMORE SOIL

1445-1515 **Afternoon Tea**

Session 3 : Regional Policy Initiatives

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

1515-1530 **Shane Gilmer**
Hawkes Bay Regional Council, Napier
UPDATE ON POLICY ROLLOUT IN THE HAWKES BAY REGION

1530-1545 **Leo Fietje and J Chalmers**
Environment Canterbury, Christchurch
UPDATE ON POLICY ROLLOUT IN THE CANTERBURY REGION

1545-1600 **Kate Proctor**
Horizons Regional Council, Palmerston North
THE ONE PLAN – INTERIM FIXES AND LONG TERM SOLUTIONS

1600-1615 **Mark Gasquoine**
Waikato Regional Council, Hamilton
THE HEALTHY RIVERS CHALLENGE – 5,000 FARM PLANS IN EIGHT YEARS

1615-1630 **Graham Sevicke-Jones**
Environment Southland, Invercargill
POLICY ROLLOUT FOR SOUTHLAND – USING SYSTEMS APPROACHES

1630-1640 **Questions**

1640-1700 **Panel Discussion**

1700 **Day One concludes**

Wednesday 13th February

Session 4 : Reducing Agricultural Emissions

Chairman: **Professor Marta Camps-Arbestain**
NZ Biochar Research Centre, Massey University

0840-0850 **Joel Gibbs**
Ministry for Primary Industries, Wellington
FERTILISER EMISSIONS IN THE LIMELIGHT – ESTIMATING NATIONAL GREENHOUSE GAS EMISSIONS FROM FERTILISER AND LIME

0850-0900 **Jacqueline Rowarth and M Manning**
Agri-environment analyst, Tirau
NITROGEN AND CARBON INTERACTIONS

0900-0910 **Donna Giltrap, M Kirschbaum, J Laubach and J Hunt**
Manaaki Whenua – Landcare Research, Palmerston North
MODELLING THE IMPACTS OF IRRIGATION ON CARBON BALANCES IN A GRAZED DAIRY PASTURE

0910-0920 **Roberto Calvelo Pereira, M J Hedley, J Hanly, M Hedges, M Bretherton, M H Beare and S R McNally**
Fertilizer & Lime Research Centre, Massey University
FULL INVERSION TILLAGE PASTURE RENEWAL OFFERS GREENHOUSE GAS MITIGATION OPTIONS: THE MANAWATU EXPERIENCE

0920-0930 **Sam McNally, M H Beare, C Tregurtha, R Gillespie, E Lawrence-Smith, G Van der Klei, S Thomas, M J Hedley and R Calvelo Pereira**
Plant & Food Research, Christchurch
FULL INVERSION TILLAGE PASTURE RENEWAL OFFERS GREENHOUSE GAS MITIGATION OPTIONS: THE CANTERBURY EXPERIENCE

0930-0945 **Discussion**

0945-1000 **Poster Papers**

Marcela Gonzalez, R Singh, N Jha and A McMillan
Fertilizer & Lime Research Centre, Massey University
DENTRIFICATION IN SHALLOW GROUNDWATERS – AN ECOSYSTEM SERVICE OR A POLLUTION SWAP?

Kamal Prasad Adhikari, S Sagger, J A Hanly and D F Guinto
Fertilizer & Lime Research Centre, Massey University
EFFECTIVENESS AND LONGEVITY OF THE UREASE INHIBITORS 2-NPT AND nBTPT IN REDUCING NH_3 EMISSIONS FROM CATTLE URINE APPLIED TO PASTURE SOILS

Scott Post
Lincoln AgriTech, Canterbury
EFFECTIVE BOUT WIDTHS FOR UNIFORM SPREAD OF LIME FROM GROUND SPREADERS

Scott Post
Lincoln AgriTech, Canterbury
FLOWABILITY TESTING FOR AERIAL LIME

Georgia O'Brien, D Bloomer and P McVeagh
Page Bloomer Associates, Hastings
FERTILISER APPLICATOR CALIBRATION – WHAT PERFORMANCE METRIC SHOULD WE USE?

Stephen Trolove, S Wijeyekoon and Y Tan
Plant & Food Research, Havelock North
EFFECT OF TEMPERATURE ON THE RATE OF NITROGEN RELEASE FROM SMARTFERT®

Thomas Wilson and M C E Grafton
School of Agriculture & Environment, Massey University
DEMONSTRATING THE COMPATIBILITY OF A NEW SPREADMARK TEST WITH THE CURRENT METHOD

1000-1030 **Morning Tea**

Session 5 : Reducing Nutrient Loss to Water

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

1030-1040 **Jamie Thompson**
Ravensdown, Napier
CLEARTECH – A NEW TECHNOLOGY TO IMPROVE EFFLUENT MANAGEMENT

1040-1050 **Brian Ellwood, B Paton, H Lowe and S Cass**
Lowe Environmental Impact, Christchurch
INCORPORATING BIOSOLIDS AND WASTEWATER AS A SOIL AMENDMENT INTO NUTRIENT BUDGETS AND THE ASSOCIATED ENVIRONMENTAL MANAGEMENT CONSIDERATIONS

1050-1100 **Rachel Durie, K Woodford and G Trafford**
Lincoln University, Canterbury
MODELLING OF NITROGEN LEACHING WITHIN FARMING SYSTEMS THAT INCORPORATE A COMPOSTING BARN: A CASE STUDY OF THE LINCOLN UNIVERSITY DAIRY FARM

1100-1110 **Jacqueline Rowarth, A Roberts, A Metherell and M Manning**
Agri-environment analyst, Tirau
RIGHT P FERTILISER, RIGHT PLACE, RIGHT TIME

1110-1120 **Ian Williams, P Beukes and R Densley**
Genetic Technologies, Auckland
DEDICATED CROPPING BLOCKS WITHIN DAIRY FARMS: USING KNOWN MITIGATION STRATEGIES AT A FARM SYSTEMS LEVEL

1120-1130 **Peter Carey, B Malcolm and S Maley**
Lincoln Agritech, Christchurch
CATCH CROPS TO MITIGATE N LOSS AFTER WINTER FORAGE GRAZING: FROM PLOT TO PADDOCK

1130-1140 **Pip McVeagh, D Bloomer and G O'Brien**
Page Bloomer Associates, Hastings
OPPORTUNITIES TO REMOVE NITRATES FROM DRAINAGE WATER UNDER INTENSIVE VEGETABLE PRODUCTION

1140-1150 **Mark White**
Coastal Kiwis Orchard, Opotiki
GROWING KIWIFRUIT WITH AN ENVIRONMENTAL FOCUS

1150-1205 **Discussion**

1205-1230 **Poster Papers**

Nicole Wheadon
Ravensdown, Christchurch
EFFLUENT NUTRIENT MANAGEMENT – USING CLEARTECH TO REDUCE MODELLED NUTRIENT LOSSES AND ENVIRONMENTAL RISK

Anne-Maree Jolly
WSP Opus, Palmerston North
BORIS AND HIS FOUR FRIENDS ADVENTURE TO PINEDALE: MEASURING NUTRIENT LOSSES FROM DAIRY FACTORY WASTEWATER APPLICATION ON LAND

Vicki Burggraaf, G Rennie, P Edwards, I Pinxterhuis
AgResearch, Hamilton
MEETING NITROGEN DISCHARGE ALLOWANCES ON A ROTORUA DAIRY FARM – A CASE STUDY

Hannah Stalker, B Allen and J Morris
DairyNZ, Otago
CHOOSING TO SUCCEED: HOW FARM ENVIRONMENT PLANS CAN INCREASE GOOD MANAGEMENT PRACTICE IN OTAGO

T (Gere) Geretharan, P Jeyakumar, M Bretherton and C W N Anderson
Fertilizer & Lime Research Centre, Massey University
CONSEQUENCES OF FLUORINE (F) ACCUMULATION IN ALLOPHANIC SOIL

Nilusha Ubeynarayana, P Jeyakumar, P Bishop, R Calvelo Pereira and C W N Anderson
Fertilizer & Lime Research Centre, Massey University
INFLUENCE OF SOIL Cd LEVELS ON ROOT EXUDATE SECRETION IN CHICORY AND PLANTAIN

Abhiram Gunaratnam, M McCurdy, M Grafton, P Jeyakumar, P Bishop and C E Davies
School of Agriculture & Environment, Massey University
ASSESSMENT OF NITROGEN FERTILISERS UNDER CONTROLLED ENVIRONMENT – A LYSIMETER DESIGN

Jim Risk and A Dawson
Ballance Agri-Nutrients, Tauranga
COMPARING FINE PARTICLE AND GRANULAR NITROGEN RESPONSE ON SOUTHLAND PASTURES

Aimee Dawson, P Turner and D Gorrie
Ballance Agri-Nutrients, Tauranga
THE EFFECT OF CONTROLLED RELEASE NITROGEN FERTILISER ON PASTURE PRODUCTION ON TWO DAIRY FARMS IN WHATAROA, SOUTH WESTLAND

Bert Quin and G Rajendram
Quin Environmentals, Auckland
RPR REVISTED 6: SWITCHING TO REACTIVE PHOSPHATE ROCK (RPR) – BASED FERTILISERS REDUCES ALL FORMS OF DIFFUSE SOIL P LOSSES, NOT JUST DRP

Lamis Javid, C Bremner, S McNally, G D Lewis and L P Padhye
Department of Civil and Environmental Engineering, University of Auckland
ROLE OF BIOREMEDIATION IN NUTRIENT REMOVAL FROM RUNOFFS TREATED WITH LIGHT-WEIGHT MEDIA

Kien Tat Wai, C Bremner, S McNally and L Padhye
Department of Civil and Environmental Engineering, University of Auckland
ROLE OF PHYTOREMEDIATION IN NUTRIENT REMOVAL FROM RUNOFFS FOR LIGHT-WEIGHT MEDIA

Dilieka Weerakoon, Sumaraj, B Nanayakkara, N Wijeya, D Gapes and L P Padhye
Department of Civil and Environmental Engineering, University of Auckland
INORGANIC NITROGEN CONTAMINANT REMOVAL FROM RUNOFFS BY BIOMASS-DERIVED ADSORBENT

Jesus A Jimenez-Torres, C W N Anderson and P Jeyakumar
Fertilizer & Lime Research Centre, Massey University
THE EFFECT OF PHOSPHORUS IN GLYPHOSATE ADSORPTION-DESORPTION IN NEW ZEALAND SOILS

1230-1330 **Lunch**

Session 6 : Managing Critical Pathways

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

1330-1340 **Stephen Collins, R Singh, A Rivas, D Horne and P McGowan**
Fertilizer & Lime Research Centre, Massey University
SPATIAL AND TEMPORAL VARIABILITY OF GROUNDWATER CHEMISTRY AND REDOX CONDITIONS IN AN AGRICULTURAL LANDSCAPE

1340-1350 **Rebecca Eivers**
Streamlined Environmental, Hamilton
DESIGN CONSIDERATIONS FOR CONSTRUCTED TREATMENT WETLANDS TO MITIGATE NUTRIENT AND SEDIMENT RUNOFF FROM LOWLAND INTENSIVE AGRICULTURAL CATCHMENTS

1350-1400 **John-Paul Praat, J Sukias, A Wright-Stow, A Bichan and A Perrie**
Groundtruth Ltd, Te Awamutu
CHANGES IN WATER QUALITY THROUGH A CONSTRUCTED WETLAND ON A WAIRARAPA DAIRY FARM – MITIGATION IN ACTION

1400-1410 **Aldrin Rivas, G Barkle, B Moorhead, J Clague and R Stenger**
Lincoln AgriTech, Hamilton
NITRATE REMOVAL EFFICIENCY AND SECONDARY EFFECTS OF A WOODCHIP BIOREACTOR FOR THE TREATMENT OF AGRICULTURAL DRAINAGE

1410-1420 **Neale Hudson, E Baddock, L McKergow, S Heubeck, C Tanner, J Scandrett, D Burger, A Wright-Stow and C Depree**
NIWA, Hamilton
EFFICACY OF A NITRATE-N WOODCHIP FILTER: THREE YEARS OF FIELD TRIALS

1420-1430 **Brandon Goeller, C Tanner, J Sukias and R Craggs**
NIWA, Hamilton
IMPROVING EDGE-OF-FIELD NUTRIENT MITIGATION TOOLS TO ENHANCE CONTAMINANT ATTENUATION AND WATERWAY HEALTH

1430-1440 **Brian Levine, L Burkitt, C Tanner, L Condron and J Paterson**
School of Agriculture & Environment, Massey University
PHOSPHORUS MITIGATION PROJECT: QUANTIFYING THE ABILITY OF DETAINMENT BUNDS TO ATTENUATE PHOSPHORUS AND SEDIMENT LOADS IN SURFACE RUNOFF FROM GRAZED PASTURE IN THE LAKE ROTORUA CATCHMENT

1440-1455 **Discussion**

1455-1515 **Poster Papers**

Roland Stenger, A Rivas, S Wilson, M Friedel, G Barkle, J Clague, T Wöhling, B Moorhead, L Lilburne, A Eger, R McDowell, U Morgenstern, R Fuller, P Journeaux and I Kusabs
Lincoln AgriTech, Hamilton
CRITICAL PATHWAYS PROGRAMME: UNRAVELLING SUB-CATCHMENT SCALE NITROGEN DELIVERY TO WATERWAYS

Grace Chibuike, L Burkitt, M Camps-Arbestain, R Singh, M Bretherton and P Bishop
School of Agriculture & Environment, Massey University
NITRATE ATTENUATION CAPACITY OF A HILL COUNTRY SEEPAGE WETLAND AND ADJACENT DRY AREAS AS INFLUENCED BY THE CONCENTRATION AND CHEMISTRY OF DISSOLVED ORGANIC CARBON

John-Paul Praat, A Wright-Stow, L Brown and L Burkitt
Groundtruth Ltd, Te Awamutu
EFFECT OF RANK GRASS BUFFER WIDTHS FOR REDUCING CONTAMINANTS FROM DAIRY-FARM LANEWAYS

Mette Vodder Carstensen, S G W van Veen, D Zak and B Kronvang
Department of Bioscience, Aarhus University, Denmark
INTEGRATED BUFFER ZONES FOR AGRICULTURAL NITROGEN REMOVAL: A DANISH CASE STUDY

Dave Horne and R Singh
Fertilizer & Lime Research Centre, Massey University
INNOVATIVE DRAINAGE MANAGEMENT TECHNOLOGIES

Lee Burbery, R Mellis, P Abraham M Finnemore and M Close
Institute of Environmental Science and Research, Christchurch
TESTING WOODCHIP DENITRIFICATION WALL TECHNOLOGY IN A SHALLOW GRAVEL AQUIFER

Sian Cass and H Lowe
Lowe Environmental Impact, Palmerston North
NUTRIENT MANAGEMENT STRATEGIES – HOW CAN YOU GET BEST BANG FOR YOUR BUCKS

Phil McKenzie
Change for Good Consulting, Wellington
SUSTAINING POSITIVE PRACTICE CHANGE

1515-1545 **Afternoon Tea**

Session 7 : Developments with Overseer

1545-1700 *- At the request of Overseer Ltd*

Facilitator: **Dr Caroline Read**
OVERSEER Ltd, Wellington

Overseer Limited was established in 2016 to create a sustainable future for the now nationally significant nutrient budgeting tool OVERSEER. Following the successful session looking at functionality for the Science version of Overseer at the FLRC workshop in 2018, Overseer Ltd will facilitate a similar interactive afternoon session to cover the following topics:

1. Update on OverseerFM since release in June 18 and the release of the new Science product
2. Update on science modelling work underway and how to get involved
3. Presentation of the Overseer Development Roadmap

The session will progress with a rapid-fire highlight of the software updates over the past 8 months – specifically the inclusion of the GHG emissions reporting, trend analysis visualization and work on the scenario tool. Overseer Ltd will showcase the OverseerScience MVP (the research version workshopped last year) and how to get access to this service.

This will be followed by an update on the science modelling work that is currently underway, including the new approach being used to provide transparency and enable inclusive development. This will cover a range of pieces of work in various stages of development including:

1. Urease inhibitors
2. ME requirements modelling updates
3. Plantain and findings coming from the FRNL programme

The final part of the session will engage with participants on our current Development Roadmap, setting out our priority focus areas over three business horizons – core, emerging and next generation.

1700-1800 **Poster Papers on Display**
Informal Drinks in the Ag Hort Lecture Block

1815- **Workshop Dinner at Wharerata**

Thursday 14th February

Session 8 : Challenges for Irrigated Agriculture

Chairman: **Dr Jacqueline Rowarth**
Agri-environment analyst, Tirau

0845-0905 **Andrew Curtis** *Invited Speaker*
Water Strategies Ltd, Christchurch
IRRIGATION IN NEW ZEALAND – AN EVOLVING INDUSTRY

0905-0915 **John J Drewry, A K Manderson and C B Hedley**
Manaaki Whenua – Landcare Research, Palmerston North
EVALUATION OF IRRIGATION STRATEGIES FOR ARABLE FARMS TO MITIGATE NITROGEN LOSS USING THE OVERSEER MODEL

0915-0925 **John Bright**
Aqualinc Research Ltd, Christchurch
REDUCING NUTRIENT LOSSES THROUGH IMPROVING IRRIGATION EFFICIENCY

0925-0935 **M S Srinivasan, C Muller, T Carey-Smith, P Blackett, A Fear,T White, L Chan, S Fitzherbert, S Beechener, M Kinsman and G Elley**
NIWA, Christchurch
IRRIGATION INSIGHT – AN MBIE PROGRAMME THAT BLENDS CLIMATE, HYDROLOGY, ECONOMICS AND SOCIAL SCIENCE FOR IMPROVED WATER USE EFFICIENCY

0935-0945 **Jim Hargreaves**
WaterForce, Napier
SCADAfarm – USING THE CLOUD TO IMPROVE IRRIGATION MANAGEMENT ON NEW ZEALAND FARMS

0945-1000 **Discussion**

1000-1030 **Morning Tea**

Session 9 : Measurements and Tools

Chairman: **Dr Vera Power**
Fertiliser Association of NZ, Wellington

1030-1040 **Nathan Odgers, L Lilburne, J Guo, S Vickers, T Webb, S Carrick and J Barringer**
Manaaki Whenua – Landcare Research, Lincoln
METHODS FOR UPSCALING AND DOWNSCALING S-MAP INFORMATION: PROVISION OF SPATIAL SOIL INFORMATION IN VARIOUS FORMATS AND SCALES

1040-1050 **Ben Jolly, S Saggar, J Luo, G Bates, D Smith, P Bishop, P Berben and S Lindsey**
Manaaki Whenua – Landcare Research, Palmerston North
TECHNOLOGIES FOR MAPPING COW URINE PATCHES: A COMPARISON OF THERMAL IMAGERY, DRONE IMAGERY AND SOIL CONDUCTIVITY WITH SPIKEY-R

1050-1100 **Donna Giltrap, B Jolly, P Bishop, J Luo, G Bates, S Lindsey, P Berben, T Palmada and S Saggar**
Manaaki Whenua – Landcare Research, Palmerston North
IMPROVED MEASURING AND MODELLING OF THE 3D DISTRIBUTION OF URINE PATCHES IN GRAZED PASTURE SOILS

1100-1110 **John Paterson, T Stephens, S Bermeo, T Nolan, N Miedema and B Levine**
The Phosphorus Mitigation Project, Rotorua
PHOSPHORUS MITIGATION PROJECT: FARM BASED MANAGEMENT OF STORMWATER WITH DETAINMENT BUNDS FOR REDUCING PEAK FLOW AND IMPROVING WATER QUALITY

1110-1120 **Neale Hudson, E Baddock, L McKergow, J Sukias, S Heubeck, V Montemezzan and G Olsen**
NIWA Hamilton
APPLICATIONS OF CONTINUOUS NITRATE-N ANALYSERS IN NEW ZEALAND FOR IMPROVED NUTRIENT ESTIMATION

1120-1130 **Linh Hoang**
NIWA, Hamilton
ESTIMATING NUTRIENT LOSS FROM A DAIRY FARMING CATCHMENT USING THE SOIL AND WATER ASSESSMENT TOOL

1130-1140 **John-Paul Praat, P Handford and N Edgar**
Groundtruth Ltd, Te Awamutu
SMARTFARMS ENVIRONMENTAL MONITORING SYSTEM

1140-1200 **Discussion**

1200-1300 **Lunch**

Session 10 : Going Forward

Chairman: **Professor Chris Anderson**
Fertilizer & Lime Research Centre, Massey University

1300-1310 **Alec Mackay, F J F Maseyk and E J Dominati**
AgResearch, Palmerston North
WHOLE FARM PLANNING TO DELIVER INTEGRATED SOLUTIONS

1310-1320 **Richard Parkes, A Bradley and N Beeby**
Beef + Lamb New Zealand, Masterton
PROCESS NOT PRESCRIPTION: CATERING TO THE HETEROGENEITY OF THE NEW ZEALAND FARMING LANDSCAPE

1320-1330 **Terry Parminter, S Ridsdale and S Bryant**
KapAg Ltd, Kapiti
THE POSSIBLE IMPACT OF A PROPOSED NITROGEN CAP ON MILK PRODUCTION AND FINANCIAL VIABILITY OF DAIRY FARMS IN THE UPPER MANAWATU RIVER CATCHMENT OF THE TARARUA DISTRICT

1330-1340 **Simon Redmond**
Consultant, Palmerston North
HELPING FARMS COMPLY WITH ENVIRONMENTAL REGULATIONS: CASE STUDIES IN THE MANAWATU

1340-1350 **Simon Park, H Creagh and C Sutton**
Landconnect Ltd, Tauranga
TARAWERA FARM ENVIRONMENTAL PLANS – FARMERS BUILDING ON THE PAST, PREPARING FOR THE FUTURE

1350-1400 **Mike Freeman**
Landpro, Cromwell
HOW WE CAN ALL CONTRIBUTE TO RESOLVING NUTRIENT WATER QUALITY ISSUES AND SUSTAINABLE LAND USE

1400-1410 **Phil Journeaux**
AgFirst, Hamilton
THOUGHTS ON THE ALLOCATION OF NUTRIENTS: THE ISSUE WITH NATURAL CAPITAL ALLOCATION

1410-1420 **Gavin Marshall**
Fonterra Farm Source, Auckland
DEVELOPMENT OF A NITROGEN RISK SCORECARD

1420-1430 **Lania Holt, A Renwick, P Johnstone, R Dynes and W King**
Scion, Rotorua
THE CASE FOR A NOVEL AGROFORESTRY SYSTEM AND CROSS-SECTOR COLLABORATION

1430-1445 **Discussion**

1445-1500 **Closing Remarks**

1500 **Afternoon Tea and depart**

THE KEY WATER QUALITY ISSUES IN IRELAND
AND THE IRISH RIVER BASIN MANAGEMENT PLAN

Jenny Deakin

Catchments Unit, Environmental Protection Agency, Ireland

Ireland's water quality is comparatively good within the European Union, however there are significant water management issues: 43% of rivers, 54% of lakes, 69% of estuaries, 24% of coastal waters and 9% of groundwaters are not achieving their ecological water quality objectives, as set out in the EU Water Framework Directive (WFD). The key issue is eutrophication, driven by excess phosphorus in freshwaters and excess nitrogen in estuarine and marine waters. Changes to the physical habitat including excess sediment (hydromorphology) is the next biggest issue, but is less well understood. Agriculture is the most important significant pressure, followed by urban discharges, channel maintenance and other physical habitat changes, forestry, peat cutting and domestic waste water. Diffuse pollution is widespread and presents the greatest challenge.

