35th Annual FLRC Workshop

DIVERSE SOLUTIONS FOR EFFICIENT LAND, WATER AND NUTRIENT USE

8th, 9th and 10th February 2023

Massey University

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Teaching and Research on Nutrient and Environmental Management for Agriculture, Horticulture and Forestry

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Massey University FLRC 35th Annual Workshop Programme

Wednesday 8th February

10.10am	Welcome & Opening Remarks - Prof Chris Anderson, *Director, Farmed Landscapes Research Centre*	
10.20am	Prof Ray Geor, *Pro-Vice Chancellor, College of Sciences, Massey University*	

Session 1: Diverse Solutions - The Big Picture

Chair: Chris Anderson

10.30am	**Richard McDowell *(Invited Speaker)*** *AgResearch* OVERVIEW OF 'GROWING FOR GOOD'	Pg. 11
11.05am	**Jacqueline Rowarth** *Lincoln University* THE GOAL, THE CONCEPTS, AND THE PATH TO SUCCESS	Pg. 12
11.25am	**Alec Mackay** *AgResearch* THE GRASS IS TELLING US SOMETHING DIFFERENT	Pg. 13
11.45am	**Discussion**	

Lunch: 12.00pm - 1.10pm

Session 2: Diverse Solutions for Carbon

Chair: Lucy Burkitt

1.10pm	**Beverley Henry *(Keynote Speaker)*** *School of Biology and Environmental Science, Queensland University of Technology* SOIL CARBON CREDITS – HUGE OPPORTUNITY OR POTENTIALLY HIGH RISK? IT'S COMPLEX!	Pg. 14
1.50pm	**Dan Bloomer** *LandWISE* CAN WE REGENERATE SOIL CARBON IN SOILS USED FOR INTENSIVE FIELD CROPPING?	Pg. 15
2.00pm	**Neha Jha** *Massey University* BUILDING SOIL CARBON STOCK BY PLANTING SHELTERBELTS IN TEMPERATE GRAZED PASTURES	Pg. 16
2.10pm	**Miko Kirschbaum** *Manaaki Whenua - Landcare Research* OBSERVED AND MODELLED CARBON FLUXES AT A GRAZED SITE WITH CO2 ENRICHMENT	Pg. 18
2.20pm	**Discussion**	

Afternoon Tea: 2.35pm - 3.05pm

Session 3: Diverse Solutions for GHGs

Chair: James Hanly

3.05pm	**Keren Ding** *AgResearch* THE EFFECTS OF DIFFERENT URINARY NITROGEN RATES ON GASEOUS NITROGEN FLUXES AFTER SYNTHETIC COW URINE DEPOSITION	Pg. 19
3.15pm	**Donna Giltrap** *Manaaki Whenua - Landcare Research* THE CHALLENGE OF ENSURING GOOD PHYSICAL MIXING OF INHIBITOR APPLIED TO A URINE PATCH	Pg. 20
3.25pm	**Grace Chibuike** *AgResearch* AN ASSESSMENT OF THE THRESHOLD CONCENTRATIONS OF NITRIFICATION INHIBITORS TO REDUCE URINE NITROGEN NITRIFICATION RATES ON PASTURES SOILS	Pg. 21
3.35pm	**Jiafa Luo** *AgResearch* THE EFFECTS OF DIFFERENT PLANTAIN (PLANTAGO LANCEOLATA) PROPORTIONS IN PASTURE ON GASEOUS NITROGEN LOSS AFTER URINE DEPOSITIONS ON CONTRASTING SOIL TYPES	Pg. 23
3.45pm	**Priscila Simon** *AgResearch* SOIL N STATUS AND MOISTURE AFFECTING THE ABILITY OF PLANTAIN TO REDUCE N2O EMISSIONS FROM CATTLE URINE	Pg. 24
3.55pm	**Bill Carlson** *AgResearch* COMPARISON OF NITROUS OXIDE EMISSIONS AND SOIL NITROGEN LEVELS FROM PLANTAIN AND RYEGRASS/ WHITE CLOVER PASTURES ON A WAIKATO FARM	Pg. 25
4.05pm	**Liyin Liang** *Manaaki Whenua - Landcare Research* LOWERING FOLIAGE N CONTENT BY CHANGING PASTURE PLANT SPECIES COULD REDUCE N2O EMISSIONS AND INCREASE FORAGE PRODUCTION: AN ANALYSIS COMBINING EDDY COVARIANCE MEASUREMENTS WITH PROCESS-BASED MODELLING	Pg. 26
4.15pm	**Nigel Meads** *Alltech New Zealand* THE RELATIONSHIP BETWEEN DIETARY INCLUSION OF WHEAT AND PALM KERNEL AND METHANE EMISSIONS DETERMINED USING IN VITRO METHODOLOGY	Pg. 27
4.25pm	**Di Lucas / Larry Burrows** *LandPlan Trust* LANDPLAN - THE ONLINE TOOL FOR TESTING VIRTUAL CHANGES IN LAND USE MANAGEMENT ON GHG EMISSIONS	Pg. 29
4.35pm	**Catherine Sangster** *Ministry for Primary Industries - Manatū Ahu Matua* INCLUSION OF SUPPLEMENTARY FEED IN THE AGRICULTURAL INVENTORY MODEL FOR DAIRY, SHEEP AND BEEF	Pg. 30
4.45pm	**Discussion**	