Under the WFD, Ireland must develop river basin management plans to address these issues every 6 years. The first plan proved less effective than expected and resulted in no nett improvement in water quality, despite significant investment in agri-environmental schemes, on-farm storage and urban waste water treatment. Three key learnings from the first plan were used to shape a new approach for the second plan:

1. Inadequate governance structures resulted in no clear leadership or mechanisms for delivery
2. Multiple river basin districts led to disjointed and ineffective planning and implementation
3. Targets and objectives were too ambitious and were not founded on a solid evidence base.

Ireland's 2nd cycle river basin management plan was published in April 2018. Its key innovation is a change in philosophy to move away from dependence on the regulatory-based 'one size fits all' approach, towards being more collaborative, and identifying and implementing 'the right measure in the right place', whilst supporting local communities to get involved in protecting their water resources. Three new interlinked teams have been established to progress actions in 190 priority areas. They will investigate the issues at a local scale, collaborate with other public bodies and farmers to have specific measures implemented, and engage with the public and landholders. Further details are provided in the poster by Keegan and Meehan.

ENGAGING FARMERS IN ENVIRONMENTAL MANAGEMENT IN DENMARK

Flemming Gertz

Chief Consultant, SEGES, Denmark

From 1990 until today, the nitrogen load to Danish coastal waters has decreased from approx. 100,000 tonnes N to approx. 50,000 tonnes N. The decrease has mainly happened through national and general legislation including N-quotas on farm level, winter green fields, catch crops, timing of fertilization etc. The result of the “top-down” management tradition is a general lack of ownership from farmers to develop and implement new measures. A new program for more targeted measures including a 90 million NZD program for implementing constructed wetlands was decided by the Danish government in 2015. 900 ha of constructed wetland - approx. 1000-1500 pcs - are planned to be implemented over 3 years. To fulfill this decision a new national management concept – Catchment Officers - was implemented in 2017 to support a “bottom up” approach. This new concept has a potential for introducing a suite of new targeted drain filter solutions that each have different ecosystem services and suites different locations in the landscape.

It is crucial that the best measure is chosen for each different location, to optimise environmental impact and costs. This will only succeed with a “person on ground” with knowledge of the landscape, drains, a suite of measures and a direct and trustful relation to the landowner. The Catchment Officer plays an important role as “intermediary person” between landowner and other stakeholders and authorities, helping to find the win-win solutions and optimising communication between the different actors.

"DIGITAL AGRICULTURE" HELPING FARMERS REDUCE IMPACTS OF CROPPING ON THE GREAT BARRIER REEF

Peter Thorburn[1], Peter Fitch[2], YiFan Zhang[1], Yuri Shendryk[1], Tony Webster[3], Jody Biggs[1], Martijn Mooij[4], Cate Ticehurst[2], Maria Vilas[1] and Simon Fielke[5]

[1]CSIRO Agriculture and Food, Brisbane, [2]CSIRO Land and Water, Canberra
[3]CSIRO Agriculture and Food, Cairns, [4]CSIRO Data61, Brisbane
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Nitrogen (N) losses to the environment from intensive cropping in coastal catchments of north Queensland are a major threat to the health of Great Barrier Reef ecosystems. N losses are directly related to N fertiliser inputs to these crops, so there is considerable effort improving and extending best practices through traditional agronomic experiments and demonstrations. This paper describes a major program using "digital agriculture" approaches to create innovative solutions to the problems farmers face in optimising their N management. These solutions include:

- Providing farmers with real-time access to high-frequency water quality data gathered from sensors deployed in their catchments in both research projects and government monitoring programs to overcome farmers' scepticism that N in their catchments comes from their farms.
- Using artificial intelligence techniques to improve the quality of data streams coming from these sensors, by overcoming the inevitable loss and/or corruption of data from automated sensors.
- Giving farmers site- and time-specific decision support systems (DSS) to assess the effects of fertiliser types (e.g. EEF v conventional) and other management factors on the optimum rate of N fertiliser. The DSS outputs include predictions of N losses to the environment through different pathways arising from the different management decisions. This information will allow farmers to participate in emerging markets for abating both greenhouse gas (i.e. nitrous oxide emissions from soils) and N discharges from catchments.
- Devolving novel techniques for monitoring crop performance, from satellite- and drone-based sensors, to allow farmers to better evaluate the effects of N management. Persistent cloud cover in these catchments limits image acquisition from traditional satellites (e.g. LANDSAT) so this work focusses on more modern satellites and drone-based collection of multispectral and LiDAR images.

These innovations will have multiple outcomes: They will reduce barriers to farmers engaging in the water quality debate; provide farmers with higher quality information on the likely effects of novel management practices; allow them to potentially gain additional income streams from the pollution abatement arising from these practices; and, help them evaluate the outcomes of these practices early in the crop's life rather than at harvest (trough yield) which is the current standard.

LEAP – A GLOBAL TOOL TO SUPPORT NEW ZEALAND SUSTAINABILITY

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The United Nations Food and Agriculture Organization Livestock Environmental Assessment and Performance (LEAP) partnership's objective is to develop comprehensive guidance and methodology for understanding the environmental performance of livestock supply chains. The guidelines relate to, for example, small and large ruminant supply chains Guidelines, nutrient and environmental impacts, and measuring and modelling soil carbon. LEAP involves stakeholders from across the livestock sectors. In New Zealand, this includes scientists, companies, and the Ministry for Primary Industries. The goal of New Zealand's engagement is to increase NZ's environmental efficiency and provide our primary producers with verifiable information they can use in international markets.

Internationally, companies are increasingly seeking recognized, objective international guidelines to develop various environmental efficiency assessments for livestock supply chains. LEAP guidelines have been picked up by, for example, the European Commission's Product Environmental Footprinting work, and dairy companies, with further uptake by other international organisations likely in the near future. An explanation of LEAP, and its relevance to New Zealand, is provided to raise awareness, and increase New Zealand industry engagement in, and uptake of LEAP, including the road testing of guidelines, and improved understanding of LEAP to assess efficiency, for use in product marketing, trade and labelling.

WHAT ENVIRONMENT MANAGEMENT CHALLENGES ARE FACING NORTH ISLAND PASTORAL FARMERS?

Lee Matheson

Perrin Ag Consultants, Rotorua

The environmental management challenges facing pastoral farmers in the North Island are numerous and often complex. While diffuse nutrient loss to water is an issue many are familiar with, environmental challenges are not limited to N & P losses. Sediment loss, bacterial contamination, discharge to air of fertiliser and agrichemicals, contamination of soil by heavy metals and agrichemicals, effluent disposal, water use and the spectre of carbon losses are all having to be considered by many of our pastoral farmers. Animal welfare and managing inaccurate public perceptions might also be considered environmental challenges to modern farmer in a wider sense.

These issues, associated regulation and tighter supply requirements don't solely impact farm management and the physical farm system. They can also impact asset values and increase administrative pressure. This can be exacerbated by difficulty in accessing the necessary knowledge and support from competent rural professionals. Variation in the methods by which environmental externalities in different catchments or sectors need to be managed also provide a strong basis for confusion and frustration amongst farmers and service providers alike.

Unsurprisingly, the attitudes of farmers to address these new challenges and their capacity to adopt new practice varies considerably. This seems to be particularly so where adoption of best practice alone is insufficient to meet community expectations, the required rate or extent of change is significant and/or where [new] science or public perception is challenging long held beliefs or conventions. Variable leadership amongst sectors and industry has also, in my view, contributed to the extent of farmer action or inaction. The "move along - nothing to see here" mantra or "greenwash" of existing practice can send the wrong signal to both farmers and the community alike. Consequently, many of the positive actions and voluntary change by farmers have been ignored by or lost on the wider community, as has the magnitude of change and financial burden that will face numerous farming businesses.

The key to accelerating farmer engagement and practice adoption is lifting farmer knowledge, farmers acknowledging ownership of the issues, improved empathy by agencies and collaborative and positive engagement with their communities.

ENVIRONMENT MANAGEMENT CHALLENGES FACING SOUTH ISLAND FARMERS

Andy Macfarlane

Macfarlane Rural Business, Ashburton

I categorise the farmland from which we produce into classes by, firstly, slope (flat, or capable of cultivation or conservation tillage, or oversowable); secondly, soil moisture holding capacity; thirdly, rainfall and/or irrigation; and fourthly, drainage environment. We can then think about management challenges on the land from the perspective of first soil, second, water (and waste water if applicable); third, land cover and associated systems, fourth, animal and/or crop utilisation, fifth, biodiversity, and sixth, Greenhouse gases.

I note that it took modern man over 200 years to identify the problems associated with point source pollution, and while we have the solutions, they are yet to be fully implemented. We have really only identified diffuse pollution as an issue in the past 20 years, and my take on science, innovation and management skills, is that, with the exception of Greenhouse gases, we are well advanced towards solutions.

Much of the focus (research, innovation, and publicity, good & bad, centred in the South Island has been on east coast and central irrigation. Ironically, solutions are easier on much of that land, partly due to ability to control inputs and mitigations and partly to a relatively young infrastructure.

The three key challenges on relatively flat, potentially irrigated predominately low SMC soils are therefore nitrogen losses; biodiversity and greenhouse gases.

The two key issues for more intensively farmed, non flat South Island areas are first – sensitive recovery environments (groundwater, rivers, lakes) typically challenged by drainage systems and slope. The predominant issues in those environments will be phosphorus losses; sediment loss and greenhouse gas mitigation.

In "high country" environments with low stock intensity, variable rates of slope (flat to very steep), variable rainfall, and major challenges from introduced animal and plant species, the challenges are different again. I rate priorities as control of introduced pests (mammalian); control of introduced plants now wilding (pines, broom, rosehip, hieracium etc) and preventing soil erosion from soil exposed to wind blow.

The paper will discuss observations, progress on solutions from an on-farm perspective, and challenges to address.

ENVIRONMENTAL CHALLENGES FACING INTENSTIVE HORTICULTURE

Dan Bloomer, P McVeagh and G O'Brien

Page Bloomer Associates, Hastings

Intensive horticulture faces many environmental challenges including loss of nutrients and sediment from their systems. Vegetable and arable production systems "leak" and can have adverse impacts on water bodies. Public pressure for change has increased with growing awareness and regulators have moved to strengthen rules and requirements.

While the environmental impacts are apparent, understanding the contribution of intensive horticulture and knowledge of how to reduce losses while maintaining profitable food supply are limited. The consumer's quality demands and expectations of year round supply seem in conflict with recommendations to minimise losses through restricted nutrient use and avoidance of high risk sites and seasons. It is complicated: the environmental challenges facing intensive horticulture make a wicked problem.

The response of central and regional government to environmental stresses has been to increase regulation and set environmental limits that are generally output related. The reasoning for limits is understood but the limits are, in some cases, seen as impossible to achieve. At present the methodologies by which outputs (nutrient losses) from intensive horticulture are determined are expensive and questionable. It seems the cart may have got ahead of the horse.

The LandWISE "Future Proofing Vegetable Production" project is working with vegetable growers in Arawhata and Gisborne to reduce nitrate leaching and other nutrient losses in their catchment. The project focuses on four areas: precise prescription, precise application, management practices that maximise retention of nutrients and soil, and introducing ways to mitigate losses through downstream capture.

The project is working at catchment scale, with growers involved from the very beginning. We believe Elinor Ostom's concepts of Commons Pool Resources for how humans interact with ecosystems to maintain long-term sustainable resource yield may hold the key. We are not sure that wicked problems can be solved, but they can be tamed.

CURRENT AND FUTURE CHALLENGES IN LAND AND WATER SCIENCE

Rich McDowell

Our Land and Water National Science Challenge, AgResearch, Lincoln

The Our Land and Water National Science Challenge has been underway for 2.5 years. It is time to review what has been achieved and how we can drive towards a mission that sees our land and water resources and productive sectors improving. The Challenge has taken a strategic approach and focused on: 1) value chains that distribute to producers more of the value consumers pay for primary products, 2) use those value chains to reward sustainable practice that are better suited to what the land can produce and water can sustain, and 3) determine if collaborative practice can yield better, faster, more robust results than adversarial processes. Our data shows that certain 'sustainable' attributes do extract a premium, but that these attributes are somewhat bespoke to different markets and their understanding of NZ production systems. The value extracted could be used to drive sustainable practice, but schemes and the quality of the evidence that they are sustainable or rewarding producers, is nascent. We now have a better understanding of how farms sit within catchment systems, for example, *c*. 30-80% of nitrate produced can be removed via denitrification. We can use this knowledge in a system we have developed called – land use suitability to improve land and water resources and produce more. Finally, we also know that early evidence suggest that collaborative processes are no quicker, but those involved do have a greater sense of trust than adversarial processes.

The Challenge finishes in 2024. However, the current time taken for an idea to reach peak adoption is around 16.5 years. Science can play a key role in reducing this time and achieving our mission, but to do so the Challenge is testing a new way of working – co-innovation. Early metrics are encouraging, for example, collaboration inside the challenge is twice that in science programmes outside of the challenge. This new way of working has been combined with a subtle change in the Challenge towards focusing on future landscape according to land use suitability, incentivising change and testing our capacity for transition captured in a hypothesis which states that: when the incentives and pathways are compelling, the future contains the right enterprises, in the right place to deliver the right outcomes.

A NEW COLLABORATIVE APPROACH TO DELIVERING WATER QUALITY IMPROVEMENTS IN IRELAND

Margaret Keegan[1] and Noel Meehan[2]

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Ireland published its second Water Framework Directive River Basin Management Plan (RBMP) in 2018. The Plan outlined a collaborative, evidence-based blueprint to protect and improve the quality of our groundwaters, rivers, lakes, estuaries and coastal waters. New National, Regional and local structures have been established to ensure a coordinated approach to problem solving, policy development and on-the-ground delivery. Where national scale measures are insufficient to affect an improvement in water quality, supporting measures will be prioritised to ensure the implementation of the 'right measure in the right place'.

190 catchment areas have been prioritised for action in the RBMP, where evidence suggested that they could achieve their status objectives during this cycle or that they would facilitate the progression of pilots in sub-catchments with more complex issues requiring multidisciplinary and cross agency approaches.

In 2016, the ***Local Authority Waters Programme*** was established to support and coordinate the efforts of public bodies working in areas connected with water quality. The programme has two teams:

Communities Team: supports local water quality initiatives by communities and stakeholders. The Community Water Development Fund, administered under the Programme, incentivises community-led projects and initiatives to deliver water quality benefits.

Catchments Team: this interdisciplinary team of scientists (established in 2018) provides the evidence base to put the 'right measure in the right place'. This involves on the ground catchment assessments and collaboration with communities, landowners, and public bodies to develop and implement workable solutions.

The ***Agricultural Sustainability Support and Advisory Programme*** (ASSAP), was established to collaborate with the Catchments Team, where agriculture is a significant pressure. 30 ASSAP advisors (Teagasc & Dairy Co-op) will work with farmers on a voluntary basis to affect behavioural change, through improved knowledge transfer and advice. ASSAP is funded by two Government Departments and the dairy industry and it is expected that up to 5,000 farmers will receive support. 18,000 dairy farmers will receive advice on sustainable farming practices under the **Dairy Sustainability Ireland** Initiative. These new collaborations will all assist in achieving our water quality objectives.

WHOLE FARM SOIL TESTING:
SOIL FERTILITY TRENDS OVER TIME

Hendrik Venter

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Traditionally nutrient management was based upon soil test results obtained from monitor paddocks representative of different topographies, management and soil types. Greater environmental consciousness and economics contributed to the process of Whole Farm Soil Testing being established to improve nutrient monitoring and fertiliser application. Ravensdown has been offering this service since 2011, with the aim to reduce variability between paddocks and driving nutrient levels closer to optimum range limits. A random selection of test results for pH, Olsen P and MAF QT K from 160 properties spanning the period 2011 to 2017 were paired with year of first sampling resulting in more than 18,000 sample pairs (Year1:Year 2, ………, Year1: Year7). These sample pairs were separated into three scenarios based on whether the first year results were below, within or above the optimum level for the particular soil parameter. Mean values for consecutive years following first year of sampling showed that initial below optimum value paddocks trended higher, within optimum range paddocks remained within the optimum range and above optimum range paddocks trended lower. Encouraging from an environmental and economic perspective was the decreasing trend where initial values were above upper optimum range limits. It can be concluded that the practice of Whole Farm Soil Testing is a responsible approach to nutrient management with changes in mean parameter values ideally ascribed to improved nutrient management.

USING PROXIMAL HYPERSPECTRAL SENSING TO MEASURE SOIL OLSEN P AND pH

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This paper reports on work undertaken to use a large data set of hyperspectral data measured on dry soil samples to obtain regression analysis which allows predictions of pH and Olsen P to be obtained from an independent data set. The large data set was obtained from 3,190 soil samples taken from the Ravensdown Primary Growth Partnership to a depth of 7.5cm. The spectra were measured using an Analytical Spectral Device which recorded 2,150 wavebands of 1nm resolution between 350nm and 2,500nm. Values for Olsen P and pH were provided from chemical analysis by Analytical Research Laboratories. The spectra were regressed using "R" statistical software which has the power to handle the data and report the wavebands with the most significance for the model. The data set for the prediction came from a stratified nested grid soil sampling exercise which was used to find Olsen P stability at varying depths. This set had 400 samples from each of two data sets from different areas on Patitapu Station using a grid sample protocol. The 100 most significant wavebands from the PGP data set were used to regress the Patitapu data which were combined. These were regressed using "R" (Version 3.41, The R Foundation) and Statdata (Palisade, New York), which produced the same result. The partial least square regression of pH was very significant and was predicted well. Olsen P had a very significant correlation which was quite noisy, correlating the log10 of Olsen P was also undertaken and it would appear something is being measured that is associated with Olsen P. This work shows that it is possible to measure soil nutrient by proximal hyperspectral analysis which is transferable to an independent data set.

IDENTIFYING PHOSPHORUS LEACHING SOILS USING A SIMPLE LANGMUIR-BASED MODEL

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During the past century, phosphorus (P) in fertilizers has exceeded the output of P in agricultural products resulting in an accumulation of P in Danish agricultural soils. This is especially true on livestock farms due to the high P content in pig and cow slurry. Long-term accumulation of P may exceed the soils' phosphorus sorption capacity, causing P to leach through the soil matrix and increase the risk of P losses to surface waters.

In order to identify soils with a high risk of subsurface P leaching, we investigated whether the soil solution P concentration could be estimated by a simple model describing the kinetics of the reversible P sorption and desorption based on Langmuir adsorption theory, using water extractable P and soil P sorption properties as model input.

We selected 276 samples of top soil from the Danish national 7 km sampling grid in combination with 78 soil samples from the Danish Agricultural Monitoring program and another 27 samples from livestock farms scattered around Denmark.

All soil samples were analyzed for oxalate extractable phosphorus, iron and aluminum, as well as water extractable P. For a subset of samples, the phosphorus equilibrium concentration (ortho-P and total P) was determined in extractions with 0.01M $CaCl_2$ in a soil-to-solution ratio of 1:4 (w/v) in order to approximate phosphorus content in the soil solution.

Predicted concentrations were compared to observed equilibrium concentrations, concentrations in suction cups as well as in tile drains.

Combined with knowledge on local drainage and hydrological pathways, the model could help identify areas with particularly high risk of phosphorus leaching.

MEASUREMENT OF SOIL MOISTURE AND NUTRIENTS UNDER WINTER GREEN FEED CROPS IN A TYPICAL DAIRY SUPPORT OPERATION ON LISMORE SOIL

Ian Ferguson

Viable Agriculture Ltd, Ashburton

Basic understanding of fundamental nutrient dynamics in crops and soils is prudent in mitigating risk of nutrient losses. Lismore soil is typified by 60 % stones in the top 300 mm cultivated layer, another 300 mm B horizon of gravels in a silty matrix, and free running sandy shingle below. From S-Maps, plant available water is 75mm. These soil types have been referred to as “leaky Lismores” in terms of their nutrient holding ability and hence the need for strategic nutrient management is also closely allied to various perceptions of the mandatory obligations on growers to conform to the received environmental standards. Growers are also mindful of the economic imperative to maintain a financially viable farming business, whilst simultaneously improving yield and environmental compliance.

The ultimate measure of Nutrient Use Efficiency (NUE) and Water Use Efficiency (WUE) is yield, (as kg/ha of Dry Matter produced per mm of water and kg of nutrient applied), then to show increased NUE and WUE, yield must go up. As yield approaches the economic threshold, WUE and NUE will also be approaching optimum, i.e. yield will be nearing full potential at the point where NUE and WUE is also at, or very near to, the agronomic and economic optimum.

The perception that with increased yield comes increased nutrient loss and hence reduced water quality, is not a safe assumption as shown by the information gained in this investigation.

Soil tests from the site show that soil nutrients remaining after the second green feed crop (kale following beet); as well as the additional barn effluent applied; are retained within the root zone of the crop after successive drainage events; and are thus available to be utilised by current and subsequent crops. Actual measurement by electronic probes and accurate soil testing is able to affirm that appropriate nutrient management strategies can be successfully employed to mitigate risk of nutrient losses in such locally typical scenarios. This approach also has the added advantage of giving growers confidence to continue to improve the NUE & WUE along with the yield of the crops they grow, knowing that there is robust technology available to demonstrate that they can measure the NUE and WUE of the management system they choose to employ, and also provide objective proof of good practice and environmental stewardship.

UPDATE ON POLICY ROLLOUT IN THE HAWKES BAY REGION

Shane Gilmer

Hawkes Bay Regional Council, Napier

The Hawkes Bay region has one third generation catchment plan that was developed under NPSFM 2011/14. This plan covers the Tukituki catchment and the focus of this discussion.

The policy requires landowners (amoung other things) to meet LUC based leaching rates for nitrogen and to have Farm Environment Management Plans (FEMP's).

The implementation of this policy has revealed challenges in the interpretation of policy and a wide gap between policy expectations and capacity and capability of this council, rural professionals and farmers to respond.

Extensive promotion of the policy requirements for FEMP's occurred over several years with financial incentives, focus groups, heavy enagement with rural professionals and advertising through the catchment. In spite of this the vast majority of landowners failed to obtain a FEMP early and were channelled through a regulatory gate by signing up with approved FEMP providers at or about the deadline date. We will talk about the learnings from this and the signficant investment required if FEMP's become a regionwide or national requirement.

The learnings from this policy exercise have shaped the development of new policy processes, including the collaborative TANK (Tutaekuri, Ahuriri, Ngaruroro, Karamu catchments) to potentially avoid the problems we observed in the Tukituki. The potential solutions are not however without their own risks and challenges. Irrespective of the approach there is a significant gap in the capacity and capability of most parts of the system to respond. We will highlight these learnings.

UPDATE ON POLICY ROLLOUT IN THE CANTERBURY REGION

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[1]Principal Planning Advisor and [2]Senior Consents Planner
Environment Canterbury, Christchurch

Canterbury's Policy framework for dealing with diffusely-sourced nutrients is a two-staged approach – the first being a regional "hold the line", the second being a catchment-focussed community-driven approach looking at whether the regional approach needs fine-tuning to deal with specific challenges. The regional "hold the line" approach has been modified by Plan Change 5 which came into effect 1 February this year, addressing two key matters. Firstly moving away from reliance on fixed Overseer estimates as a threshold for requiring land use consent to farm and replacing these with narrative thresholds based on area in irrigation and area in winter grazing by cattle. Secondly adjusting the nitrogen limits to incorporate Good Management Practice, thereby creating a fairer and more level playing field.

In terms of the second stage, Council adopted recommendations presented by the OTOP (Otaio, Temuka, Opihi and Pareora) and Waimakariri Zone Committees late last year. These recommendations will now be converted into proposed Plan Changes and notified this year, adding to the four sub-regional chapters already in place – Selwyn; Hinds, South Canterbury Streams and Waitaki.

Having the above in place enables increased focus on implementation and ensuring expected outcomes are actually achieved – the community's desire for results is as strong as ever with high expectations these will be delivered and delivered soon. A key tool in achieving that is the audited Farm Environment Plan – with emphasis on the 'audit'. The Plan requires every Consent granted to be accompanied by a Farm Environment Plan requiring on-farm actions needed to achieve targets fixed in the Plan and these must be audited within 12 months of the consent being granted. Each audit results in a grade from A to D – A and B a 'pass', C and D a 'fail' – with timing of subsequent visits anywhere from 6 months to 3 years depending on grade.

Over 1,200 audits were completed last season with some very encouraging results, particularly when it's realised just how much effective and efficient systems contribute towards overall business success and bottom line.

Our presentation will provide examples of the above and highlight how we will incorporate new learnings into future Plan Changes.

THE ONE PLAN – INTERIM FIXES AND LONG TERM SOLUTIONS

Kate Proctor

Horizons Regional Council

The Manawatū-Whanganui regions guiding statutory document, the One Plan has received its fair share of media attention over the years. A pioneering attempt at integrated catchment management, it's now at the stage where parts of it need updating.

In the short term we know the nutrient management provision in the One Plan have an outdated Nitrogen leaching table. But even once updated, there are farms and horticultural operations that leach outside of this table. In the long term, what changes are needed to the plan to manage land use into the future?

Progress has been made over the past year into developing an updated nitrogen loss table, and assessing farm data against this. Work has also begun to look at what policy and objectives changes would be needed in the plan for those who leach outside the table.

Looking towards the future- 'Our Freshwater Future' is Council's non statutory catchment process, to inform future plan changes which will therefore implement the NPSFM. The Manawatū is the first of these catchments, and will be started early in 2019.

Plan reviews and changes take time, a lot of the ground work done over the past 12 months will support and inform some big decisions that need to be made in early 2019.

THE HEALTHY RIVERS CHALLENGE

– 5,000 FARM PLANS IN EIGHT YEARS

Mark Gasquoine

Waikato Regional Council, Hamilton

Proposed Plan Change 1 (PC1) – Waikato and Waipā River Catchments Plan Change 1 was developed in partnership with iwi as a co-management project, and alongside the community as a collaborative planning project establishing a 24 member Collaborative Stakeholder Group (CSG). The CSG settled on an 80-year timeframe to achieve the water quality objectives of the Vision and Strategy for the catchments under the co-governance arrangements.

This plan is the first of eight ten-year steps to improve water quality for four contaminants. This first step addresses diffuse discharges of nitrogen, phosphorus, sediment and bacteria and its objective is to achieve ten percent of the required change between current water quality and the long-term water quality targets. The key policies in PC1 are:

- All rural properties over 2ha must register with WRC and provide information on how the land is used.
- Most properties over 20ha must provide a Nitrogen reference point (NRP) detailing the nitrogen leaching from the property in 2014/15 or 2015/16 (whichever is higher).
- Land use change to higher intensity uses is a non –complying activity requiring a consent, and the applicant must show that the new use will have lower contaminant losses than the original use.
- Most farms over 20ha must have an approved FEP within a prioritised timeframe based on sub-catchment condition.

The numbers: The catchment is 1.1m ha 61% in pastoral farming (28% dairy, 33% sheep and beef) >670,000ha farmed, 31% in forest (15% forestry, 16% natives).

- 14,000 properties in catchment
- 10,000 must register
- ~ 5,000 farms requiring an FEP & NRP (roughly 50% dairy)
- 8 years to complete
- Requires an average of 300 non-dairy FEPs per year
- ~ 15 to 20 farmers per FEP workshop
- ~ 20 workshops per year
- = 300 to 400 FEPs per year

Farmer engagement is critical to achieve that. We expect that there will be relatively slow uptake at the beginning of each 3-year tranche, followed by a rush to complete as the deadline approaches. That will put pressure on farmers, and on WRC and our systems.

POLICY ROLLOUT FOR SOUTHLAND
– USING SYSTEMS APPROACHES

Graham Sevicke-Jones

Environment Southland, Invercargill

As Environment Southland nears completion of the first phase of regional plan development, with the Water and Land Plan about to have its appeals heard, the council has been working on the second integrated phase. The People, Water and Land Programme which is the Council's integrated approach to freshwater management in Southland that is designed to improve our land and water. The programme is a partnership between Environment Southland and TAMI., with a vision to "inspire change to improve Southland's water and land". It recognises that we will need to adapt our activities to reduce the adverse effects that land use practices have on the environment, and enabling our economy and society.

Taking this step is critical if Southland is to be more resilient and sustainable in the future. The Programme aims to enable Southlanders to improve their water and land through knowledge, decision-making and on-ground action. As a result there is a clear focus on supporting and enabling action on the ground (which has been referred to as implementation first) supported by the regulatory framework to set limits.

The programme consists of three main workstreams to ensure integrated management. The first is Action on the Ground, which is focused on catchment management activities that improve our land and water environment and help build resilient communities. The other workstreams are Values and Objectives and a Regional Forum, which are needed to implement the National Policy Statement for Freshwater Management (NPSFM) 2017. The Values and Objectives workstream precedes and will inform the Regional Forum workstream and the two workstreams will guide Action on the Ground. It is recognised that there are dependencies within each of the workstreams to ensure effective water and land management.

These workstreams work towards identifying and implementing regulatory and non-regulatory methods to achieve the community's values and objectives by 2021/22. A plan change will be required and notified in order to meet the NPSFM requirement of setting limits by 2025. This in effect is the second phase of the plan development where limits within a regulatory context are developed.

FERTILISER EMISSIONS IN THE LIMELIGHT
– ESTIMATING NATIONAL GREENHOUSE GAS EMISSIONS
FROM FERTILISER AND LIME

Joel Gibbs

Ministry for Primary Industries, Wellington

The application of nitrogen fertilisers, lime and dolomite lead to the production of greenhouse gases. In 2016 these sources were responsible for 2.7 million tonnes of carbon-dioxide equivalent emissions, or about 3.4% of New Zealand's gross GHG total. Fertilisers and lime have also been one of New Zealand's fastest growing emission sources (increasing by 300 per cent since 1990) mainly due to the increased use of nitrogen fertiliser over this period.

This paper will discuss how fertiliser emissions are currently estimated in the national greenhouse gas inventory and will include:

- A description of the different types of fertiliser which are included in New Zealand's emissions reporting, and the emissions generated per tonne of these different fertiliser types
- A summary of the New Zealand-specific research that is used to estimate emissions, and changes that have been made to the reporting methodology and emission factors in recent years
- An analysis of fertiliser emissions trends since 1990

The 2017 Agricultural Production Census included questions on the use of fertiliser, and the paper will conclude by going through a short summary of the Census data relating to fertiliser use.

NITROGEN AND CARBON INTERACTIONS

Jacqueline S Rowarth[1] and Mike Manning[2]

[1]*Agri-environment analyst, Tirau*
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This paper considers various landuse alternatives for New Zealand, comparing nitrogen use and greenhouse gas production. It discusses physical and chemical intervention, presents case study data from a high input dairy farm with maize block, and shows that removing ruminants from the food production equation is not the panacea imagined.

Concerns about water quality and climate change have resulted in regulations and initiatives at local and national level. These tend to focus on one or the other, overlooking the fact that nitrogen (N) and carbon (C) cycles are inextricably linked through photosynthesis and respiration.

Ruminants have been blamed for impacts on both, and horticulture and cropping have been promoted as being less environmentally damaging. However, nitrogen loss factors from horticulture and cropping have been estimated globally at 6.4 and 2.7 times that of improved pasture. In areas of relative heavy rain (New Zealand) N loss can be exacerbated, whether or not precision irrigation is the norm.

For greenhouse gases (GHG) a focus on biological emissions (methane and nitrous oxides) means that the long-term impact of carbon dioxide is omitted. Calculations of carbon dioxide equivalents (i.e., carbon dioxide, methane and nitrous oxide) per hectare for different land uses indicates that impact of some horticulture crops is greater than that of dairying (a factor of 1.5); cropping is generally considerably lower (a factor of 0.25).

Further suggestions of replacing dairy cows with drystock have been made. However, when the calculations are based on optimising grass growth and intake per hectare (for equivalence reasons), N loss is greater from drystock than dairying (and food production is decreased).

N loss from dairying can be further reduced by irrigation (overcoming a photosynthesis deficit and allowing ongoing N uptake into plants and then milk) and use of a low N feed supplement (allowing increased conversion of N in grass to milk by matching carbon requirements); both irrigation and supplement will increase methane marginally because of increased feed intake by the animal.

Any land-use change requires analysis of many aspects, not just those receiving media coverage.

MODELLING THE IMPACTS OF IRRIGATION ON CARBON BALANCES IN A GRAZED DAIRY PASTURE

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In New Zealand, increasing areas of dryland farming are being converted to irrigated farming. There are conflicting findings whether this will lead to gains or losses of soil organic carbon (SOC). In this study, we used 2 years of eddy-covariance data from an irrigated, grazed dairy pasture in Canterbury and compared observed gas exchange fluxes with those from the process-based CenW model.

We found that gross primary production (GPP) was substantially reduced after grazing, with rates ~30 kgC ha^{-1} d^{-1} lower than the expected reduction due to leaf area loss alone. GPP then gradually recovered over the subsequent 2 weeks. We therefore added an empirical modification to CenW for this post-grazing GPP reduction.

Simulations of the modified model agreed very well with observations for evapotranspiration, GPP, and ecosystem respiration rates with model efficiencies ~0.8–0.9 for daily and weekly mean values. Model efficiency for net ecosystem productivity was ~0.7–0.8 for daily and weekly averages.

CenW was then used to compare SOC levels after 50 years of irrigated dairy farming with non-irrigated systems. However, one cannot assess the effect of irrigation in isolation. Changes in water availability are inevitably accompanied by changes in fertiliser use and grazing regimes. We dealt with changing nutrient needs and feed availability by using automated routines to apply fertiliser and initiate grazing. Conditions to initiate grazing were set to values that were typical of either cattle grazing or sheep grazing. We then ran three scenarios: cattle-grazed systems with and without irrigation, and sheep-grazing without irrigation.

After 50 years, the irrigated-cattle system only had 4 ± 3 tC ha^{-1} (mean ± se) more SOC than the unirrigated cattle system. However, under these scenario conditions, the unirrigated system had unrealistically low production (<0.1 tC ha^{-1} y^{-1} in animal products). When we instead compared unirrigated sheep-grazed systems with irrigated cattle-grazed systems, SOC was 13.9 ± 1.5 tC ha^{-1} lower under the unirrigated than under the irrigated system. The mean C removed in animal products was 0.67 ± 0.02, 0.06 ± 0.02, and 0.32 ± 0.04 tC $ha^{-1}y^{-1}$ for the irrigated cattle, unirrigated cattle, and unirrigated sheep-grazed systems, respectively.

FULL INVERSION TILLAGE PASTURE RENEWAL OFFERS GREENHOUSE GAS MITIGATION OPTIONS: THE MANAWATU EXPERIENCE

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Increasing soil organic carbon (SOC) stocks has been proposed as one strategy to reduce global atmospheric CO_2 concentrations and slow climate warming. New Zealand's grazed pastures accumulate large amounts of SOC because grasses allocate a high proportion of photosynthate C to root turnover and rhizodeposition. Near-surface rhizodeposition causes the topsoil layers (0 - 10 cm) to become saturated in SOC, whilst C stocks are often 2 - 4-fold lower in the sparsely rooted, deeper layers (15 - 30 cm). This vertical stratification of roots and SOC limits the topsoil's capacity to sequester more carbon.

Full inversion tillage at pasture renewal (FIT-renewal) has been proposed as a technique to accelerate SOC storage in pastoral soils showing strong stratification. Using a modified mouldboard plough, full soil inversion (i) transfers carbon-rich topsoil into the subsoil (potentially slowing its decomposition), and (ii) exposes the inverted, carbon unsaturated, subsoil to higher C inputs from the new pasture.

During 2016 - 2018, two trials were established on a Pallic soil in the Manawatu at Massey University to assess the effects of FIT on SOC stocks, crop and pasture yields, nitrous oxide emissions, and N leaching. In trial 1, FIT-renewal involved full cultivation of a summer brassica crop followed by autumn re-grassing; in trial 2, full cultivation occurred at autumn re-grassing. Other treatments included pasture renewal by no-till (trials 1 and 2) and shallow till (trial 1), and continuous pasture (trial 2). Plant growth, herbage quality, and nutrient leaching were monitored at both trial sites. Changes in nitrous oxide emissions during pasture renewal and grazing were evaluated for trial 2 only. These field trials complement a similar field trial established in the Canterbury region (McNally et al., oral presentation).

The modified plough successfully transferred SOC below 10 cm depth. In the crop rotation (trial 1), losses of mineral nitrogen during the crop and pasture cycle were lower under FIT, and crop yield increased. In trial 2, FIT reduced the peak emission of nitrous oxide after urine addition. FIT-renewal shows potential to maintain crop and pasture yields whilst reducing net greenhouse gas emissions from grazed pastures.

FULL INVERSION TILLAGE PASTURE RENEWAL OFFERS GREENHOUSE GAS MITIGATION OPTIONS: THE CANTERBURY EXPERIENCE

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Soil organic carbon (SOC) sequestration has been proposed as one method to reduce atmospheric CO_2 concentrations and in turn help offset agricultural greenhouse gas emissions. In New Zealand grasslands, SOC is typically concentrated at the surface and declines rapidly with depth (i.e. stratified). The use of full inversion tillage (FIT) during a pasture renewal (FIT-renewal) event provides an opportunity to redistribute and potentially increase the SOC stock. A field trial was established on an imperfectly drained Pallic soil near Lincoln, Canterbury to assess the effects of FIT-renewal on the SOC stock, dry matter production, nitrogen losses and agronomic costs. This field trial complements similar field trials established in the Manawatu region (See Calvelo Pereira et al., oral presentation).

The trial at Lincoln 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 included plots sown to a mix of forage oats and Italian ryegrass following either FIT or NT. All treatments were established in March 2018. FIT resulted in a redistribution of the SOC in the top 30 cm of soil but did not change the total C stock immediately after cultivation. FIT deposited C rich topsoil below 10 cm and brought low C subsoil to the surface providing an opportunity to increase C stocks at the surface. Establishment of ryegrass-clover pasture in the FIT plots was slower than for the NT and ST treatments but the green chop oats/Italian ryegrass crop produced more dry matter following FIT compared to NT. The accumulation of mineral N following FIT-renewal appeared to increase the risk of NO_3^- leaching losses in winter, but resulted in lower emission of N_2O from urine applied to ryegrass/clover pasture. Greater uptake of mineral N by the green chop oats/Italian ryegrass reduced the risk for nitrogen losses over the winter/spring period. Preliminary results suggests that any additional agronomic costs (e.g. tillage, fertiliser) associated with FIT is more than offset by the increase in dry matter production.

DENTRIFICATION IN SHALLOW GROUNDWATERS
– AN ECOSYSTEM SERVICE OR A POLLUTION SWAP?