Thursday 9th February

Session 4: Delivery of Diverse Solutions

Chair: Ants Roberts

8.30am	**John Roche *(Invited Speaker)*** *Ministry for Primary Industries - Manatū Ahu Matua* AN INTRODUCTION TO ON FARM SUPPORT, A NEW SERVICE FOR FARMERS AND GROWERS	Pg. 32
9.00am	**Simon Rosendahl Bjorholm *(Keynote Speaker)*** *SEGES Innovation* DANISH EXPERIENCE WITH CATCHMENT OFFICERS AND IMPLEMENTATION OF NITROGEN MITIGATION PRACTICES	Pg. 33
9.45am	**Adrian Brocksopp** *Element Environmental Ltd* BUILDING CAPABILITY AND CAPACITY FOR RESOURCE MANAGEMENT	Pg. 34
9.55am	**Discussion**	

Morning Tea: 10.10am - 10.35am

Session 5: Diverse Solutions On-Farm

Chair: Dave Horne

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10.45am	**Estelle Dominati** *AgResearch* FARM PLANNING: MOVING FROM COMPLIANCE TO STRATEGIC PLANNING	Pg. 36
10.55am	**Laura Grundy** *AgResearch* CHALLENGES TO ENABLING OPEN DATA: A FARM SYSTEMS CASE STUDY	Pg. 38
11.05am	**Tom Stephens** *Te Kaunihera o Tāmaki Makaurau - Auckland Council* ACCOUNTING FOR CHANGE: A PIONEERING APPROACH TO OPTIMISED CATCHMENT ACTION PLANNING USING THE FRESHWATER MANAGEMENT TOOL	Pg. 39
11.15am	**Carla Muller** *Perrin Ag* IMPROVED UNDERSTANDING OF HORTICULTURAL GROWER SYSTEMS WITHIN THE PUKEKOHE AREA TO INFORM THE FRESHWATER MANAGEMENT TOOL	Pg. 40
11.25am	**Eva Harris** *Enviro Collective* PRINCIPLES OF SUCCESSFUL SUSTAINABLE CHANGE SOLUTIONS – A CASE STUDY	Pg. 42
11.35am	**Shane Gilmer** *Environment Canterbury* ŌTŪWHAREKAI – ASHBURTON ALPINE LAKES ADVANCED FARM PLANNING	Pg. 43
11.45am	**Lisa Arnold** *WSP New Zealand* LAND USE FEASIBILITY STUDY FOR NGĀTI TAHU NGĀTI WHAOA (WAIKATO)	Pg. 44
11.55am	**Discussion**	

Lunch: 12.10pm - 1.10pm

Session 6: Diverse Solutions for Water

Chair: Chris Tanner

1.10pm	**Fleur Matheson** *National Institute of Water and Atmospheric Research (NIWA)* NEW DESIGN GUIDE FOR RIPARIAN BUFFERS TO MEET WATER QUALITY OBJECTIVES	Pg. 45
1.20pm	**Reza Moghaddam** *University of Waikato* METHANOL DOSING INCREASES NITRATE REMOVAL IN WOODCHIP BIOREACTORS WITH NO SUBSTANTIAL ADVERSE EFFECTS: LABORATORY AND FIELD EVIDENCE	Pg. 46
1.30pm	**Gimhani Perera** *University of Waikato* BIOGEOCHEMICAL PATHWAYS FOR PHOSPHORUS REMOVAL IN WOODCHIP BIOREACTORS	Pg. 47
1.40pm	**Dorisel Torres-Rojas** *University of Waikato* SIMULTANEOUS PHOSPHORUS REMOVAL AND REDOX BUFFERING OF DENITRIFYING BIOREACTORS USING ORGANO-MINERAL COMPOSITES	Pg. 49
1.50pm	**Rupert Craggs** *National Institute of Water and Atmospheric Research (NIWA)* FILAMENTOUS ALGAE NUTRIENT SCRUBBERS FOR AGRICULTURAL DRAINAGE TREATMENT AND NUTRIENT RECOVERY	Pg. 50
2.00pm	**Harizah Hariz** *National Institute of Water and Atmospheric Research (NIWA)* FILAMENTOUS ALGAE AS A NUTRIENT SCRUBBER FOR AGRICULTURAL DRAINAGE TREATMENT	Pg. 51
2.10pm	**James Sukias** *National Institute of Water and Atmospheric Research (NIWA)* A CONSTRUCTED WETLAND RECEIVING DAIRY FARM RUN-OFF: EFFECTIVENESS DURING HIGH FLOW EVENTS COMPARED WITH BASEFLOW	Pg. 52
2.20pm	**Ben Woodward** *National Institute of Water and Atmospheric Research (NIWA)* MITIGATING THE POTENTIAL FOR CONSTRUCTED WETLANDS TO RELEASE DISSOLVED REACTIVE PHOSPHORUS	Pg. 54
2.30pm	**Chris Tanner** *National Institute of Water and Atmospheric Research (NIWA)* DIVERSE SOLUTIONS FOR DIFFUSE CONTAMINANT MITIGATION: WHICH GOES WHERE FOR WHAT?	Pg. 55
2.40pm	**Discussion**	

Afternoon Tea: 2.55pm - 3.20pm

Session 7: More Diverse Solutions for Water

Chair: Ranvir Singh

3.20pm	**Lee Burbery** *DairyNZ* A COMPARISON OF THREE DIFFERENT EDGE-OF-FIELD NITRATE MITIGATION PRACTICES, AS REALISED FROM FIELD TRIALS	Pg. 56

3.30pm	**John Paterson** *Phosphorus Mitigation Project Inc.* DETAINMENT BUNDS PS120 AS A TOOL FOR MITIGATING THE HYDROLOGICAL IMPACT OF POST-SETTLEMENT LAND DISTURBANCE AND CLIMATE CHANGE	Pg. 57
3.40pm	**Andrew Hughes** *National Institute of Water and Atmospheric Research (NIWA)* HOW EFFECTIVE ARE DETAINMENT BUNDSPS120 AS A POLLUTANT MITIGATION TOOL IN NEW ZEALAND?	Pg. 58
3.50pm	**Linh Hoang** *National Institute of Water and Atmospheric Research (NIWA)* HYDROLOGICAL MODELLING FOR DETAINMENT BUNDS	Pg. 60
4:00pm	**Zachary Dewhurst** *AgResearch* SPATIAL DISTRIBUTION OF DUNG UNDER REGENERATIVE AND CONVENTIONAL GRAZING PRACTICES	Pg. 61
4.10pm	**Ryan Barlow** *AgResearch* NITROGEN LEACHING IN A DAIRY FARMLET GRAZING STUDY AS AFFECTED BY USE OF SPIKEY®	Pg. 62
4.20pm	**Donna Giltrap (on behalf of Joseph Pollacco)** *Manaaki Whenua - Landcare Research* REDUCING NITRATE LEACHING AND IRRIGATION BY BRINGING USER-FRIENDLY, PHYSICAL AGRO-HYDROLOGICAL MODELS TO THE FARMING COMMUNITY	Pg. 63
4.30pm	**Rowland Tsimba** *Genetic Technologies Ltd* DEVELOPING A SUCCESSFUL NITROGEN MITIGATION STRATEGY IN A MAIZE GRAIN - CATCH CROP PRODUCTION SYSTEM	Pg. 64
4.40pm	**Alex Dickson** *LandWISE* BEST PRACTICE MANAGEMENT OF NITRATES IN PROCESS CROPPING	Pg. 65
4.50pm	**Suha Sanwar** *Massey University* CHARACTERISATION OF HYDROLOGY AND DENITRIFICATION POTENTIAL IN HILL COUNTRY SEEPAGE WETLANDS	Pg. 66
5.00pm	**Discussion**	