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Denitrification in groundwaters has been identified as a key attenuation process, where leached NO_3^- can be reduced to dinitrogen (N_2 — a harmless gas), offering an ecosystem service in terms of water quality protection. However, a partial denitrification can release nitrous oxide (N_2O — a greenhouse gas), resulting into a pollution swap protecting water quality but adding to global warming potential. There is very limited information available about occurrence, characteristics and dynamics of subsurface denitrification in shallow groundwaters across New Zealand agricultural catchments.

We studied 6 pastoral farms located in various hydrogeological settings in the Manawatu and Rangitikei Rivers catchments, in the lower North Island of New Zealand. We collected a set of monthly groundwater observations over a period of 7 months from March to September, 2018. The collected groundwater samples were analysed for the groundwater redox parameters, including dissolved oxygen (DO), oxidation-reduction potential, pH, NO_3^-, iron, manganese and sulphate. We also conducted a set of push-and-pull tests to gain insights into dynamics of subsurface denitrification occurring in the groundwater samples at the study sites. We measured changes in NO_3^-, dissolved N_2O, dissolved N_2, and excess N_2 during the push-and-pull tests.

Our results suggested a spatially variable groundwater redox conditions and subsurface denitrification occurring across the study sites. The dominant terminal product of subsurface denitrification (whether it was N_2O or N_2) also spatially varied according to the redox status of the groundwater. We observed an increase in excess N_2 concentrations under the anoxic groundwater conditions during the push and pull test. While under oxic groundwater conditions, dissolved N_2O appeared to be the dominant product.

Our observations highlight the influence of different hydrogeological settings on spatial variability of partial or complete (benign) denitrification in shallow groundwaters. A better understanding and quantification of spatial and temporal variability of subsurface denitrification process will help inform, design and formulation of targeted and effective management measures for sustainable agricultural production while protecting soil, water and air quality.

EFFECTIVENESS AND LONGEVITY OF THE UREASE INHIBITORS 2-NPT AND NBTPT IN REDUCING NH_3 EMISSIONS FROM CATTLE URINE APPLIED TO PASTURE SOILS

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In New Zealand, animal urine deposited on pasture soils during livestock grazing is the primary source of ammonia (NH_3) emissions resulting in both economic and environmental losses. The more commonly used short-lived inhibitor N-(n-butyl) thiophosphoric triamide (nBTPT) will potentially reduce these emissions from only a single grazing event, and hence a longer lasting inhibitor is needed.

Our previous laboratory study showed that the urease inhibitor N-(2-Nitrophenyl) phosphoric triamide (2-NPT) exhibited greater longevity compared to nBTPT. Here, we extend this evaluation of the effectiveness and longevity of 2-NPT and nBTPT under field conditions and report the results of two field experiments conducted in 'summer' and 'autumn' on a pasture site at Massey University's No. 1 Dairy Farm, Palmerston North. In the summer experiment, the inhibitors nBTPT and 2-NPT were applied at the start of the experiment and urine was applied at 3 stages; (A) 3 hours before, (B) 28 days after, and (C) 68 days after inhibitor application. In the autumn experiment, urine was only applied either 3 hours before or at the time of inhibitor application. In the summer experiment, only 2-NPT significantly reduced total NH_3 emissions and only when urine was applied at stage (B).

In the autumn experiment, both of the inhibitors significantly reduced total NH_3 emissions when urine was applied either 3 hours before or at the time of inhibitor application, however, the effectiveness was greater when urine was applied 3 hrs before the inhibitors. The reduction in emissions was greater with 2-NPT compared to nBTPT when urine was applied at the same time as the inhibitors.

These results complement the findings of laboratory studies showing greater longevity and effectiveness of 2 NPT at reducing NH_3 emissions compared to nBTPT.

EFFECTIVE BOUT WIDTHS FOR UNIFORM SPREAD OF LIME FROM GROUND SPREADERS

Scott Post

Lincoln AgriTech, Canterbury

There is a strong correlation between crop yields and evenness of application of lime. Lime is the most widely used fertiliser/soil conditioner product in New Zealand, but it is not very mobile in the soil, so it is important to achieve uniform application of lime. Lime is a very challenging material to spread, due to its fine particle size and its non-uniform size distribution, resulting in poor ballistic properties. Further, lime also has adhesive properties that cause it to come off the conveyer belt in discrete chunks or cakes rather than as a smooth continuous granular flow.

Field testing was conducted to measure the uniformity of lime spreading over a range of application rates relevant to variable-rate application. Five different trucks were tested over application rates from 500 to 5000 kg/ha, and also at different driving speeds. Spread patterns were measured across three tray lines for each test condition, and coefficients of variation (CV) calculated as a function of bout width for each line. Measurements were also made of the particle size distribution for the lime used, and videos were taken of the lime motion in the vicinity of the spreader disks.

The results of the field trials show that on average a bout width of 10 m was obtained at a coefficient of variation (CV) of 25%, and a bout width of 5 m at a CV of 10%. There was variation of lime in the longitudinal as well as the transverse direction, with a CV of 22% averaged across all trucks in the direction of truck travel. This variation is caused by the caking of the lime as it comes off the belt, which can be observed both directly and indirectly in the videos taken by the truck-mounted camera.

FLOWABILITY TESTING FOR AERIAL LIME

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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.

For granulated materials that are nearly uniform in size and of spherical shape, this requirement is not a problem, as such materials have good flowability. Agricultural lime however, is typically a fine powder which can have poor flowability, particularly when wet.

Two different devices were tested for their ability to assess lime flowability. Lime from six different sources was evaluated. The lime was dried in an oven, and then water added in discrete amounts, so that the flowability of the lime samples could be assessed at moisture levels from 0 to 5% by mass. Tapping and compressing the lime before testing was used to simulate conditions at the bottom of an aircraft hopper. The dried lime samples were also used for measuring the particle size distribution using an Endecotts sieve shaker. From the sieving data, the only particle size distribution parameter that correlated strongly with flowability test results was the Uniformity Index, a measure of the standard deviation of the size distribution.

FERTILISER APPLICATOR CALIBRATION
– WHAT PERFORMANCE METRIC SHOULD WE USE?

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As part of the Sustainable Farming Fund project, "Future Proofing Vegetable Production", we assessed the performance of fertiliser application equipment used in vegetable growing operations in Gisborne and Levin. Direct placement of fertiliser (either by planters, side-dressers or from modified tail-wag spreaders) is much more common than broadcast application in these growing systems.

To collect and process data from a variety of different spreaders, we propose a set of data collection protocols and analyses. A spreadsheet calculator created to process data and prepare reports for growers evolved as we gained experience with equipment and through our engagement with growers. We want assessment to be valid and reporting to be meaningful.

We now have a Placement-Applicator Calibration Calculator that determines the rate of fertiliser being applied, the evenness of application across different outlets and consistency between tests.
The application variability of the spreaders we tested has varied quite markedly from 0.4% CV to 16% CV. These are both within the SpreadMark accepted performance for broadcast spreaders applying nitrogen based fertilisers.

With the knowledge that direct placement can be much more accurate than broadcast spreaders, what performance metrics are appropriate?

EFFECT OF TEMPERATURE ON THE RATE OF NITROGEN RELEASE FROM SMARTFERT®

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Large applications of highly soluble nitrogen (N) fertilisers to crops can increase the risk of nitrate (NO_3) leaching, which results in the pollution of waterways. The use of slow or controlled release N fertilisers may better match crop demands for N and reduce these risks. However, one of the reasons why growers are reluctant to use slow release fertilisers is that the timing of release from slow release fertilisers has often been difficult to predict. Smartfert® is a controlled release fertiliser where it is claimed that the release of N is governed solely by temperature, although no data was provided on the website to state the rate of N release. This paper describes a soil incubation trial and pot trial to determine the rate of N release from Smartfert®.

Four fertiliser treatments: Smartfert®, two experimental N fertilisers and urea were applied to a low-N soil at 75 kgN/ha. There was also an unfertilised control. These were incubated at three temperatures: 10, 20 and 25°C, at 80% of field capacity for 105 days. Soil mineral N concentrations were measured at regular intervals. A pot trial was conducted using ryegrass grown on the same soil, fertilised with Smartfert®, an experimental N fertiliser and an unfertilised control. The pot trial was conducted using the same soil and fertiliser rate as the incubation study. There were three harvests at 31, 61 and 91 days after fertiliser addition.

The rate of release of N from Smartfert® (measured as mineral N in the soil) was 4% of Smartfert® N every 100 degree days for the first 1600 degree days. After 1600 degree days the incubation trial showed a slowing in N release rate. There was good agreement between the N release rate measured in the incubation trial and in the ryegrass pot trial, except that the slowing in N release observed in the incubation trial was not observed in the ryegrass pot trial.

DEMONSTRATING THE COMPATIBILITY OF A NEW SPREADMARK TEST WITH THE CURRENT METHOD

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The New Zealand Spreadmark test which although proven to accurately measure the Coefficient of Variation (CV) of spreading equipment, entails a laborious procedure which is expensive to implement. This study aims to validate the accuracy of a newly developed test method based on the current one which hastens the process, making it increasingly cost effective. The proposed solution reduces the amount of trays used to collect and measure the fertiliser spread pattern.

The proposed method reduces the number of trays by half, placing them one meter apart compared to the current industry standard of half a meter. An electronic tray weighing system developed by EuroAgri streamlines the process by removing the need to empty trays after each pass as the weigh cell can be zeroed after weights are recorded. Collated data of previous Spreadmark tests sourced from certified Spreadmark testers with the support of the Fertiliser Quality Council which manages the scheme was used in the study.

Tray weights of each successive 0.5 and 1.0 meters were averaged to imitate tray spacings of 1.0 meter. The 1.0 meter tray spacing showed a strong correlation to the 0.5 meter spacings, maintaining the normal distribution pattern of the spread fertilizer albeit in a slightly lower definition. Coupled with the electronic scales which reduces human error, this forms an accurate and efficient method of undertaking testing. This new system could have marked effects upon the future of spreader testing in New Zealand, including higher proportions of conforming spreaders (due to increased time and cost effectiveness) leading to lower field CV's. As a result, fertiliser efficacy would increase as would financial returns.

CLEARTECH

– A NEW TECHNOLOGY TO IMPROVE EFFLUENT MANAGEMENT

Jamie Thompson

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ClearTech represents a new method of treating farm dairy effluent (FDE) by removing the solid material and producing clarified water that can be recycled to wash the farm yard.

With FDE consisting mainly of fresh water (99%) and a small amount of solid material (1%), the method uses a coagulant to flocculate and settle the colloidal particles in the FDE.

The settled colloidal particles (treated effluent) typically represent one third of the total FDE and clarified water two thirds. The clarified water can be recycled to wash the yard and therefore there is less effluent going to the pond.

The resulting reduction (up to two thirds) in volume of FDE entering the storage pond increases the number of days of pond storage capability and enables greater opportunities for deferred applications of FDE to land, reducing the necessity to irrigate in periods with higher risk of nutrient loss (Autumn and Spring).

Treatment of FDE in trials shows ClearTech significantly reduces the average turbidity of the clarified water by 99%. *E.coli* concentrations are reduced by 99.98% meaning the resulting recycled yard wash water is much safer for farm staff to use than current practices of using green water.

This new method of treating farm dairy effluent has been successful in producing clarified water that can be recycled to wash the farm yard and save over 14,000 L per day on a typical NZ dairy farm. If adopted by all 10,500 dairy farms in NZ this new treatment system could save approximately 41 billion litres of water per year. In addition, land application of clarified water and/or treated effluent would reduce the current risks of water pollution posed by land application of untreated FDE and that this can be achieved without compromising plant growth.

INCORPORATING BIOSOLIDS AND WASTEWATER AS A SOIL AMENDMENT INTO NUTRIENT BUDGETS AND THE ASSOCIATED ENVIRONMENTAL MANAGEMENT CONSIDERATIONS

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This presentation will discuss the use and management of biosolids and wastewater as a fertilizer/soil amendment. Farmers may have the opportunity to use biosolids or wastewater as a fertilizer substitute, adding nutrients onto their land. However, there are a number of management considerations that are different to conventional fertilizer. Due to the complex nature of biosolids and wastewater, with nutrients being bound within the material, only a percentage of the nutrients may be initially available for plant uptake or to be potentially leached. Nutrient release requires mineralisation for the nutrients before they become soluble and mobile.

A conservative approach to application is often taken in regional plans, using loading rates based on total nitrogen content vs nitrate and ammonium. This approach may limit the total amount that can be applied (e.g. 150 or 200 kg/ha). Further complexity and misunderstanding can occur if the nitrogen loading rate is thought of as an equivalent of urea fertilizer, were farmers may not see the plant responses that they were hoping for. Communication of fertilizer form and benefits to farmers needs to factor in the expected plant availability of the nutrients. Only with time will a high percentage of the nutrients will be released, which has implications for both nutrient budgeting, environmental management and nitrogen leaching mitigation regimes to limit overall N losses. An additional consideration when using Overseer to assess the leaching potential is the cumulative impact of mineralisation beyond the application month and reporting year. The nutrient modeller may have to provide a fertiliser input equivalent for the historic applications and expected mineralisation. Examples from various projects around NZ will be presented.

MODELLING OF NITROGEN LEACHING WITHIN FARMING SYSTEMS THAT INCORPORATE A COMPOSTING BARN: A CASE STUDY OF THE LINCOLN UNIVERSITY DAIRY FARM

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We present Overseer modelling data for the Lincoln University Dairy farm (160 ha milking platform, comprising Templeton, Paparua, Wakanui, Temuka and Eyre soils) assuming a composting barn and duration-controlled grazing systems (six hours grazing April and September, four hours May to August, 12 hours October to March), compared to the current 100 percent paddock-based system but with cows wintered off-platform (eight weeks). Cow numbers were 558 for both systems but with higher liveweights (500 cf. 480 kg), higher days in milk (305 cf. 264) and higher per cow milksolids production (585 cf. 485 kg) for the composting system. For the composting system, 24 ha of maize silage and 12 ha of fodder beet were grown, with a winter green-crop grown between maize and fodder beet. In line with industry experience, all liquid effluent was assumed to evaporate off and solid nutrients were returned to the farm as compost.

Urine-related N leaching decreased from 42 kg/ha for the current system to 3 kg/ha under duration-controlled grazing. However, 'other' sources of N leaching increased from 5 to 29 kg/ha. These other losses were primarily from maize silage (96 kg per crop hectare) and fodder beet (150 kg per crop hectare) and the associated loss of organic soil-pool N from mineralisation. Accordingly, overall N leaching declined from 47 kg/ha to 32 kg/ha. It should be noted that the current figures do not include losses occurring off-platform during winter whereas for the composting system the measures are for all 12 months.

Overseer estimates for urinary-N leaching from pasture are supported by published science of duration-controlled grazing during late autumn and winter. However, the validation of the cropping sub-models is less developed. Nevertheless, the results highlight the importance of further investigations of winter-feed systems that minimise N losses including from soil mineralisation.

Benefits of duration-controlled grazing are not specific to composting-barn systems. However, composting barns provide internationally proven cow-friendly housing without the fit-out costs of free-stall barns, combined with simpler and lower-cost effluent systems than for free-stall systems. Results reported here are part of a larger systems study to be reported elsewhere.

RIGHT P FERTILISER, RIGHT PLACE, RIGHT TIME

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This paper reviews reactive phosphate rock (RPR) research, past and present, to remind people what has and hasn't been researched. It identifies where RPR and superphosphate can be of value in improving phosphate uptake efficiency, and how RPR and superphosphate can be managed to assist in mitigating against nutrient loss. Economic considerations in P fertiliser choice are also presented.

Based on the edaphic parameters, identified in pasture trials, of soil pH<6.0 and mean annual rainfall >800 mm, the potentially suitable area of New Zealand for RPRs was estimated at 8 million hectares. However, slow release of P from RPR, which can be of benefit in maintenance situations, renders it less suitable for properties where development of soil P status is required. Although speed of dissolution can be improved by grinding to reduce particle size, difficulties in spreading are increased, as is the cost. The latter continues to be a factor in choice of P source, particularly if sulphur (S) is required, as it must be added to RPR.

The economic calculations associated with P source choice are complicated by the difference in S form and the availability of P and S within the budget year: purchasing RPR in one year when only some of the P applied will be available in that year 'frontloads' the expenditure.

Environmental impact calculations are also complex. The use of RPR has been shown to result in reduced P loss to waterways in some situations in comparison with superphosphate. However, following best practice for superphosphate application (e.g., avoiding application when heavy rain is forecast and tailoring applications to meet plant P uptake requirements) results in minimal losses.

Further reduction in P loss, which can occur through sediment and dung movement to surface water, might require a change in farm system; the changes will depend on individual farm physical, climatic and management factors whatever the source of P applied.

Best practice means checking the research and considering all aspects of the choices – production, protection and economics.

DEDICATED CROPPING BLOCKS WITHIN DAIRY FARMS: USING KNOWN MITIGATION STRATEGIES AT A FARM SYSTEMS LEVEL

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With increasing pressure coming on dairy farmers to reduce the impact of dairying on the environment, there has been a number of trials completed looking at various mitigation strategies at a farm systems level (Pastoral 21). These mitigation strategies included feeding low protein feed to reduce Urinary Nitrogen (UN) output, reducing the amount of fertilizer N applied to pasture, standing animals off pasture during periods of high leaching risk, reducing stocking rate and increasing per cow output, applying effluent over a large proportion of the farm and more recently, the feeding of plantain. There have also been a number of studies looking at reducing losses from cropping blocks completed under the Forages for Reduced Nitrates program but these have mainly concentrated on grazed forages as opposed to stored forages.

One strategy that hasn't been modelled is the use of a long term, dedicated cropping block within the dairy farm to grow a high yielding, low protein silage in summer (e.g. maize silage), using stored effluent as the fertilizer source, followed by an annual ryegrass catch crop over winter. The maize silage feed is then fed back to the cows on a feeding area during times when excess pasture protein increases UN losses and therefore increases the risk of N being leached.

A simulation study using DairyNZ's Whole Farm Model over the 2017/18 season compared a typical Waikato dairy farm (3.2 cows/ha, 125 kg N/ha on pasture, grass silage to fill feed gaps) with a potential future farm (3.2 cows/ha, feed pad, dedicated cropping block comprising 15% of the farm, growing maize silage in summer and annual ryegrass in winter, 85 kgN/ha on pasture). The model compared differences in N loss over the whole farm and potential impacts. Results showed a potential 42% reduction in N loss compared to the base farm (32 kgs N/ha vs 59 kgsN/ha), with an increase in milksolids/ha (1478kgMS/ha vs 1267kgMS/ha) resulting in increased efficiency in N use (43.5kgsMS/kgN leached vs 21.5kgMS/kgN leached). No economic analysis of either system was conducted.

CATCH CROPS TO MITIGATE N LOSS AFTER WINTER FORAGE GRAZING: FROM PLOT TO PADDOCK

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Recent research has shown sowing a catch crop can reduce nitrate leaching and denitrification loss after simulated winter forage grazing. However, most of this research has been reported from lysimeter and small plot trials where the pragmatic considerations of drilling a crop in winter, and achieving a net economic benefit to the farmer, weren't largely explored. We report the first-year results (2018) of a three-year sustainable funding project that looks to upscale this earlier research to field scale, establishing a series of catch crop trials, post-grazing, on winter forage paddocks in Mid-Canterbury. Two trials were situated at Hororata on a winter forage block on a shallow, stony Lismore soil (Pallic), and a third on a dairy farm at Te Pirita on a moderately-deep Waimakariri soil (Recent). Trials measured DM yield, N uptake and soil mineral-N (where possible). The Hororata trials (using oats only) compared differing cultivation and drilling treatments (conventional cultivation/drilling vs direct drill) on ex-kale and ex-fodder beet paddocks while the trial at Te Pirita considered differing catch crop species (oats, triticale and Italian ryegrass),

Trial establishment from early July to early August was aided by a relatively dry and mild month that provided favourable soil conditions for drilling, with the Hororata and Te Pirita trials being harvested mid and late November, respectively, at a similar time as the surrounding paddock was harvested for green chop silage. DM production and N uptake over both sets of trials ranged from 4-12 tonnes/ha and 100-350 kg N/ha, respectively, significantly reducing soil mineral-N levels. We discuss the effects of the differing cultivation/drilling treatments and effectiveness of the three catch crop species on N uptake and farmer's bottom lines in our paper.

OPPORTUNITIES TO REMOVE NITRATES FROM DRAINAGE WATER UNDER INTENSIVE VEGETABLE PRODUCTION

Pip McVeagh, D Bloomer and G O'Brien

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Vegetable growers are facing major challenges regarding nutrient use in their systems – particularly for nitrogen. Future Proofing Vegetable Production aims to work with vegetable growers in Arawhata to reduce nitrate leaching in their catchment. The project focuses on four areas: precise prescription, precise application, management practices that maximise retention of nutrients and soil, and introducing ways to mitigate losses through downstream capture.