Networking in AgHort Foyer: 5.15pm - 6.15pm

Workshop Dinner at Refectory: 6.30pm

Friday 10th February

Session 8: Developments with Overseer

Chair: Alastair Taylor

9.00am	**Donna Giltrap** *Manaaki Whenua - Landcare Research* MULTI-LAYER SOIL HYDROLOGY MODELLING IN OVERSEER	Pg. 67
9.10am	**Jean-Paul Tavernet** *Overseer* IMPACT OF USING DIFFERENT CLIMATE DATASETS IN THE OVERSEER MODEL	Pg. 68
9.20am	**Hamish Brown** *Plant and Food Research* ACCOUNTING FOR DEEP ROOT N UPTAKE IN OVERSEER	Pg. 70
9.30am	**Hamish Brown** *Plant and Food Research* IMPROVEMENTS TO THE OVERSEER CROP MODEL	Pg. 71
9.40am	**Jean-Paul Tavernet** *Overseer* SENSITIVITY AND UNCERTAINTY ANALYSES FOR N-LOSS ESTIMATES BY THE OVERSEER MODEL	Pg. 72
9.50am	**Discussion**	

Morning Tea: 10.05am to 10.35am

Session 9: Diverse Solutions for Soils and Pastures

Chair: Ian Power

10.35am	**Nicole Schon** *AgResearch* ON FARM-SOIL HEALTH ASSESSMENT AND DECISION MAKING	Pg. 73
10.45am	**Duy Tran** *AgResearch* APPLYING ADVANCED GEOSPATIAL TECHNOLOGIES TO QUANTIFY SOIL HEALTH VARIATIONS IN AGROECOLOGICAL LANDSCAPES: A CASE STUDY IN NEW ZEALAND HILL COUNTRY FARM	Pg. 74
10.55am	**Matthew Taylor** *Waikato Regional Council* RECOVERY OF SOIL AFTER OVERIRRIGATING WITH DAIRYSHED EFFLUENT	Pg. 75
11.05am	**Katie Beecroft** *Lowe Environmental Impact* MATCHING SOILS AND IRRIGATION AUTOMATION FOR SUSTAINABLE USE OF WASTEWATER	Pg. 76
11:15am	**Janani Palihakkara** *Massey University* REDOX-INDUCED PHOSPHORUS RELEASE IN CRITICAL SOURCE AREAS UNDER SHORT-TERM SUBMERGENCE IN WINTER	Pg. 78
11.25am	**Dugald Hamilton and Jeff Brown** *Respond International and Fonterra* FIELD TRIALS OF MULTISPECIES PASTURES AND ACTIVE BIOLOGICS TO ENHANCE PRODUCTIVITY AND NUTRIENT UPTAKE	Pg. 79
11.35am	**Jeff Morton** *MortonAg* STARTER NITROGEN AND PHOSPHORUS FERTILISER TO ESTABLISH CLOVER SWARDS	Pg. 81

11.45am	**Jeff Morton** *MortonAg* CLOVER TEST STRIPS FOR IDENTIFICATION OF MOLYBDENUM DEFICIENCY	Pg. 82
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Lunch: 12.10pm - 1.20pm

Session 10: Diverse Solutions for Animals

Chair: Callum Rees

1.20pm	**Rene Corner-Thomas** *Massey University* INFLUENCE OF SHELTER ON THE SPATIAL BEHAVIOUR OF EWES DURING LAMBING	Pg. 83
1.30pm	**Muhammad Wasim Iqbal** *Massey University* FACTORS AFFECTING GRAZING AND RUMINATION BEHAVIOURS OF DAIRY COWS IN A PASTURE-BASED SYSTEM IN NEW ZEALAND	Pg. 84
1.40pm	**Rachel Durie** *Perrin Ag Consultants* INCORPORATING COMPOSTING SHELTERS ON FARM: FINDINGS FROM RECENT FARMER CASE STUDIES	Pg. 85
1.50pm	**Yin Ying Chin** *Massey University* THE QUANTIFICATION OF RELATIVE STOCK UNITS FOR HORSES WITHIN A PASTURE-BASED PRODUCTION SYSTEM	Pg. 86
2.00pm	**Yin Ying Chin** *Massey University* SEASONAL FLUCTUATION OF LIVESTOCK NUMBERS ON EQUINE STUD FARMS AND THE IMPACT ON MODELLING OF FARM LEVEL NITROGEN LEACHING	Pg. 87
2.10pm	**Discussion**	

Concluding remarks: 2.25pm - 2.40pm

Thank you to the following sponsors for their ongoing support of FLRC and our Workshop


Stable Micro Systems

GROWING FOR GOOD: PRODUCING A HEALTHY, LOW GREENHOUSE GAS AND WATER QUALITY FOOTPRINT DIET IN AOTEAROA, NEW ZEALAND

R.W. McDowell[1,2], A Herzig[3], T J van der Weerden[3], C. Cleghorn[4], W. Kaye-Blake[6]

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[2] Faculty of Agriculture and Life Sciences, Lincoln University, Lincoln, New Zealand
[3]Manaaki Whenua, Landcare Research, Palmerston North, New Zealand
[4] AgResearch, Invermay Agricultural Centre, Mosgiel, New Zealand
[5]Department of Public Health, University of Otago, Wellington, New Zealand
[6] New Zealand Institute of Economic Research, Wellington, New Zealand
[*]Corresponding author's email: richard.mcdowell@agresearch.co.nz

Food production plays a central role in the health of humanity and our environment. New Zealand produces a large amount of food, but it is unknown if it can produce enough of the right crops in the places to better the health of New Zealanders, profitably, while maintaining New Zealand's primary production exports and meeting ambitions to lower greenhouse gas (GHGs) emissions and nutrient losses to water. We tested two scenarios that aimed at delivering a healthy diet while maximising profit and minimising GHGs (climate-focused scenario) or losses of nitrogen (N) and phosphorus (P) to water (freshwater-focused scenario). Land use change was targeted to areas not currently meeting bottom lines for N or P loss but needed to spill over to other areas to meet dietary targets in both scenarios. The maximum cost of the required land use change was about 1% of the primary sector's export revenues, and orders of magnitude less than the estimated savings for the health system from an optimised diet. We conclude that shifting productive land uses can help meet environmental targets for GHGs, N and P while saving money and improving the health of its people. The full paper outlining this work is available at: https://doi.org/10.1080/03036758.2022.2137532

THE GOAL, THE CONCEPTS AND THE PATH TO SUCCESS

Jacqueline S. Rowarth[1,2], Ants H.C. Roberts[2] and Mike J. Manning[2]