While nitrate leaching can be reduced, some level of leaching will be inevitable under current intensive vegetable production systems. Options to capture nutrients lost to drainage water include wetlands and bioreactors. The project aims to work at a catchment scale, with grower input from the outset. Wetlands are already under construction on some blocks in the Arawhata catchment and more planned. A bioreactor will also be constructed as part of this project, with sites and designs currently being researched. Monitoring of nitrate levels throughout the catchment and work previously completed developing a catchment wide drainage plan will help identify suitable sites.

Wetlands and bioreactors are being trialled to mitigate nitrate loses in sensitive catchments in both New Zealand and Australia, and initial results are promising. A forum was recently held in Townsville, Queensland where researchers shared information and lessons learnt from their installations. There is a strong working group in Australia with links to New Zealand groups and great opportunity and interest in sharing information and collaborating in this area.

GROWING KIWIFRUIT WITH AN ENVIRONMENTAL FOCUS

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A challenge for all New Zealand based food growers is how to merge continual science and technology improvements together to support the evolvement of modern horticulture food production methods. It is now apparent to land based food producers for the need to be much more cognoscente of a range of environmental considerations during the production of the food, as this is both what consumers and local government regulatory authorities are now demanding.

Coastal Kiwis Orchard has been established to produce food in a manner that meets an increasing level of consumer demand for “safe food”. A holistic approach to designing the orchard system resulted in planting plant species that minimises the longer term need for use of agrichemicals to control pests, and has subsequently lowered the levels of emissions from operating machinery. Various certified organic inputs are utilised to feed the soil biology, and to ensure adequate soil fertility exists to support sustainable production levels. The combination of these deliberate strategies has resulted in the delivery of top quality export fruit (and financial returns), while simultaneously achieving measurable low environmental impacts.

EFFLUENT NUTRIENT MANAGEMENT
– USING CLEARTECH TO REDUCE MODELLED NUTRIENT LOSSES AND ENVIRONMENTAL RISK

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Improving farm dairy effluent (FDE) management and increasing water use efficiency is a major solution in reducing the environmental effects of nitrogen (N), phosphorous (P) and *E.Coli* in water bodies. ClearTech represents a new method to treat FDE, resulting in the removal of solid material, and production of clarified water for recycling. It allows the flexibility to transfer nutrients from 'high risk, low demand' periods to 'high demand, low risk' periods, where there is a soil moisture deficit. Overseer® (v6.3.0) was used to model the nutrient loss effects of utilising ClearTech on a farm scale across four dairy farms in New Zealand.

Treatment of FDE in trials showed ClearTech significantly reduced *E.coli* levels (99.98%; $P<0.001$), total N concentration (57%; $P<0.001$), total P concentration (99%; $P<0.001$) and dissolved reactive phosphorus (DRP) concentration (99%; $P<0.001$) in the clarified water. These reductions indicate that land application of the clarified water would be less likely to cause adverse environmental impacts on water quality than the current practice of untreated FDE. In the 'treated' FDE portion, there was a significant reduction in *E.coli* concentration (91%; $P<0.001$) and DRP concentration (99%; $P<0.001$). There were significant increases in a range of nutrients including total-N, total-P and sulphur concentrations due to the coagulation process and increased solids content. With increased pond storage availability (320%), there is opportunity to optimise the application of nutrients in the form of the treated FDE to meet optimum plant uptake & demand. With the inclusion of ClearTech, Overseer® (v6.3.0) showed a reduction in whole farm nitrogen loss (kgN/yr) (up to 3.5%), in particular the effluent blocks reduced by up to 20%. N loading on the effluent area (kgN/ha/yr) reduced by 42 to 59% across the farms.

The reduction of several nutrients in trials to date, combined with initial findings from Overseer® modelling, indicates that ClearTech has the potential to significantly reduce nutrients applied and lost to the environment. In addition, remaining FDE nutrients can be further managed to align with soil & plant demands. With further investigation, ClearTech may be suitable for incorporation into Overseer® as a mitigation tool in the future, to highlight the farm scale nutrient loss reductions in a compliance frame work.

BORIS AND HIS FOUR FRIENDS ADVENTURE TO PINEDALE: MEASURING NUTRIENT LOSSES FROM DAIRY FACTORY WASTEWATER APPLICATION ON LAND

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The use of lysimeters to measure nitrate leaching losses is common within the research world and they are widely used in New Zealand to measure nitrate losses from animal urine patches. However, when a commercial farm has questions around their environmental footprint, how does this tried and true research methodology and equipment work on an everyday working farm?

Fonterra Pinedale is an ex-forestry block located in South Waikato that receives a variety of different dairy factory waste products for disposal. The entire property is 1250 ha of which 315 ha is run as a maize and ryegrass cut and carry system. These products are applied to ryegrass with an annual nitrogen loading rate of 400 kg N/ha. Given the nature of this system - ex-forestry now a cut and carry system with a range of waste products being applied with varying composition - the Overseer model is pushed to its limits when trying to model nitrogen loss accurately. Therefore, Fonterra have asked how much nitrate is getting into the local groundwater through leaching.

The use of lysimeters was determined to be the most suitable way to measure nitrate leaching losses, however many challenges arose during methodology development, collection, and installation as we took a research tool and tried to integrate it into a working commercial farm. Nine months after installation, we take a look at how successful the lysimeters have been.

MEETING NITROGEN DISCHARGE ALLOWANCES ON A ROTORUA DAIRY FARM – A CASE STUDY

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Nitrogen (N) discharge allowances are proposed for farms in the Lake Rotorua catchment to reduce the amount of N entering the lake. As part of the Forages for Reduced Nitrate Leaching Programme, a monitor dairy farm was established in the catchment to trial alternative forage crop options; low N crops (fodder beet) and a catch crop (oats) to remove N from the soil. These crops were incorporated into the standard management of the farm, replacing kale, which typically has higher nitrogen concentrations than fodder beet. However, it is known that winter crops grazed *in situ* result in large amounts of N being excreted onto bare soil at a time when it is susceptible to leaching. Hence, further alternatives to growing crops on the milking platform were explored to reduce N leaching, using the models Farmax Dairy Pro and OVERSEER™. Leaching from adjoining support land was included in the analyses.

The 369 ha base farm milking platform included fodder beet followed by oats, summer turnips, palm kernel expeller (PKE) and pasture silage, with fodder beet and kale grown on the support land for cow wintering and dairy replacements. Crops were modelled using typical yields recorded on the farm. Scenarios investigated were: removing crops from the milking platform whilst either; A) reducing stocking rates; B) feeding additional PKE; C) replacing crops, PKE and pasture silage with purchased low N feed (maize grain and maize silage); or D) wintering cows on the milking platform at a reduced stocking rate.

Nitrate leaching was reduced by 9, 5, 19 and 23%, for A, B, C and D, respectively, compared to the base farm, with scenarios C and D meeting leaching targets for the farm (dairy plus support). Scenarios A and D reduced milk production, but scenario D was the only one that increased profitability (7%) under the 2015/16 prices ($6/kg milk solids) used in these scenarios.

CHOOSING TO SUCCEED:

HOW FARM ENVIRONMENT PLANS CAN INCREASE GOOD MANAGEMENT PRACTICE IN OTAGO

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Otago Dairy Farmers are currently facing an increased focus on their environmental practices from upcoming regional rules and proposed new government policies. Farming under an effects-based plan has provided limited guidance around specific environmental requirements. However, increased pressure from the Otago Regional Council (ORC), Government and the wider public to improve environmental performance, means meeting environmental bottom lines will need to become a focus for many dairy farmers in the next few years.

Farm Environment Plans (FEP) provide a framework for farmers to assess their current environmental performance and identify risks and tailor actions to minimise or eliminate those risks. Having a FEP can also act as proof that a farm operation has a focus on environmental sustainability and, if reviewed regularly provides a record and plan for past and future activities. As the ORC Regional Plan does not currently require an FEP, there is a greater challenge around uptake of FEPs in the region but the benefits of having a FEP will likely future proof the farm for any changes to plans or policies.

DairyNZ in conjunction with Fonterra have implemented a case study project across six dairy farms in the Otago region to create FEPs for each property. These FEPs will identify key actions for each farm to enhance good management practice (GMP) and support will be provided to implement the identified actions. It is intended that there will be a variety of actions across the farms which will give an indication of the different GMP required within the farming operation. Field days and media articles relating to the case study farmers will be used to increase awareness of GMP around Otago and encourage more farmers to be aware of their environmental footprint and the practices they can use to improve it as well as promoting the positive change being made in the dairy industry to the wider public.

CONSEQUENCES OF FLUORINE (F) ACCUMULATION IN ALLOPHANIC SOIL

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Fluorine (F) is a significant contaminant in most phosphate fertilisers, the continuous application of which significantly contributes to F accumulation in agricultural soil. Accumulated soil F may have the potential to alter soil properties, and thus may require changes to future land use and management practices.

Allophanic soil is one of the most productive soil orders in New Zealand. It is characterised by a high phosphate retention capacity requiring high application rates of phosphate fertiliser, resulting in high F accumulation rates in these soils. The objective of this study was to quantify the effect of added F on selected Allophanic soil properties.

A bulk soil sample (478 mg/kg total F) was collected from a dairy farm near Hawera in Taranaki. Pot experiments were conducted under glasshouse conditions, with treatments being amended with NaF to deliver spiked F concentrations of 0, 77, 154, 231, 308, and 385 mg F/kg of soil. These soil F concentrations are estimated to be equivalent to 0, 10, 20, 30, 40 and 50 years of F accumulation respectively, *via* the continuous application of phosphate fertiliser. Each treatment was replicated 6 times.

After 14 months, soil pH, Dissolved Organic Carbon (DOC), $CaCl_2$-extractable, and water-extractable F concentrations were measured. These analyses showed that soil pH significantly ($p<0.05$) increased from 5.18 to 5.53 with increased F addition. Dissolved organic carbon ranged from 270.5 to 331.3 mg/kg and significantly increased ($p<0.05$) with increased F addition. $CaCl_2$-extractable and water-extractable F values ranged from 4.95 to 12.67, and from 2.57 to 5.11 mg/kg soil respectively. These increases correlated significantly ($p<0.05$) with increasing F addition to the soil.

On average, F extracted by water and 0.01 M $CaCl_2$ was 0.37 % and 1.49 % of the added F respectively, and suggests that the major fraction of F added as NaF was immobilised by Allophanic soil. Immobilisation resulted in an increase in soil solution pH and an increase in DOC concentration by 0.4 unit and 60.8 mg/kg, respectively.

INFLUENCE OF SOIL CD LEVELS ON ROOT EXUDATE SECRETION IN CHICORY AND PLANTAIN

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Cadmium (Cd) is a key environmental contaminant associated with long term high application rates of superphosphate fertilizer to New Zealand agricultural soils. Recent studies indicate that elevated levels of Cd in New Zealand soils can lead to high Cd accumulation in forage species such as chicory and plantain. These studies suggest the different abilities of pastoral species to absorb Cd by roots and to translocate it from root to shoot. Plant roots exude Low Molecular Weight Organic Acids (LMWOAs) into rhizosphere which are important to enhance Cd mobility in soil. Therefore, a glasshouse experiment was carried out to evaluate the influence of soil Cd levels on root exudate secretion in chicory and plantain. Germinated seedlings were grown in a rhizo-column under increasing Cd levels: 0 (Control), 0.4, 0.8 and 1.6 mg Cd/kg soil for 8 weeks. At harvest, root exudates were collected from plants separately and LMWOAs determined using High Performance Liquid Chromatography. The results showed that oxalic, fumaric, malic and acetic acids in chicory, and oxalic, fumaric and malic acids in plantain were the major LMWOAs in all treatment root exudates. There was no significant difference in fumaric acid secretion in chicory up to 0.8 mg Cd/kg, and then significantly ($P<0.05$, $n=3$) increased by 141% at 1.6 mg Cd/kg compared to the control. The acetic and oxalic acids concentration in chicory did not significantly vary among the Cd treatments. Malic acid in chicory, and fumaric and malic acid concentrations in plantain did not show any definite trend with increasing levels of Cd. Further, there were no significant differences in oxalic acid secretion in plantain with increasing soil Cd levels, only 21% increase of oxalic acid observed at 1.6 mg Cd/kg compared to control. Therefore, this study highlights that elevated Cd concentrations in soil (i.e. 1.6 mg Cd/kg) modify the root LMWOAs secretion, especially in chicory, which may influence plant Cd uptake.

ASSESSMENT OF NITROGEN FERTILIZERS UNDER CONTROLLED ENVIRONMENT – A LYSIMETER DESIGN

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This paper introduces a closed system lysimeter design to measure fertilizer performance on rye grass. The lysimeter will measure plant mass growth, gas emissions and leachate in a controlled climate environment based on a long term 90 day spring climate from the Taranaki. A range of commercial fertilizers will be compared to bespoke fertilizers manufactured in an MBIE funded Endeavour Smart Ideas research programme undertaken by CRL Energy and Massey University. This work, although undertaken in laboratory conditions will help quantify the impacts of nitrogenous fertilizers on the environment by mimicking actual conditions in a controlled setting. The study should provide data on the effectiveness of novel fertilizers manufactured within the programme; and other slow and controlled fertilizers, in reducing nitrogen leaching and greenhouse gas (GHG) emissions on pasture. Nitrogenous fertilizers readily leach as nitrates are highly soluble and GHG are emitted through volatilisation of ammonia and nitrous oxide. Reduced leaching and volatilisation increases fertilizer efficiency as less is wasted and more is attenuated in the plant. The aims of the research are to increase the effectiveness and efficiency of nitrogen fertilizer use in New Zealand. This should benefit farmers by reducing the amount of fertilizer applied, ideally reducing fertilizer cost, or at no extra cost by improved plant attenuation. This would also have an environmental benefit through reduced leaching and GHG emissions.

COMPARING FINE PARTICLE AND GRANULAR NITROGEN RESPONSE ON SOUTHLAND PASTURES

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Nitrogen fertiliser is utilised by farmers to increase pasture growth post grazing in rotationally grazed systems and during early spring and in autumn to increase pasture growth rates. Granular N in the form of urea is the most common form of nitrogenous fertiliser utilised in New Zealand. Recently, there has been interest re-emerging in the application of nitrogen fertiliser using fine particle application (FPA) methods. Fine particle application can be described as the fine grinding of granular fertiliser mixed with water prior to application and has been suggested to improve urea N efficiency.

This trial was established to compare fine particle application and granular application of nitrogen fertiliser (SustaiN) on pasture production on a Southland dairy farm. Replicated small plot trials were carried out on a dairy farm in the Awarua district in Spring 2017 and again in Autumn 2018. Three treatments were compared, control, 25 kg N/ha and 50 kg N/ha via either fine particle or granular application. Pasture was harvested at four and eight weeks post nitrogen application with wet weight, dry-matter measured to determine pasture production and nitrogen response rates.

In line with the literature there was found to be no significant difference in pasture growth between the two application approaches.

THE EFFECT OF CONTROLLED RELEASE NITROGEN FERTILISER ON PASTURE PRODUCTION ON TWO DAIRY FARMS IN WHATAROA, SOUTH WESTLAND

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A controlled release fertiliser was compared to a standard nitrogen fertiliser approach on two dairy farms in Whataroa, South Westland to determine if there was an effect on pasture production. Replicated plot trials were carried out on two dairy farms in the Whataroa district in Spring 2018. Three treatments were compared, control, a controlled release fertiliser Smartfert® and a standard nitrogen fertiliser programme applied after every grazing. Smartfert® was applied at 135kg/ha (60kg N/ha), in combination with SustaiN nitrogen at 87kg/ha (40kg N/ha) in one application. In contrast the standard nitrogen fertiliser programme of SustaiN was applied after every cut over a three month period at rates of 87kg/ha (40kg N/ha), 65kg/ha (30kg N/ha) and 65kg/ha (30kg N/ha) respectively. Pasture wet weight, dry-matter and nitrogen content was measured monthly over 4 months to determine pasture production and nitrogen uptake.

RPR REVISTED 6: SWITCHING TO REACTIVE PHOSPHATE ROCK (RPR) – BASED FERTILISERS REDUCES ALL FORMS OF DIFFUSE SOIL P LOSSES, NOT JUST DRP

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Reactive phosphate rock (RPR) is recognised in Overseer® as being less susceptible to loss of dissolved reactive phosphorus (DRP) in run-off from than is soluble P fertiliser, although far less than field trials demonstrate. There is no recognition of lower particulate P losses, and P leaching is essentially ignored by being lumped in with DRP run-off loss without separate calculation.

Typically, 30-70% of P run-off is in the form of particulate P (P adsorbed onto soil particles). It is mistakenly considered by many to be independent of the form of P fertiliser used. However, many field trials show reductions in both DRP and particulate P with RPR. This is consistent with field data demonstrating that RPR maintains maximum pasture growth with considerably lower readily-available Olsen P levels (which includes water-soluble and weakly-adsorbed P) than does soluble P.

The dissolution of RPR particles is dependent on reactivity, particle size, soil pH, soil moisture and soil calcium status. Levels of weakly-adsorbed P achieved with long-term RPR are usually 20-30 ug/gm soil, a good match with concentrations of weakly-adsorbed P and soil solution P levels required for optimum growth of pasture. Levels higher than this can be achieved on very acid soils.

Soluble P fertilisers on the other hand maintain soil concentrations of very weakly adsorbed P up to many hundreds of ppm for several weeks or even months in the dissolution zone surrounding individual particles. Average soil P concentrations are highest near the soil surface, where the dissolving granules largely reside (until moved lower by trampling and worm activity etc). This near-surface particulate P is much more likely to be carried off in run-off, and much of it can then be desorbed in mildly-acidic streams, rivers and lakes as the P equilibrium changes with dilution, resulting in eutrophication.

Particles of undissolved RPR however are far less likely to reach receiving water than are particles of either soil particles or soluble P fertiliser, because of the much higher density of RPR particles.

More intensive P run-off research on farms with a long-term history of RPR should be a priority.

ROLE OF BIOREMEDIATION IN NUTRIENT REMOVAL FROM RUNOFFS TREATED WITH LIGHT-WEIGHT MEDIA

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The increase in agricultural runoff has led to leaching of inorganic nitrogen and phosphorus contaminants that are carried downstream resulting in damaged ecological habitats and poor water quality. Our study focuses on understanding the role of microbial activity for bioremediation of runoff contaminants within novel lightweight media. The media can be installed in patches, trenches, or in standalone units to intercept surface or near surface runoff. Work to date shows high but variable microbial activity between media of different compositions. Media compositions also affected water flow and retention. The media dominated by compost yielded lower flow rates while other non-soil media components experimented with showed higher flowrate and better microbial activity. The removal efficiency of Total suspended solids (TSS) ranged from 50 to 70% while for nitrate it was up to 65%. The ongoing work will evaluate optimal conditions to promote the growth of specific biodegrading populations in lightweight media.

ROLE OF PHYTOREMEDIATION IN NUTRIENT REMOVAL FROM RUNOFFS FOR LIGHT-WEIGHT MEDIA

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Concerns have been raised regarding nutrient leaching from agricultural soils due to excess use of fertilisers. High concentration of these nutrients, nitrogenous compounds and orthophosphates, upon discharge to receiving water bodies can lead to eutrophication and other negative environmental consequences. Hence, reducing nutrient losses via leaching by applying a suitable choice of soilless growing media is one of the possibilities. This study focuses on the development of locally obtained, light-weight media mix which not only allows satisfactory growth of plant's root system, thus supporting vegetation, but also aids in mitigating nutrient leaching.

The current stage of the study involved unvegetated column experiments, which tested pollutant removal performance on two combinations of the five different light-weight media components in the presence of green compost: perlite, vermiculite, activated carbon, zeolite, and coconut coir. Our findings indicated that there was a significant removal of ammonium, nitrite, and nitrate through these media mixes. Ammonium and nitrite were removed by more than 90% in all trials, while minimum nitrate removal was recorded at more than 70%. Orthophosphate removal could not be quantified due to leaching of phosphorus from the media in the initial run.

INORGANIC NITROGEN CONTAMINANT REMOVAL FROM RUNOFFS BY BIOMASS-DERIVED ADSORBENT

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Inorganic nitrogen contaminants (INCs) pose a great risk to the ecosystems since they are harmful to many organisms and are stable in the environment. Agricultural runoffs are widely blamed for environmental pollution due to presence of INCs as substantial amounts of unutilized nitrogenous compounds, applied as fertilisers, eventually enter the environment and contaminate ground- and surface water bodies. These excess nutrients lead to eutrophication, water quality degradation, and numerous health issues.

Incorporating waste to value approaches is one of the principal objectives of current water treatment strategies. This study is focused on the development of an efficient adsorbent from biomass waste, which can capture INCs effectively while simultaneously supporting the waste minimisation and reuse concept. Hydrochar is the carbon-rich, value-added solid product derived from hydrothermal carbonisation (HTC) of biomass. In this study, hydrochar was obtained from biomass waste through varying HTC parameters. Experiments were conducted to optimise the removal of ammonium from aqueous media by varying the hydrothermal treatments to produce optimal surface chemistry for adsorption. Results showed that biomass waste derived hydrochar can significantly remove ammonium from aqueous media (up to 80%). Removal efficiencies were comparable to carbon with much superior surface physical properties, surface area and pore volume, indicating that chemisorption may be a dominant adsorption mechanism.

THE EFFECT OF PHOSPHORUS ON GLYPHOSATE ADSORPTION-DESORPTION IN NEW ZEALAND SOILS

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Glyphosate is a broad-spectrum systemic herbicide and is the most widely used agrochemical worldwide. The active ingredient carries a negative charge across a soil pH range of 5 to 9, and thus competes with phosphate for adsorption sites on soil surfaces. However, phosphate has greater affinity for Al–Fe oxy-hydroxide surfaces than glyphosate, and P accumulation in soil may enhance glyphosate solubilisation. The aim of this work was to elucidate the antagonistic effect between phosphate and glyphosate in Pallic, Brown and Allophanic soils of New Zealand using an adsorption-desorption batch experiment. Soils were saturated with KH_2PO_4 solution (1,000 mg P/L) at pH 4.5, using a soil:solution ratio 1:10 (w/v) by shaking overnight (16 hrs). The P-saturated soils were then re-suspended with 10 mg glyphosate/L solution at pH 5 and again shaken overnight (16 hrs). The supernatant of the glyphosate equilibrium solution was collected, then glyphosate was desorbed from the solid phase using an alkaline extractant. The concentration of residual glyphosate in the supernatant and in the extraction was quantified using RP-HPLC with FMOC-Cl pre-column derivatisation.

The results showed that P saturation reduced glyphosate adsorption in the soils. The Allophanic soil with control treatment had the greatest glyphosate adsorption of 99%; however, P saturation reduced glyphosate adsorption by 14%. The P saturated Pallic soil had the lowest glyphosate adsorption of 59%, compared to 87.12% of glyphosate adsorbed in the control soil. Glyphosate adsorption in P saturated soils was positively correlated ($P<0.0001$) with the dithionate extractable Fe content, suggesting that the previously adsorbed phosphate could be exchanged by glyphosate in the Fe oxy-hydroxides, due to the high Fe reactivity. Findings from this study may help in the assessment of potential glyphosate solubilisation risk according to soil characteristics and P status.

SPATIAL AND TEMPORAL VARIABILITY OF GROUNDWATER CHEMISTRY AND REDOX CONDITIONS IN AN AGRICULTURAL LANDSCAPE

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Nitrate (NO_3^-) leaching from agricultural soils is a key concern for contamination of surface and groundwaters in sensitive agricultural catchments. Leached nitrate (NO_3^-) from agricultural soils can be attenuated by biogeochemical processes such as denitrification, which occurs under favourable hydrogeochemical (redox) conditions in the subsurface environment (beyond the root zone). However, we have very limited information available on the occurrence and variability of groundwater redox conditions in our sensitive agricultural catchments.

We collated and analysed a large set of groundwater observations (150+ wells) to identify spatial and temporal variations in groundwater chemistry and redox conditions in the Horizons Region. The collected groundwater dataset was comprised of one-off groundwater surveys and repeated (temporal) observations at selected groundwater monitoring sites. Using the framework and threshold concentrations of groundwater redox species (McMahon & Chapelle, 2008), the collected groundwater samples were assessed for their dominant groundwater redox conditions and processes. Further, a range of hydrogeological characteristics such as soil texture, drainage class, carbon content and underlying geology associated with the sampling sites were identified and analysed for their influence on the spatial and temporal variability of the groundwater redox conditions and processes.

Our analysis suggests highly spatially-variable but generally temporally-stable groundwater redox conditions in the study area. Areas with well-drained soils and highly permeable rocks (e.g. gravels) have oxic groundwaters (dissolved oxygen > 1 mg/L), suggesting a low potential for NO_3^- attenuation in the subsurface environment. Areas with fine texture soils and low permeability geology are dominated by reducing groundwaters (dissolved oxygen < 1 mg/L), suggesting a high potential for NO_3^- attenuation in the subsurface environment. Interestingly, the coastal sand country of the study region has mostly anoxic reducing groundwater conditions.

This observed variability in groundwater chemistry and redox conditions highlight the influence of different landscape characteristics on the transport and potential for NO_3^- attenuation in the subsurface environment. Further research focused on a better understanding, quantification and mapping of these influences will help inform the design of targeted and effective mitigation measures for improved water quality in sensitive agricultural catchments.

DESIGN CONSIDERATIONS FOR CONSTRUCTED TREATMENT WETLANDS TO MITIGATE NUTRIENT AND SEDIMENT RUNOFF FROM LOWLAND INTENSIVE AGRICULTURAL CATCHMENTS

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Constructed treatment wetlands (CTWs) have been implemented as mitigation tools to manage diffuse pollution from intensive agricultural catchments to shallow peat lakes in the Waikato region. This research investigated CTW efficacy, evaluating different predictors of performance, and exploring morphological and environmental variables influencing treatment efficiency.

The CTWs were comprised of a sedimentation pond 'module', with around half including shallow wetland-modules planted with native species, and three CTWs with additional sedimentation pond-modules. The inflows were surface-flow watercourses diverted from modified or artificial drainage networks, and the outflows were either surface-flow (through drainage channels or culverts), or filtration (through vegetated riparian margins). Morphological predictors of CTW performance included area (range 7 – 1950 m^2), depth (0.2 – 2.1 m), volume (12 – 2030 m^3), Wetland to Catchment Area Ratio (0.01 – 1.18), hydraulic retention time (0.2 – 37.2 h), and hydraulic loading rate (0.4 – 130 $m^3\ d^{-1}$).

The presence/absence of macrophytes as well as outlet type and the number of CTW modules were included as categorical variables in analyses. Reductions in nitrogen (N), phosphorus (P) and suspended solids (SS) differed considerably across CTWs, driven by varying influent concentrations and dominant forms of N, P, and SS, as well as CTW morphologies. Generally, CTWs with larger areas and volumes improved removal performance of nitrate, total N and coarse sediments, while deeper CTWs more effectively reduced particulate N and volatile SS. Macrophytes improved removal of nitrate and P, whereas CTWs with filtration outlets frequently increased ammonium. Greater accumulated sediment depths significantly reduced P removal efficiency, signifying the importance of CTW maintenance, and increasing the number of CTW modules generally improved performance.

A simple, nonetheless comprehensive wetland treatment-train concept is presented, designed to accommodate anticipated variability in agricultural pollutant loads and internal nutrient cycling, whilst fitting practically within the productive farming landscape.

CHANGES IN WATER QUALITY THROUGH A CONSTRUCTED WETLAND ON A WAIRARAPA DAIRY FARM – MITIGATION IN ACTION

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A constructed wetland was installed on a Wairarapa dairy farm in October 2014. The wetland features a serpentine flow at three levels in the landscape and has a permanent metered inflow and is planted with native aquatic plants. As such it demonstrates an ideal design as described by the Overseer® wetland module. Initial flow through the wetland was increased to 14 Litres/second in January 2016. The quality of the water entering and leaving the wetland has been sampled on a monthly basis since February 2015. Electronic monitoring of wetland flow has also been installed.

Nitrate-N removal - On average 626kg N per year was removed from the farm output over the two years from January 2016 to March 2018. This is significant as the farm average is (as calculated by Overseer) 13 kg N/ha/yr or 6024 kg N in total. The wetland effectively reduces loss from the farm by more than 10%.

Other results - Total N has been reduced in line with nitrate-N since the wetland was installed. A recent report by the National Institute of Water and Atmosphere (NIWA) stated that total N removal at Kaiwaiwai wetland was higher than most NZ constructed wetlands. Results for Total Phosphorus were similar in that 14.3% was removed, again above the 10% removal normally expected.

NITRATE REMOVAL EFFICIENCY AND SECONDARY EFFECTS OF A WOODCHIP BIOREACTOR FOR THE TREATMENT OF AGRICULTURAL DRAINAGE

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Artificial drainage has been instrumental in the viable use of poorly drained soils for agriculture. However, artificial drains can also provide a pathway for fast and unattenuated nutrient transfers to streams and rivers. To remove nitrate from drainage water, bioreactors have been recently widely adopted as an edge-of-field mitigation measure, especially in the USA. These bioreactors are fundamentally a lined pit filled with woodchips as a source of carbon, which microorganisms use to transform nitrate through the process of denitrification into gaseous forms of nitrogen, mostly N_2. However, there is a lack of information on the performance of these bioreactors under the very flashy drainage flow conditions typical for New Zealand. Moreover, to avoid pollution-swapping, any possibly occurring negative side effects need to be understood. A pilot-scale woodchip bioreactor was constructed on a dairy farm on the Hauraki Plains in Waikato and was monitored for two drainage seasons (2017, 2018). The nitrate removal efficiency of the bioreactor, calculated from the difference in nitrate load between the bioreactor influent and the outflow, was 99% and 48% in 2017 and 2018, respectively. The difference can be attributed to the much longer residence times and greater organic carbon (OC) availability in the bioreactor in 2017. While the long residence times in 2017 resulted in nearly complete denitrification with diminished concentrations of the greenhouse gas nitrous oxide in the bioreactor outflow, it also led to very reduced conditions with substantial production of methane (another greenhouse gas) and hydrogen sulphide ("rotten egg smell"). The shorter residence times observed in 2018 after bioreactor modification rectified this strongly reduced condition; however the nitrate removal efficiency decreased. Substantial release of OC and dissolved reactive phosphorus (DRP) was only evident during the first start-up phase of the bioreactor in 2017, whereas in 2018 significant removal (89%) of DRP was measured. Ongoing investigations aim to optimise installation costs and treatment efficiency, while minimising any side effects. Specifically, options to improve the poor treatment during high flows will be investigated in the 2019 drainage season (e.g. by adding readily available OC source such as ethanol).

EFFICACY OF A NITRATE-N WOODCHIP FILTER:

THREE YEARS OF FIELD TRIALS

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Nutrient enrichment is a major contributor to water quality impairment internationally. The New Zealand response to water quality problems includes the National Objectives Framework (NOF), and the National Policy Statement for Freshwater Management (NPS-FM, 2014 and 2017), which describe water quality targets and resource management actions. These targets include nitrate-N concentrations and loads.

Achieving catchment water quality targets may require change in land use, land management practices and implementation of various mitigation tools. One device with potential to decrease the load of nitrate-N entering surface waters is the wood chip filter.

We describe the performance of a wood chip filter deployed in the Waituna Lagoon catchment, Southland, over the period 2016-2018. The annual performance was reasonably consistent over the assessment period (greater than 60% removal). There was marked seasonal variation in removal efficacy. Removal was lowest in the winter (approximately 60%), related principally to residence time in the filter bed, and temperature. Removal efficacy in summer and spring exceeded 90%. Month-to month removal rates were principally related to inflow rates, which directly affected bed residence times.

The filter bed was always a net source of ammoniacal-N, but the flux of ammoniacal-N was small and unlikely to impact adversely on receiving water quality. Several strategies for optimising performance are identified, including hydraulic buffering and bypassing excess flows during winter. Several challenges to performance assessment are identified, as well as a very simple, cost-effective and practical strategy whereby estimation of removal efficiency may be improved.

IMPROVING EDGE-OF-FIELD NUTRIENT MITIGATION TOOLS TO ENHANCE CONTAMINANT ATTENUATION AND WATERWAY HEALTH

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Artificially-drained agricultural lands can be significant sources of diffuse nutrients, sediment, and faecal contaminants to aquatic ecosystems. These contaminants degrade water quality, mahinga kai (food gathering locations), and recreational values of waterways over significant areas of New Zealand. To mitigate these adverse impacts, edge-of-field tools, such as riparian buffers, constructed wetlands, and emerging options such as denitrifying woodchip bioreactors and P-adsorption filters, can be implemented to intercept and attenuate contaminants

Besides improving water quality, these mitigation tools will likely help to improve the ecosystem health of receiving waterways, thereby ensuring that farming can be sustainable and economically viable within the new paradigm of "farming within limits". For example, the nutrient attenuation performance of edge-of-field tools is influenced by environmental parameters like dissolved oxygen and nitrate-nitrogen concentrations, dissolved organic carbon availability, flow and temperature regimes, and fine sediment accumulations. These parameters are also linked to the overall health of waterways by influencing rates of organic matter decomposition, nutrient cycling, aquatic food webs, and biodiversity. However, a clearer understanding of how edge-of-field tools might improve catchment water quality, mahinga kai, and aquatic ecosystem health is needed to support and guide their implementation, especially for newer tools like denitrifying bioreactors

Evaluations of the potential ecosystem-level impacts of edge-of-field mitigation tools should be conducted at ecologically-relevant spatial and temporal scales and should also incorporate Mātauranga Māori (traditional knowledge) to promote holistic resilience, sustainability, and cultural acceptability. Overall, this will require combining economic, logistical, cultural, and ecological information to support the implementation of edge-of-field mitigation tools to enhance contaminant attenuation and waterway health.

PHOSPHORUS MITIGATION PROJECT: QUANTIFYING THE ABILITY OF DETAINMENT BUNDS TO ATTENUATE PHOSPHORUS AND SEDIMENT LOADS IN SURFACE RUNOFF FROM GRAZED PASTURE IN THE LAKE ROTORUA CATCHMENT

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The 'Lake Rotorua Nutrient Management Plan' aims to decrease the quantity of phosphorus (P) delivered to the lake by 10 $t{\cdot}yr^{-1}$ in order to restore water quality parameters to those measured in the 1960s. Pastoral farming is the primary agricultural practice in the Lake Rotorua catchment and is responsible for ~43% of the total P load entering the lake. Farmers in the Rotorua lakes catchments developed the Phosphorus Mitigation Project (PMP) in 2016 to advance understanding of P mitigation through applied research. Storm events have been identified as opportunities to reduce P loss from agriculture. Detainment Bunds (DBs) are being investigated for their ability to treat storm generated surface runoff before it reaches natural water bodies. Detainment Bunds are low, earthen dams constructed in targeted ephemeral streams, which are capable of temporarily retaining large quantities of runoff. Prior research suggests DBs may attenuate P and suspended sediment loads transported by surface runoff, but there is no quantitative data available on the magnitude of this attenuation under New Zealand conditions. This study seeks to quantify the attenuation performance of a DB receiving runoff from 19.7 ha of mainly grazed pasture located within the Lake Rotorua catchment over 12 months, beginning November 2017. Preliminary results from 15 measured events showed a combined reduction of 4.5 kg (59%) dissolved reactive P, 10.4 kg (61%) total P and 1423 kg (65%) suspended sediments in runoff released from the DB. The decreased quantity of P and sediments is similar to the quantity of runoff that infiltrates the soil during ponding. The results of this study suggest that DBs may enable pastoral farmers with well-drained soil to reduce the quantity of P and sediment transported from their farm by surface runoff. Understanding the treatment mechanisms and quantifying DB performance is necessary for decision makers interested in utilising DBs at a wider scale and for the potential development of a nutrient attenuation credit program using nutrient management software.

CRITICAL PATHWAYS PROGRAMME: UNRAVELLING SUB-CATCHMENT SCALE NITROGEN DELIVERY TO WATERWAYS

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To be effective and efficient, decision making on land use, land management, mitigation measures, as well as policy, need to be based on a clear understanding of cause-effect relationships. Present practice is to link activities on the land and water quality outcomes at spatial scales of 100s to 1000s of km^2. However, such large catchments are inevitably heterogeneous. Consequently, it is very difficult to link an observed contaminant flux at the catchment outlet to the many past and present activities within the large catchment that collectively have caused it. The need to focus on the sub-catchment scale (10s of km^2), i.e. the local streams that feed the large rivers that are typically being monitored has therefore recently been emphasised internationally.

To unravel sub-catchment scale nitrogen delivery to waterways, we are introducing an innovative multi-scale measurement, data analysis and modelling approach that allows to coherently link transect, sub-catchment and catchment scale hydrogeophysical information. Three key innovations will collectively enable us to achieve this. Firstly, we will introduce a novel geophysical measurement suite (airborne and ground-based) to gain information on structural, hydrological, and chemical characteristics controlling N transport and attenuation, particularly in the shallow subsurface (top 20m). Secondly, innovative Environmental Data Analytics (EDA) techniques will be used to integrate the information from the 'Big Data' created by the geophysical measurements. Thirdly, we will use the hydrogeophysical units, identified by EDA together with Lidar to conceptualize and develop a numerical structure for catchment-scale flow models. To simulate the sub-catchment scale flow, transport, and attenuation, we will nest finer resolution models within the coarser catchment models using information gathered at the sub-catchment scale.

Two intensively farmed catchments with contrasting hydrological and biogeochemical conditions provide our case study. The Waiotapu Stream catchment (approx. 300 km^2) on the North Island's Central Plateau represents a baseflow-dominated upland catchment with large groundwater store in young volcanic deposits. In contrast, the Piako Stream headwater catchment is a lowland catchment (approx. 100 km^2) in the upper part of the Hauraki Plains with aquifer deposits of lower transmissivity and a high quickflow fraction in the stream hydrograph.

NITRATE ATTENUATION CAPACITY OF A HILL COUNTRY SEEPAGE WETLAND AND ADJACENT DRY AREAS AS INFLUENCED BY THE CONCENTRATION AND CHEMISTRY OF DISSOLVED ORGANIC CARBON

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Naturally occurring seepage wetlands in hill country agricultural landscapes have the potential to reduce nitrate leaching through denitrification. However, the effect of dissolved organic carbon (DOC) concentration and chemistry on the denitrification capacity of these seepage wetlands relative to adjacent dry areas in the landscape have not yet been assessed. This study investigated the denitrification capacity, and DOC concentration and chemistry of a seepage wetland and adjacent dry areas within a hill country paddock, located in Palmerston North, New Zealand. Soil samples were collected in November 2017 from different soil depths down to 1 m. The results showed that the denitrification capacity of the seepage wetland within the 0-30 and 30-60 cm depths was 7 and 69 times greater, respectively, than that of the adjacent dry areas. The DOC concentration of the seepage wetland was 4-5 times greater than that of the dry areas, within the surface 60 cm soil depth. This higher DOC concentration and the presence of readily-decomposable (lower molecular weight) DOC in the seepage wetland contributed to its higher denitrification capacity. The contrasting nitrate attenuation capacities of the hill country seepage wetland versus that of dry areas highlights the potentially important contribution of seepage wetlands to attenuate nitrate and thus improve water quality. It also suggests that contrasting management practices (such as maintaining/enhancing DOC levels) are required for these distinct areas, if nitrogen loss restrictions are imposed on hill country farms in the future.

EFFECT OF RANK GRASS BUFFER WIDTHS FOR REDUCING CONTAMINANTS FROM DAIRY-FARM LANEWAYS

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Dairy farm laneways adjacent to drains pose a risk as a potential source of contaminants to water. Laneways represent locations with large amounts of effluent loading. Furthermore, cow movement across a laneway of compacted gravels is likely to mobilise fine sediment, increasing the possibility of transport into waterways via runoff during rainfall events. Despite the risk of contaminant losses from laneways to nearby waterways, few studies have quantified the effects of good riparian practices to reduce loading of nutrients, sediment and faecal material from surface runoff.

A trial has been installed on a Pāmu (Landcorp) farm in the Manawatu, Moutua complex where a cow laneway runs adjacent to an open (pumped) drain for 700m+. Six rank grass riparian buffers plots have been installed at increasing distances from the cowshed (up to 500m) to determine the effects of differing riparian widths (0.5 to 3.5m) and different loading rates. A novel sampling technique to capture surface runoff- and estimate attenuation of contaminants has been installed. Care has been taken to ensure constant slope away from the laneway centre at each of the six plots.
This paper will report on an initial trial using a water tanker to apply a standard volume and application rate of water to the laneway to determine contaminant load (N, P, sediment and bacteria) at increasing distances from the cowshed. Future studies at the site will include an analysis of differing vegetation types to attenuate contaminants from critical source areas.

INTEGRATED BUFFER ZONES FOR AGRICULTURAL NITROGEN REMOVAL: A DANISH CASE STUDY

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The nutrient load to Danish lakes and coastal waters needs to be reduced in order to improve the ecological status and to meet the requirements of the EU Water Framework Directive. The intensive agricultural on arable land and the livestock production are the primary sources of nutrients and has been under regulation since the 1980's. However, further reduction is still required. Therefore, a new collective and targeted agro-environmental nutrient regulation has just been implemented, as a new direction for nutrient management and regulation in Denmark. This new regulation implies a shift towards differentiated and regionalized strategies directed towards catchments with the greatest needs for reduction e.g. catchments with low nitrogen (N) retention and vulnerable water bodies.

Subsurface tile drainage of agricultural fields lowers the natural N retention capacity of the land, as the drain water transports N directly to the surface water. The contribution of N from drainage systems to surface waters are considerable, as 50 % of the Danish agricultural area is tile drained today. Thus, in the intensely drained catchments there is a need for more and new mitigation measures such as integrated buffer zones (IBZs) that can assist in reducing the N loss from drainage systems to surface waters.