[1]Lincoln University and [2]Ravensdown

New Zealand has set the goal of reducing the environmental footprint of agriculture, particularly through reducing greenhouse gasses (Climate Change Response (Emissions Trading Reform) Amendment Act 2020) and contaminants to ground and surface water (Essential Freshwater Reforms 2020), especially nitrogen. In Fit for a Better World, the Government's vision for the future launched in 2020, regenerative agriculture was proposed as a foundation for the design of a New Zealand approach to agricultural sustainability with an expectation "that regenerative farming systems will improve the profitability of farming while leaving behind a smaller environmental footprint". Reviews have been produced supporting the opportunity and identifying research needs and significant funding has been invested in setting up trials through the Sustainable Food and Fibre Futures Fund of the Ministry for Primary Industries. At the same time, research results from ongoing conventional research, plus farmer experience, are building a picture that what is being proposed in RA does not, in grazing systems in New Zealand (and Australia), improve profitability and does not necessarily result in a decreased environmental footprint. When area of land required for a given yield is considered, environmental footprint is higher than conventional approaches. The less than positive economics associated with grassland RA have been highlighted in the media and analysed for Australia. The problem is the amount of feed grown without application of mineral fertilisers, including nitrogen and the ability of the stock to be managed to maintain pasture quality when hyper-diverse pastures are sown. This leads to slower growth/production and increased GHG per kg of product. In addition, the soil disturbance for sowing (or undersowing) species plus the effect if increased bare land, has been found to increase GHG emissions over all in comparison with conventional pasture. The increase in soil carbon is small against New Zealand's already high content and does not offset the increase in methane associated with slower growing animals. RA does have potential in some arable and horticultural operations where the approach could be integration with animals in some circumstances, and to include cover crops to minimise bare soil where appropriate. Note that rotational cropping is the norm in NZ already, and the type of tillage (conventional, strip till or no-till, for instance) used depends upon the ground to be cropped, the crop and season. For New Zealand's sustainable agricultural future, research that allows drivers of change to be identified, and then integrated into farm systems, continues to be the likely path to success. The holistic pursuit of continuous improvement, touted as a distinguishing feature of RA, is not unique in NZ where soil, plant, animal and environmental research have combined with economics to put New Zealand at the forefront of sustainable food production. It is, however, the integration of specific disciplines that have made the difference, in combination with innovative farmers challenging the *status quo*.

THE GRASS IS TELLING US SOMETHING DIFFERENT

Alec D. Mackay[1], Mike B. Dodd[1], Kathryn J. Hutchinson[1], Ronaldo E. Vibart[1], Brian P. Devantier[1] and Franco Bilotto[1]

[1]AgResearch

Scientific publications and reports indicate that predicted future climatic changes and elevated CO_2 in New Zealand, using climate driven modelling will likely show generally positive or neutral outcomes for herbage accumulation in wetter and cooler environments and a neutral to small negative outcome in summer dry environments. However, evidence based on the analysis of pasture and animal production data from both dairy and sheep and beef systems collected over the last 20-40 years, suggests herbage accumulation is static or declining.

The long-term phosphorus (P) fertiliser and sheep grazing experiment at the AgResearch Research Station at Ballantrae provides a unique resource to examine long-term changes in net herbage accumulation (NHA) and animal production under conditions where soil P fertility have been non-limiting since the 1980's. In this paper, we examine historical NHA, sheep stock rate, soil phosphorus (P) and nitrogen (N) fertility from the high fertiliser (HF) farmlet, and pasture growth trends using the climate driven pasture growth module AgPasture within APSIM. On the medium slope of the HF farmlet, NHA in 2020-21 was only 87% of that measured on the same farmlet between 1982-88, even though P is non-limiting. The measured decline in NHA aligns with a reduction of on-site nominal sheep stocking rates since the late 1990's.

Prior to this paper, climate driven modelling has often predicted a likely positive outcome in NHA for this environment into the future. Understanding the apparent discrepancy between predictions into the future with what is happening on the ground today is discussed in the paper, as is the implications of the findings to industry and policy going forward.

SOIL CARBON CREDITS – HUGE OPPORTUNITY OR POTENTIALLY HIGH RISK? IT'S COMPLEX!

Beverley K. Henry

Faculty of Science, Queensland University of Technology, Australia

Soil carbon is complex, existing in a mixture of compounds that transform and cycle across the biosphere and atmosphere over periods ranging from days to centuries or longer. There is wide agreement amongst agronomists and soil scientists that soils high in organic matter will generally be healthier and more productive, but there are divergent views on the value of soil carbon sequestration as a climate change mitigation strategy. Sequestration in soil counts as abatement when carbon is stored long-term ('permanently') in stable forms so that it represents a net removal of carbon dioxide from the atmosphere. The complexity of soil carbon dynamics and influence of multiple landscape, climate, and management variables contribute to differing interpretations of the role of carbon sequestration and of the value of soil carbon offsets in "carbon farming" market mechanisms. Inconsistent use of terminology and measurement methods are also significant challenges. Process understanding and prospects for accurate, cost-effective monitoring are improving, but to date there are very few data quantifying soil carbon stock changes over multiple decades to the standards required to ensure verifiable high-quality carbon offsets which can have credibility in carbon markets. In 2014, the Australian Emissions Reduction Fund (ERF) was the first government scheme to approve methods for crediting and payment for soil carbon sequestration, with the first credits (Australian Carbon Credit Units, ACCUs) being issued for a soil carbon project in 2019. Soil carbon sequestration is expected to play a role in Australia's 2030 and 2050 Paris Agreement target, but uncertainty in achievable sequestration currently makes projections of this contribution difficult. Globally, better understanding is needed of sequestration potential and the carbon and non-carbon co-benefits or trade-offs for soil carbon positive practices to inform climate change mitigation policies and investment. Land managers interested in prospects for carbon credits (and potentially income from sale of offsets) also need relevant information for their regional conditions, farming systems and management history. Opportunities and risks differ regionally but experience with implementation of the ERF in Australia may also help inform consideration of land management for soil carbon sequestration elsewhere, including in countries with less extreme climates, higher quality soils and more intensive management systems such as New Zealand.

CAN WE REGENERATE SOIL CARBON IN SOILS USED FOR INTENSIVE FIELD CROPPING?

Dan Bloomer[1], Phillip Schofield[2], David France[2] and Alex Dickson[1]

[1]LandWISE Incorporated
[2]Hawke's Bay Future Farming Trust

To scientifically test regenerative farming principles within a typical New Zealand cropping system, we have established a six year trial on the Heretaunga Plains. The trial at the LandWISE MicroFarm is a collaboration with the Hawke's Bay Future Farming Trust. The information produced will increase understanding of benefits, impacts for conversion, support the development of decision-making tools and increase confidence in regenerative farming principles through the value chain.
Our trial is a systems comparison, evaluating differences between a conventional high input, high output cropping system and a system producing the same crops managed according to regenerative practice principles. A third hybrid treatment can adopt practices from either system, evaluating the effectiveness of selecting only some new practices, or aiming to model a transitional approach to conversion from conventional practice to a regenerative one.

Strict definition of regenerative cropping has been deliberately avoided in favour of adherence to generally agreed principles: minimise soil disturbance, keep the soil covered, keep living roots in the soil at all times, grow a diverse range of crops, and introduce grazing animals. Additional principles are to minimise the use of artificial fertilisers and sprays. Importantly, there is no "ban" on any practice should it be deemed an appropriate management response. The trial site has moderately degraded soils after almost ten years continuous cropping. It has been split into 12 mini-paddocks, each 12 m wide and 90 m long. This provides four replicates of each treatment. The width enables use of conventional process cropping machinery, fitting 12 m, 6 m, 4 m, 3 m or 2 m equipment. The length ensures equipment is functioning correctly and sampling can avoid ends of rows.

Key parameters measured include soil factors such as carbon stocks, labile carbon, visual soil assessment (VSA), aggregate stability, and worm counts. Also measured are crop development, yield and quality, and profitability assessed via gross margins using input costs and standard contractor rates.

Project establishment saw baseline measurement via an EM map at 50 and 120 cm, and VSA soil quality assessments. Carbon stocks and labile carbon (HWEC), total nitrogen and labile nitrogen (HWEN) and Olsen P were measured to 90 cm in four depth bands. The EM map shows a high degree of homogeneity across the trial site. The VSA tests were also consistent, showing the soils to be in "moderate" condition, neither good nor poor. This allows for the imposed management to either further decrease quality or regenerate it.