The primary functionality of IBZs is to intercept the drain flow, which otherwise is led beneath the riparian zone and directly to the surface water. The IBZ consist of two compartments: the first compartment is a pond with a free water surface, resembling a small wetland. The second compartment is a vegetated infiltration zone, acting as a saturated riparian zone. Both compartments potentially enhances N removal via denitrification, by supplying carbon from tile drain and plant growth in the pond, increasing hydraulic retention time and creating anaerobic conditions. The investigation of IBZs was initiated in 2014, as part of the project BUFFERTECH and later BIOWATER, and in this paper, water and N balances from two years of monitoring two IBZs will be presented.

INNOVATIVE DRAINAGE MANAGEMENT TECHNOLOGIES

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The sandy soils of the coastal Manawatu region are used for dairying, vegetable production, cropping and other intensive landuses. The favourable climate, coarse texture of these soils and use of irrigation result in highly productive farm systems which often have relatively large nitrogen leaching losses. The coarse nature of the soil and the use of irrigation mean that low cost mitigation practices tend to be less effective, and so more expensive ameliorative measures need to be employed to significantly reduce nitrogen leaching.

The position of these soils in the landscape and their proximity to sea level means that artificial surface drainage is often required to maintain groundwater levels below the root zone, particularly during the wet season. However, this drainage network provide a shortcut that sees excess water travel very quickly from the soil profile to the receiving stream, spending little time moving as groundwater. Therefore, there is limited opportunity for subsurface denitrification to occur and so drainage that is delivered to streams via the drain network often has a high nitrogen load.

A way to ensure that the nitrate-N attenuation capacity of groundwater is realised without compromising the important function of the artificial drainage system is required. This project designs and evaluates new 'edge of paddock' technologies to reduce nitrogen leaching losses from farm production systems, and increase water availability for irrigation in a cost-effective manner. This can be achieved by managing or controlling the water table height or drainage rate in the surface drain. Controlling drainage allows for short periods of rapid discharge of surplus water when required and longer periods where drainage is not needed. Controlled drainage increases the residence or travel time of surplus water as it moves along the water table to the drain and the opportunity for denitrification of nitrate-N. On the occasions that a lower water table is required, the drainage water can be routed through a wood-chip bioreactor to reduce the nitrate-N flux in these waters.

The ability of Controlled drainage in conjunction with bioreactors to reduce nitrogen leaching is being studied in the coastal Manawatu. This project will help farmers reduce the impact of their farms on surface water quality and help them conserve drainage waters for use as irrigation thereby reducing the demand on ground and surface water sources.

TESTING WOODCHIP DENITRIFICATION WALL TECHNOLOGY IN A SHALLOW GRAVEL AQUIFER

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Alluvial gravel aquifers represent the most important groundwater systems in New Zealand. They are particularly vulnerable to nitrate contamination from land-use impacts because they tend to be overlain by thin soils prone to nitrogen leaching. Furthermore, being unconfined and largely aerobic systems that lack electron donors to fuel redox reactions, gravel aquifers themselves have little capacity to attenuate nitrate (Burbery *et al*., 2013). As part of a research programme examining the feasibility of a variety of 'end-of-pipe' nitrate mitigation tools for the NZ agricultural landscape, we are piloting a woodchip denitrification wall (also known as a denitrifying permeable reactive barrier (PRB)) in an alluvial gravel aquifer that is impacted with nitrate. Whilst existing examples of denitrifying PRBs can be found for sandy aquifers (e.g. Schipper et al., 2000; Schmidt and Clark, 2012), our work represents the first case of a woodchip PRB trialled in a gravel aquifer setting.

In November 2018 we installed an experimental denitrifying PRB in the Silverstream catchment, North Canterbury, at a site where the water table rests within 0.5 m of ground level and groundwater nitrate concentrations are consistently 6-7 mg/L NO_3-N. We employed the hydrogeophysical method of electrical resistivity tomography to determine the important design parameters of groundwater flow direction and nitrate flux, in the shallow alluvial gravel aquifer. The PRB measures 25 m long and 5 m wide. It was constructed using a binary mixture of 50/50 (v/v) woodchip and gravel (Burbery *et al.*, 2014) that was emplaced in a dewatered trench excavated to 3 m below ground level. The particle sizes of both materials were over 20 mm nominal diameter.

So far, as of January 2019, the denitrification wall appears to be working effectively in so much that a plume of nitrate-free groundwater can be traced down-gradient from the PRB. Nitrite and ammonium concentrations within the plume are negligible, leading us to assume at this stage that the observed N-losses are primarily from heterotrophic denitrification. As we predicted, the PRB has led to mobilisation of arsenic, iron and manganese from the greywacke aquifer sediments in the anoxic area immediately down-gradient of the PRB.

NUTRIENT MANAGEMENT STRATEGIES
– HOW CAN YOU GET BEST BANG FOR YOUR BUCKS

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Land that receives farm dairy effluent, or municipal or industrial wastewater; or any other waste products requires mitigation of effects to ensure the receiving environment has the opportunity to develop sustainable healthy conditions. The receiving environment of concern generally refers to groundwater and surface waters (drains, streams, rivers or coastal waters). There are a range of technologies that can be implemented to minimise effects, but which ones should be chosen to get the best bang for your bucks, and time.

Dealing with waste products on land includes several stages before components from the waste move from a property to the surrounding environment. The objective is to optimise water treatment mitigation and provide confidence to the land owner and the community that effects are minimised. Stage one is the initial treatment often in ponds; stage two is distribution of the waste products on to land generally in accordance with consent requirements that have nutrient, volume and application rate limits; then stage three may be required for further mitigation if the water quality standards in the surface water require improvement.

The range of technologies for mitigation of waste product effects onto land include the following:

Stage 1 mitigation:	treatment ponds; chemical treatments;
Stage 2 mitigation:	land area; soil characteristics; plant species; irrigation infrastructure; land management and production types; application rates; application volumes; nutrient uptake rates;
Stage 3 mitigation:	riparian margins; shade planting, denitrification walls; wetlands.

Similar to any investment; planning contributes to optimisation of outcomes. A mitigation plan requires a long-term flexible vision because changes in water quality take time; plus a new technology tried now may not provide the results expected and another technology or improvement to that technology may be required in the future. Equally a technology or practice may become redundant if acceptable levels of improvement to the water quality is achieved, or technology reaches its expected life.

The identification and selection of technologies for a mitigation strategy is divided into 5 steps. The first steps are to understand each component of the system including the waste product, the receiving environment, and the applicable mitigation technology options. The following steps are to design the approach, then monitor outcomes to determine ongoing developments and future required changes.

SUSTAINING POSITIVE PRACTICE CHANGE

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Whether it is for policy, strategy, developing resilience or extension there is a need to engage effectively with the farmers we work with, and often the communities that support them. The purpose of this paper is to outline and discuss an approach that puts farmers at the positive centre of the process, and begins with what is working well and generates new ideas from this positivity. The engagement uses a process known as Appreciative Inquiry which is both a philosophical approach and a practical tool. It approaches challenges from a positive mindset, building on what is working well, rather than a deficit approach of starting where something is broken. It draws out ideas as a proactive inquiry rather than a presentation of existing findings. This proactive engagement of farmers helps bring forward the diverse complexities and interrelationships that all need to align for successful extension or any other interaction to take place. An example is given of an on farm Appreciative Inquiry workshop. The approach works best in a group where the participants can leverage off each other's ideas and energy, and works most effectively for complex issues where the solution may not be obvious or easy.

IRRIGATION IN NEW ZEALAND – AN EVOLVING INDUSTRY

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Technology has been the biggest and most exciting change in the irrigation sector. Real-time monitoring is now a given for all water takes. While this provides information to the regulator for compliance, its main benefit has been for improved irrigation performance. An array of sensor data can be telemetered alongside the water meter data in real-time.

Recent programmes in Canterbury and Hawke's Bay have shown irrigation decision-making technology uptake is now over 70%. However, there is the growing issue of technology rejection - too many are selling sensors as opposed to providing irrigators with the right option and on-going support.

Within 5 years technology will take over the human decision-making. Variable rate irrigation systems for precision application are now commonplace, and autonomous irrigation systems informed by artificial intelligence and remote sensing are not far away. The rapid pace of technology change means regulation needs to focus on robust decision-making not compelling the type of monitoring system to be used.

There has been over $2 billion invested in upgrading to modern spray and drip systems in the last decade. Despite this New Zealand's norwesterly weather pattern can significantly impact on efficiency - spray applications are blown off target changing the intended distribution pattern. The use of fertigation in New Zealand is still limited. We have made mistakes over the past decade with its operation and the lack of a bulk liquid fertiliser supplier has also created challenges. The potential nitrogen loss reductions from fertigation look to be significant and its use needs to be better understood.

There has been massive change with scheme infrastructure over the last decade with over $1 billion spent in modernisation. Scheme amalgamation is the next step. A handful of super schemes will soon manage over 50% of New Zealand's irrigation.

The introduction of audited Farm Environment Plans for the adoption of Good Farming Practice are starting to make a difference. While this is a step in the right direction it will not be enough in some catchments. Catchment solutions such as land retirement or infrastructure will be needed. However, we need to work through how we fund such solutions so that everyone who benefits contributes. It has been an uphill battle getting the good word out there about the significant changes and the world-leading nature of the New Zealand irrigation sector. More farmers need to 'put their head above the parapet' and tell their story of change. Industry organisations can only do so much as it is authenticity that is required with the wider public.

EVALUATION OF IRRIGATION STRATEGIES FOR ARABLE FARMS TO MITIGATE NITROGEN LOSS USING THE OVERSEER MODEL

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The aim of this study was to investigate how irrigation strategy choice, and climate parameterisation, influence water use and nitrogen leaching for irrigated arable-farming operations.

The study was undertaken as part of the 'Maximising the Value of Irrigation' programme. A component was to use and evaluate the irrigation module component of Overseer Nutrient Budgets, using a case study approach. Overseer is a farm nutrient cycle model, now used by many regulatory authorities and others for estimating farm nitrogen losses. It is important for farmers with irrigated systems, especially those subject to regional council N-loss restrictions, to be aware of the implications of choosing the most appropriate Overseer irrigation scheduling strategy. The Overseer irrigation module was upgraded in 2015, allowing users to investigate irrigation scheduling options (e.g. precision irrigation), which was not possible previously.

Irrigation scenarios were tested for each of three case study arable farms located in Hawke's Bay. The farms had a wide variety of arable crops, mixed sheep and cattle grazing, and a variety of soils with low, moderate and high profile available water. Scenarios were based on Overseer's four irrigation strategies, and parameterisation using Overseer defaults. Scenarios using fixed-fixed (fixed application depths and fixed return periods) produced the highest N-losses, irrigation consumption, and drainage losses. Scenarios using variable-variable (variable application depths and variable return periods) generally produced the lowest N-losses, irrigation consumption, and drainage losses. The exception was the fixed-variable scenario, which had slightly lower irrigation supply and drainage losses. However, it is likely that in certain cases, this scenario may not supply enough water to meet crop demand.

Where possible, we recommend the wider uptake of irrigation practice that includes a variable component to ensure depth applied is adequate. As demonstrated by the case studies, compared with fixed methods considerable efficiencies were available for minimising N-loss, water use, and deep drainage through the use of variable depths and/or returns. We also recommend that Overseer users undertake a simple check of comparing modelled irrigation water supply with actual irrigation water use.

REDUCING NUTRIENT LOSSES THROUGH IMPROVING IRRIGATION EFFICIENCY

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The purpose of this pilot study was to answer three important questions:

- How much can drainage and the associated N-loss to water be reduced by increasing irrigation efficiency?
- What changes in irrigation systems and their management would be needed to achieve this?
- What are the primary incentives and barriers to achieving the changes required?

A desk-top study using data from twelve representative dairy farms located in Canterbury with well-established computer models showed that changing irrigation practices to make more efficient use of both irrigation water and summer-time rainfall reduced N-loss to water by between 4% and 58% (average of 27%). These reductions in N-loss to water were achieved without significantly reducing modelled average annual pasture production.

To achieve this degree of N-loss reduction, changes were made to the irrigation rule used to determine when to irrigate and how much water to apply so that the soil is allowed to dry out more in the shoulders of the irrigation season and reduce the risk of rainfall-induced drainage throughout the season. To apply the new rule it is essential that:

- Soil water content is routinely measured using reputable soil moisture monitoring equipment.
- The irrigation application system can be adjusted to apply relatively small amounts of water.
- The irrigation application system has a relatively short return period.
- The irrigation water supply is very reliable.

The main incentives for changing irrigation management practices are economic and regulatory. Regulatory-based incentives to improve irrigation efficiency stem from the implementation of limits on irrigation water use and nutrient discharge. Capital investment is likely to be required on a significant number of farms in order to reduce N loss through using irrigation water and rainfall more efficiently. At some level cost will become a barrier. However lack of knowledge of the value propositions for improved irrigation management may well be the greatest barrier. Even where there is a general understanding of the value proposition, knowledge of the options available and the skills to implement them may not be sufficiently well developed to capture the value.

IRRIGATION INSIGHT – AN MBIE PROGRAMME THAT BLENDS CLIMATE, HYDROLOGY, ECONOMICS AND SOCIAL SCIENCE FOR IMPROVED WATER USE EFFICIENCY

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Irrigation Insight is an MBIE-funded co-innovation programme focussed on understanding how development of novel knowledge and tools affords dairy farmers the confidence to change established irrigation management practices, to more precisely apply the water needed—where, when and how much. The research examines the application and effectiveness of combining improved weather forecast and drainage estimations, and understanding of economic implications to inform on-farm water management on irrigated dairy farms. The programme aims to support dairy farmers in moving away from a 'just in case' or 'just in time' scheduling towards an irrigation approach that accounts for both current demand and future supply. Five pillars make up the work programme: weather forecasting, soil hydrology, social science, economics and knowledge exchange. The programme is currently implemented in 11 dairy farms across Canterbury Plains. The pilot farms are equipped with soil moisture sensors and provided site-specific short-term weather forecasts (1-6 days) to assist farmers with irrigation decision making. In addition, the economic component of the programme assists farmers in understanding the financial gains and losses resulting from their irrigation management choices. These three work streams will combine to assist decision making and improve financial and environmental outcomes for case study farms, and the lessons learned will be scaled to support wider behaviour change. The programme partners are DairyNZ, AgResearch, Fonterra and IrrigationNZ. LIC is a research partner.

SCADAfarm – USING THE CLOUD TO IMPROVE IRRIGATION MANAGEMENT ON NEW ZEALAND FARMS

Jim Hargreaves

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SCADAfarm is an innovative monitoring and control platform developed right here in New Zealand. It is designed to help farmers observe and understand their irrigation activity in a way that supports and facilitates improved irrigation practices.

Soil moisture monitoring systems have certainly brought about a greater level of engagement and helped improve irrigation management overall. Some methods are qualitative and have greatly facilitated daily decision-making whereas other methods are quantitative. Quantitative methods allow for the potential assessment of soil drainage and other associated environmental factors such as leaching. We present some of the quantitative soil moisture analyses currently achieved with the SCADAfarm platform and briefly extrapolate towards our future objectives.

Data collection and hosting services are clearly bringing value to the agricultural market. The challenge is to ensure the farmer is not overloaded with copious data, whilst being provided with useful and meaningful metrics that facilitate change. We present some of the latest irrigation monitoring services that SCADAfarm provide, especially the proof-of-placement platform for fresh water and effluent and describe some of the novel metrics currently under development. The importance of retrospective analysis and active user engagement will also be touched upon.

METHODS FOR UPSCALING AND DOWNSCALING S-MAP INFORMATION: PROVISION OF SPATIAL SOIL INFORMATION IN VARIOUS FORMATS AND SCALES

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S-map is published at a nominal cartographic scale of 1:50,000. The size of map units drawn at this scale means that S-map is best suited for use in regional-scale applications. S-map map units are too large to adequately depict the spatial variation of the soil at the farm scale, whereas applications at the national scale may not require as much detail as is contained in S-map. This suggests that transformations could be made to S-map that provide soil information that is a better fit for these scales. Transformation of S-map to fit farm-scale applications is a downscaling exercise, whereas the transformation of S-map to fit national-scale applications is an upscaling exercise. We identified a range of methods for performing downscaling and upscaling. We concluded that more contextual information is required to adequately downscale S-map than is currently available within S-map, so our main focus in this paper is on methods for upscaling S-map. In general, upscaling methods can be classified based on the order of operations that are performed: (i) geometric simplification followed by attribute simplification, versus (ii) attribute simplification followed by geometric simplification. We demonstrate an application of the first approach and its effect on water balance modelling, and an example of the second approach via simplification of map unit components into soil property groups.

TECHNOLOGIES FOR MAPPING COW URINE PATCHES: A COMPARISON OF THERMAL IMAGERY, DRONE IMAGERY AND SOIL CONDUCTIVITY WITH SPIKEY-R

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Animal urine patches are the major source of gaseous and leaching losses of nitrogen (N) for livestock grazed pastoral systems. These losses can be reduced by detecting and treating these patches by applying N inhibitors to slow down the N transformations, thus allowing more time for plant uptake. In this study, we seek to validate the output of the newly developed and modified Spikey-R (under a New Zealand Government, Global Research Alliance research project) for detecting and measuring the configuration of urine patches. We compare measurements form Spikey-R against thermal imagery from a handheld camera taken during urine deposition, as well as imagery taken from a remotely piloted aircraft system (RPAS or 'drone') two weeks after deposition. Patches were created by applying 1, 2 and 3 l of synthetic urine heated to 40 ⁰C over two soils contrasting in drainage (poorly drained and well drained) and moisture level (below and at Field capacity).

Spikey-R data generally compared well with the reference map produced from the thermal imagery, with similar mean patch areas for each soil moisture condition (+/- 12 %) and comparable patch outlines reported. On average, the patch areas reported by Spikey-R are larger than those detected by the thermal imagery when soil moisture was at field capacity and smaller or similar when soil moisture was below field capacity. Over the 48 hours post-deposition, the patch area as detected by Spikey-R increases slightly (~5%). The drone was successful in detecting all urine patches via elevated pasture response 14 days after application at the Massey No. 4 Dairy site, but was less effective at AgResearch Ruakura. Further results on the potential of these sensing technologies and needs for further improvements will be discussed.

IMPROVED MEASURING AND MODELLING OF THE 3D DISTRIBUTION OF URINE PATCHES IN GRAZED PASTURE SOILS

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Urine patches represent hot-spots of nitrogen (N) loss in dairy-grazed soils. Targeted application of urease and nitrification inhibitors that slow down certain N transformations in the urine patches is a potential method to reduce N losses. However, for optimum effectiveness the inhibitors need to be in close physical contact with the urine in the soil under urine patches. In practice, there will always be some time delay between urine deposition and application of inhibitors. It is therefore important to understand how the urine is transported in the soil following deposition.

In this study, we used urine patch area data (6 replicates) from two sites at two contrasting moisture contents, collected by thermal imaging, to derive a statistical model of urine patch area immediately following urine deposition. A linear regression model was fitted to (Urine volume)/(patch area) against air-filled pore space. This model explained 47% of the variability in the measured and predicted means patch areas with an efficiency of 0.64.

The initial urine patch area (measured or modelled depending on availability) was then used as an input to the HYDRUS 2D/3D model to calculate the subsequent vertical and lateral movement of the urine post deposition. Predicted changes in the patch surface area over time were compared with patch area calculation from electrical conductivity measurements (SPIKEY®), while the predicted vertical movement of N was compared with laboratory analyses of soil N. Results of these comparisons will be presented at the workshop.

PHOSPHORUS MITIGATION PROJECT: FARM BASED MANAGEMENT OF STORMWATER WITH DETAINMENT BUNDS FOR REDUCING PEAK FLOW AND IMPROVING WATER QUALITY

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High intensity rainfall can result in storm water run-off that raises nearby stream discharge. Peak flows from storm events can overwhelm the potential for stream conveyance (resulting in flooding) and channel stability (resulting in erosion). This increases risks to homes, businesses, infrastructure, and communities. Storm water events also contribute disproportionately to runoff-derived contaminants in receiving environments, principally sediment and phosphorus resulting in degraded water quality.

A key means of mitigating storm-water risks, is the detention and delay or reduction via infiltration, of runoff contributing to stream peak flow. Such approaches are common to urban environments with greater extent of impervious surfaces and more rainfall contributing to runoff. Until recently, storm water interception at source on farmland has been deemed impractical and instead, flood mitigation has been targeted to the at-risk lowland floodplains (e.g., flood embankment networks, pumping stations and impounding areas).

A Sustainable Farming Fund initiative called the “Phosphorus Mitigation Project” has resulted in research into “Detainment Bunds” (DBs) for interception and reduction of storm-water contaminant loads. This project has also raised the potential for other co-benefits from DBs including, flood mitigation through effective interception of storm water runoff *at source* mainly on productive pastoral farmland.

Targeted uptake of DBs might support both water quality and flood management objectives, better enabling integrated water management under the National Policy Statement for Freshwater Management and a source-to-sea contaminant approach.

We present an example of catchment-scale adoption on the Whakapounakau Aggregated Lands Trust property where 20 DB’s will service 400 Ha of mixed land use for storm water run-off treatment and flood protection. We describe the use of high-resolution LiDAR for selecting optimal DB sites on-farm and development of a GIS tool to broadly assess the suitability of large catchments for Detainment Bund uptake.

APPLICATIONS OF CONTINUOUS NITRATE-N ANALYSERS IN NEW ZEALAND FOR IMPROVED NUTRIENT ESTIMATION

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Nutrient enrichment is a major contributor to water quality impairment internationally. The New Zealand response to water quality problems includes the National Objectives Framework (NOF), and the National Policy Statement for Freshwater Management (NPS-FM 2014, amended in 2017), which describe water quality targets and resource management actions. These targets include nitrate-N concentrations and loads.

Recently NIWA reviewed data derived from hyperspectral devices used to measure near real-time nitrate-N concentrations in several catchments in New Zealand. Several themes were explored, with implications for resource management:

1. **Relationships between discrete grab sample and continuous data.**

   Good relationships between grab water quality samples and spectral data were achieved over wide concentration ranges, and very different river discharge conditions. Bias between grab sample estimates and nitrate sensor results could be addressed using regression techniques.

2. **Understanding flow and concentration dynamics.**

   High frequency data allow discharge-concentration relationships to be determined during multiple flood events under different seasonal conditions, providing insights regarding contaminant mobilisation, which may be used to guide mitigation strategies.

3. **Understanding short-term variability and potential drivers of this variability.**

   High frequency data reveals diurnal trends in nitrate concentration similar to those observed for dissolved oxygen, and will prove informative regarding nutrient cycling and short-term ecological processes.

4. **Trend assessment.**

   High frequency data are likely to be very useful for trend detection once adequate data exist. The case studies indicate that estimates of concentration at frequencies greater than fortnightly appear necessary to provide estimates of trend over two-year periods.

5. **Nitrate-N load estimation.**

   The case studies indicate that reasonable estimates of nitrate-N load may be derived from sensor data collected at daily frequency. The uncertainty in the load estimation decreases as the frequency of concentration measurement increases.

ESTIMATING NITROGEN LOSS FROM A DAIRY FARMING CATCHMENT USING THE SOIL AND WATER ASSESSMENT TOOL

Linh Hoang

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Dynamic catchment models have capabilities of representing the dynamic behaviours of complex processes and help to gain insights about the complex catchment system where direct measurement are not always feasible at large scales.

The Soil and Water Assessment Tool (SWAT) is the dynamic catchment model that has been applied across a wide range of catchment scales and conditions to assess hydrological and environmental issues. Moreover, SWAT has been developed particularly for agricultural catchments, thus, is possibly a suitable modelling tool for intensively agricultural region like New Zealand. However, since SWAT originated from the United States and was developed using Northern Hemisphere climate characteristics, SWAT application in New Zealand can be challenging.

This study tests the ability of the SWAT model to simulate water quantity and nitrogen load and concentration for a typical dairy farming catchment in New Zealand. The chosen case study is the Toenepi catchment in the Waikato Region of the upper North Island of New Zealand. Long term observations for both water quantity and water quality and knowledge from previous research studies in this catchment were used to evaluate the model performance.

The preliminary results showed that the SWAT model could predict discharge very well with daily Nash Sutcliffe Efficiencies (NSE) of 0.82 and 0.78 in the calibration and validation periods, respectively (NSE = 1 means "perfect fit"). The model performance was better at the monthly time step with NSE of 0.93 and 0.92 in the two periods. The flow variation was very well captured, however, flow at storm events were underestimated. SWAT also produced reasonable estimates and seasonal variation for nitrogen yield and concentration. Subsurface drainage is the main contribution to streamflow, and consequently is the dominant pathway for nitrogen transport to the streams.

SMARTFARMS ENVIRONMENTAL MONITORING SYSTEM

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The SmartFarms environmental monitoring system provides a simple and credible system of collating on-farm environmental health information. The system provides farmers with tools that enable them to measure and demonstrate their farm's environmental performance. Smartfarms takes quality assurance and compliance a step further. Currently the implementation and physical impact of activities such as land retirement, riparian fencing, riparian planting, reducing tillage and increasing biodiversity on-farm go unnoticed. Smartfarms provides a platform for land managers to show their impact on the environment.

In our experience most farmers are doing what they can to look after their environment. However, the benefits of these activities are long term. The concept with SmartFarms is to make annual physical measurements of soil, water and air quality which reflect progress with time (5-10 years say). In this way farmers can demonstrate their impact on the environment which may help with their license to operate and improve profitability. The system is available to all farmers who could use some or all features. Monitoring kit is $50 and an annual subscription is $100. A website and App are available (www.smartfarms.org.nz) and has been tested by farmers.

Practicality of innovation - A significant innovation of Smartfarms is for off-line data entry to cope with all rural conditions. There is a focus on making simple, quick, easy and robust measurements and quickly providing data in digital form for further analysis. Smartfarms facilitates this in a seamless, paperless and easily auditable way.

"WHOLE FARM PLANNING TO DELIVER INTEGRATED SOLUTIONS"

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There is an increasing recognition that farm planning needs to evolve beyond singular focus of either production or soil conservation to take a wider, more holistic view. This broader assessment needs to account for impacts of the farm system on receiving environments, as well as include consideration of the services provided by agricultural landscapes beyond food and fibre. Embedding farm-planning within a natural capital ecosystems approach provides the pathway to operationalise this shift.

It is still common for soil or biodiversity conservation to be dealt with in isolation from each other, both at the policy and farm scales, which narrows the opportunities to increase farm sustainability and resilience. With a considerable proportion of remaining indigenous biodiversity occurs on farmland in private ownership outside of the public conservation estate, coordinated actions on-farm is required to increase the opportunities to achieve biodiversity outcomes across a wider landscape and in parallel contribute to greater farm sustainability and resilience.

New approaches are needed to achieve these wider outcomes on-farm and beyond. These bring together business, environment and cultural goals and in doing so allows for social, cultural, environmental and production values to be recognised and enhanced, while focusing on farm performance. One key requirement for this integration to succeed is for current land evaluation and farm planning processes to recognise indigenous species as a mechanism for also increasing the sustainability and resilience of the farm business. Learning from and applying Mātauranga Māori is pivotal to achieving this. Our approach recognises that indigenous biodiversity contributes to a wide range of benefits including cultural, environmental, social, and economic values, of which conservation is just one, albeit an important, outcome. In this paper, we demonstrate through two case studies, the potential contribution of indigenous biodiversity to economic, environmental, cultural and social outcomes on and beyond the farm through advanced farm planning.

PROCESS NOT PRESCRIPTION: CATERING TO THE HETEROGENEITY OF THE NEW ZEALAND FARMING LANDSCAPE

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New Zealand sheep and beef farms are dynamic and heterogeneous. They are socio-agro-ecosystems with people and natural resources at their core. "One size fits all", prescriptive farm plan template struggle to cater for this individuality and are often seen as little more than a regulatory tool. This is a lost opportunity.

At B+LNZ we are redesigning our approach to farm planning building on our successful LEP templates. Farmers have told us that with that there is:

- confusion with the amount of different templates in the market
- lots going on in the environmental and regulatory areas; and that it's hard to keep track
- frustration that they don't get the recognition for the good work they are already doing
- that they want ongoing support with their farm plans and that they want to integrate farm planning with catchment community groups.
- That they want farm plans to be useful planning tools for their businesses

In response we are taking two key initiatives:

1. Developing an Environmental Management System for farmers. EMS are a great business tool for farmers to manage their environment – not just their regulatory requirements a. EMSs help farmers navigate in this congested space, support continuous improvement, enable farmers to document their journey and provide the opportunity their work verified/checked.
2. Developing a Catchment Community Programme. This will connect farm environment plans to Catchment and Community planning. This programme will form part of the wrap around support for EMS implementation reducing the incidence of relapse or inertia, and supporting continuous action as a behavioural metric for continuous improvement.

Both these programmes are designed around establishing a process, not prescribing a standard of performance. It doesn't matter the starting point, what is important is that we start, document our journey of continuous improvement, and have the opportunity to have that journey independently verified. This will provide our consumers, society and government the assurance they require.

THE POSSIBLE IMPACT OF A PROPOSED NITROGEN CAP ON MILK PRODUCTION AND FINANCIAL VIABILITY OF DAIRY FARMS IN THE UPPER MANAWATU RIVER CATCHMENT OF THE TARARUA DISTRICT

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This project examined the potential for increased dairy production whilst farmers operate within a regional nitrogen-cap for individual farm losses to water. The Manawatu Wanganui Region has the 6th largest number of dairy herds of any of the 14 regional councils and unitary authorities in New Zealand, it is therefore quite a significant dairying area, although it may not receive the same attention as larger regions such as Canterbury, Waikato and Taranaki. The Tararua District has about 40% of the region's herds, and over 200 dairy farms in the Upper Manawatu River catchment provided the focus for this study.

Under the provisions in the One Plan (Horizons 2014), landuse consents can be issued to land owners so that they can continue dairy farming for up to 20-25 years. In this project the authors examined the likely impact that a nitrogen cap in the One Plan might have on dairy production and farm financial viability for the life of the landuse consents of dairy farms in the Upper Manawatu River catchment.

In 2015/16, the dairy farms in the catchment had a median milking platform area of about 110 ha and a herd size of about 350 cows, producing 340 kgMS/cow or 900 kgMS/ha, or about 13 thousand tonnes of milk solids in total. Average farms had nitrogen losses to water of 40 kgN/ha/yr^{-1} or 550 tonnes of nitrogen in total.

In this study it was estimated that the nitrogen caps from the existing Table 14.2 in the One Plan would result in nitrogen losses from dairy farms dropping by over 200 tonnes/yr (50%) and milk production by over 5,000 tonnes/yr (40%). It is expected that imposing this on farmers would possibly result in 65% of dairy farms within the catchment not having sufficient operating profit to cover their existing debt levels. A nitrogen cap from a proposed revision of Table 14.2 in the One Plan was also considered. It was estimated that if all the farms in the catchment were required to operate within the revised table, nitrogen losses would drop by over 200 tonnes (38%) and milk production by over 700 tonnes over 20 years (6%). Although with the revised table, farms with typical debt levels should be able to remain financially viable a proportion will still struggle.. It is possible that some of the affected farmers would consider amalgamating and others to change their landuse.

HELPING FARMS COMPLY WITH ENVIRONMENTAL REGULATIONS: CASE STUDIES IN THE MANAWATU

Simon Redmond

Consultant, Palmerston North

There are alternative cost effective ways to meet N leaching targets in the Manawatu catchment that allow high production well over and beyond the district averages.

Through the use of two case studies the techniques will be demonstrated how to bring a farm producing over 1800kgMS per ha and leaching 50 units of N down to below 30 units while holding production and for the second case study a lower producing farm can lift its performance while coming down in leaching.

The lower production farm moves from 550kgMS/ha to 930kgMS per ha. The farm moves from a system 1 farm to a system 2/3 farm. The changes in management allow the high leaching farm to continue to farm under the priority catchment constraints. For the lower leaching farm it can preserve capital value. The way feed pads are used to hold cows up and allow better distribution of effluent over the summer months is key to the strategy. For the high performing farm it is necessary to remove solids from the farm and use this as part of the fertiliser for the maize production on the run off land. The lower production farm relies on distributing the effluent better and retiring land to forestry.

The economics rely heavily on how much grass is harvested and how well the supplements are managed both physically and cost effectively. In the high performing farm the profit margin is still greater with mitigation than destocking. For the lower producing farm lifting production opens a range of options which preserve the capital value for resale and provide different management choices. The farms are compared on economic and physical attributes. The project is sensitive to the cost of capital used for mitigation.

Key take home message is there are profitable farms using supplements and it is possible to meet environmental briefs while still producing milk.

TARAWERA FARM ENVIRONMENTAL PLANS – FARMERS BUILDING ON THE PAST, PREPARING FOR THE FUTURE

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The Project Rerewhakaaitu farmer group evolved in the 2000s from a series of projects looking at on-farm nitrogen and phosphorus mitigations. Many mitigations were incorporated into Farm Environment Plans (FEPs) developed by AgResearch.

In 2015 the non-statutory Tarawera Lakes Restoration Plan was developed by Bay of Plenty Regional Council (BORPC) with community input. Agreed actions included FEPs for the inner and outer Tarawera lakes catchments – the latter comprises the contributing catchments of Lake Rerewhakaaitu and five other lakes. The Restoration Plan also flagged the need for improved catchment modelling and potentially land use rules to limit increased nutrient inputs to the Tarawera lakes system.

Project Rerewhakaaitu and BOPRC agreed to base the new FEPs on industry templates and Overseer. Fonterra used its Sustainable Dairy Advisors to develop Tiaki FEPs and Beef and Lamb New Zealand ran two Land and Environment Plan workshops, with one-to-one follow-up by local farm consultants. As participation was voluntary, farmers were given written assurances that individual farm data would remain confidential and only aggregated catchment nutrient data would be published.

48 FEPs were completed by spring of 2018. There are 32 Tiaki FEPs covering 5300 hectares with a combined 1060 on-farm actions. There are 16 LEPs covering 6800 ha. Key averaged effective area Overseer results (v6.3.0) were:

- Dairy (Tiaki): 46-58 kgN/ha/yr and 1.3-2.5 kgP/ha/yr;
- Dairy Support (Tiaki) 34-51 kgN/ha/yr and 1.8-3.8 kgP/ha/yr;
- Drystock (LEPs): 16-32 kgN/ha/yr and 1.1 to 3.9 kgP/ha/yr;
- Drystock P losses appear to correlate with soil type.

While some of these lake catchments are meeting their Natural Resources Regional Plan water quality targets (expressed as 3-year average Trophic Level Index or TLI), Lake Tarawera remains above its 2.6 TLI target. Aggregated nutrient loss data from this FEP project will help inform catchment modelling. This will in turn inform the local community on the complex linkages within the Tarawera lakes system and the need for any land use rules.

HOW WE CAN ALL CONTRIBUTE TO RESOLVING NUTRIENT WATER QUALITY ISSUES AND SUSTAINABLE LAND USE

Mike Freeman

Landpro, Cromwell

There are huge challenges involved in understanding and quantifying land use practices that generate nutrient losses that result in water quality objectives not being achieved. There are also many possible different approaches to managing land use to achieve water quality objectives and many different drivers behind the different approaches that have been used, are being used and are being developed. There is no one right way. However, there are enough examples throughout New Zealand to start identifying some specific examples of opportunities for improvement.

The purpose of this paper is to highlight some important issues that reduce our ability to achieve both water quality objectives and sustainable land use management. The focus is on the use of information and the planning framework that contributes to the development and implementation of regional plan policies and rules aimed at maintaining or enhancing water quality. The issues identified in this paper are based on observations of water quality, water resource management planning and regulatory processes in many regions.

The issues and suggested solutions identified are presented to stimulate discussion. Not all issues occur in all regions, but they do occur to a greater or lesser extent in at least one region. They highlight the areas where we can all contribute to enhance the progress towards the achievement of both water quality objectives and sustainable land use.

The paper will focus on the following specific issues that are collectively having a significant adverse effect on our collective ability to make progress.

1. Deficiencies in the Resource Management Act, primarily in the regional plan development process
2. Insufficient recognition of modelling uncertainty during policy development and in the regional plan/rule implementation process.
3. Limited public access to robust, timely, relevant research, investigation and monitoring information on sustainable land use and water quality
4. Limitations in the processes used to obtain and transfer robust technical information to decision makers.
5. Poor policy strategies and tactics resulting from limited information and/or insufficient analysis of options and implications.
6. Limited plan and resource consent implementation, monitoring and feedback programmes.

THOUGHTS ON THE ALLOCATION OF NUTRIENTS:

THE ISSUE WITH NATURAL CAPITAL ALLOCATION.

Phil Journeaux

AgFirst, Hamilton

This paper principally discusses the concept of the "natural capital" approach to nitrogen allocation under the aegis of council implementation of the NPS for Freshwater Management through water quality plans. While there are some definitions of natural capital, most people relate it to the productivity of the land, based on Land Use Category (LUC) classification.

There are a number of issues that then arise with using LUC, which are discussed within the paper:

- There are large variations within and between LUC classifications, so the boundaries and productivity levels between can be very grey – some lower LUC levels can be as productive as higher levels
- The relationship between LUC and nitrogen leaching is tenuous, raising the issue that if a factor has little relationship with nitrogen leaching why use it as a proxy for allocating nitrogen leaching allowances
- Since LUC classifications were developed, technologies and farm management has moved on, meaning that they can be applied to radically alter the productivity of the soils
- Land use is driven by a wide range of factors, of which the biophysical aspects of the soil are but one, and not necessarily a significant driver. As a result, a natural capital allocation system will not drive land use to its "highest and best" or "optimal" use. Nor will it change inappropriate farming systems.
- All allocation systems have their various inequities; one of the features of a natural capital approach is that it tends to maximise economic and social disruption

Two regions have implemented a natural capital allocation approach, which provide good examples of significant anomalies and economic inefficiencies, which again will be discussed.

The paper finished with a brief discussion on trading. This is not specific to natural capital, although some natural capital proponents argue trading is not necessary as a result of the natural capital allocation. But it is, in order to improve flexibility and efficiency of nutrient use within the cap, regardless of the allocation approach.

DEVELOPMENT OF A NITROGEN RISK SCORECARD

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Fonterra's Nitrogen Management programme has been running since 2012/13 season. The programme formed part of Fonterra's commitments under the Sustainable Dairying: Water Accord, collecting nutrient management data and modelling it in OVERSEER ®using agreed industry protocols to report a nitrogen leaching to water and nitrogen use efficiency figure to all farmers.

The Nitrogen Programme has been successful in raising farmer awareness of the environmental risks around nitrogen, however, there are limitations to reporting whole farm level metrics when trying to focus farmer action on specific practices that are contributing to the nitrogen loss risk.

As a result, Fonterra, have been developing an alternative approach to delivering our Nitrogen Programme, in a way that better fits with our strategic focus on achieving good farming practice outcomes through Farm Environment Plans.

This led to the development of a Nitrogen Risk Scorecard, a tool that provides for a simplified objective assessment of the level of risk of nitrogen loss from a farm. The Scorecard uses annual farmer data relating to six key farm practices and applies a level of risk to each of those practices against a set of benchmark parameters. The Scorecard report also includes a weighted aggregated risk score for the property.

With no manual data processing, the Scorecard is a practical cost-effective method of identifying high risk farms or inefficient management practices. Our Sustainable Dairy Advisors can then focus their time to supporting farmers and utilising the Scorecard to help inform the type of actions appropriate to manage the risks through tailored Farm Environment Plans.

It's our view the Scorecard may have a place in regulated catchments due to its ability to simplify the implementation process and decrease the costs and complexity of managing nitrogen. A method that reports on factors understood by, and within the control of farmers, is more likely to lead to enduring change than the current focus on a modelled whole farm leaching number.

THE CASE FOR A NOVEL AGROFORESTRY SYSTEM AND CROSS-SECTOR COLLABORATION

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As farms throughout NZ face increasing pressure to reduce livestock intensity, there is increasing support to plant more trees, for example the one billion tree programme. Agroforestry systems that incorporate woody perennial trees on farms are widely proven with dominant systems in NZ being discrete woodlots grown for timber and/or carbon sequestration, widely spaced trees for erosion control, and shelter and amenity plantings. Next generation systems (NGS) are redesigns of enterprises and production systems, or new enterprises or technologies that can break the locked-step relationship between profitability, production and environmental footprint. As farmers are encouraged to take up NGS by replacing livestock with crops or trees, some rural entrepreneurs are showing a shared interest in new systems that dissolve the barriers between livestock, horticulture crops and forest trees.

This paper reviews the case for a novel agroforestry system in the Rotorua lakes catchments, based on an interest in trees that can produce edible nuts, shared by three quite different rural entrepreneurs; a Māori forest owner, a small block/life-style farmer, and a sheep/beef/forest farmer. Each entrepreneur has been independently exploring the changes they can make to their land use systems by either implementing field trials through to getting a fine spatial resolution, biophysical suitability assessment that considers current and future climates. These entrepreneurs have also completed a multi-criteria decision making (MCDM) framework developed to assess land use business decisions influenced by a range of factors, including regional environmental limits. The assessments identified that they all had common value priorities for the environment and social well-being. Posed as key next steps to de-risking this novel agroforestry system is to build on these value synergies using cross-sector collaborations, and to explore scalability options across the different landscapes.