The first crop planted was process sweetcorn for McCain Foods, an industry partner. Land had come out of 18 month pasture that was sprayed out. Everything was strip-tilled, then the conventional treatment also power harrowed. Compost, Trichoderma and biostimulants were added to the regenerative plots. The crop emerged quickly and evenly in all treatments, although slugs and pükeko caused some early damage. After winter cover crops, a Kraft-Heinz Watties tomato crop is planned for 2023-24.

The project is supported by McCain Foods, Kraft-Heinz Watties, BASF Crop Protection and others.

BUILDING SOIL CARBON STOCK BY PLANTING SHELTERBELTS IN TEMPERATE GRAZED PASTURES.

Neha Jha[1], Peter Bishop[1], Marta Camps-Arbestain[1], Ian McIvor[2], Nandar Yee[1], and Jacques Carvalho[1] and Catriel Espinosa[3]

[1]School of Agriculture and Environment, Massey University, Palmerston North 4442, New Zealand, [2]Plant and Food Research, Palmerston North, New Zealand, [3]Graduate School of the Agronomy Faculty, Buenos Aries University, Argentina.

Intensive pastoral farming with year-round grazing results in soil degradation, contamination of waterways and emissions of greenhouse gases (GHGs). Restoration practices to enhance soil and environmental quality are greatly warranted. These practices should be easy to adapt by farmers and economical. Planting shelterbelts on grazing farms could be a potential option to combat these environmental issues. Shelterbelts offer a range of ecosystem services such as above ground carbon (C) sequestration, to build C in the soil adjacent to trees, mitigating the GHG emissions, and enhancing biodiversity. Despite their numerous benefits, there is a limited information available on the role of shelterbelts, especially in temperate pastoral systems. Here our objective is to investigate multiple benefits of planting shelterbelts on farms.

We plan to conduct measurements of total soil organic C, mineral nitrogen (N), total phosphorus (P), nitrous oxide emissions, and nitrate leaching in paddocks with and without shelterbelts. Here we have selected grazed pasture farms across North and South Island of New Zealand to undertake these measurements. This work is part of a larger study where the influence of shelterbelts on C sequestration, N cycle, and animal welfare is investigated.

For the measurement of soil C, we collected three replicated soil cores (D = 4.35 cm, L= 60 cm) from selected paddocks with and without shelterbelts in the dairy and/or sheep and beef grazed farms in New Zealand. Collected soil was air dried, ground and sieved to 2 mm. Subsamples were further ground to < 0. 3 mm for total C content measurement using elemental analyzer. In addition to soil C we also measured total P in the same soil samples.

Our results so far have suggested the paddocks with planted shelterbelts and specifically soils closer to shelterbelt have higher soil C stock than the paddocks with no shelterbelt on the same farm. There are additional interesting results regarding total P, soil mineral N, and nitrous oxide emissions from the same farm that will be discussed during the workshop.

OBSERVED AND MODELLED CARBON FLUXES AT A GRAZED SITE WITH CO_2 ENRICHMENT

Miko Kirschbaum

Manaaki Whenua – Landcare Research

New Zealand has maintained a free-air CO_2 enrichment (NZ FACE) site from 1997 to 2020, where the CO_2 concentration inside a number of rings with 12-metre diameters was enriched by about 100 ppmv to simulate future conditions under ongoing climate change. The NZ FACE site is globally unique as it includes regular sheep grazing. In the present work, we have compared the observed patterns in pasture productivity and soil organic carbon with modelled responses using the CenW and APSIM models.

The simulations were largely consistent with observations showing biomass production and grazed by animals to be increased by about 10-15% by CO_2 enrichment. Legumes also became more prevalent under CO_2 enrichment, with total biological nitrogen fixation also increased by about 10-15%. The simulations also suggested increases in soil organic carbon under CO_2 enrichment by 1-2 tC ha^{-1} over 23 years. Empirical observation showed divergent trends, with some observations showing carbon increases, while others did not, but given the large inherent variability in soil carbon, the modelled changes were of a magnitude that would be difficult to experimentally verify.

Together, the empirical observations and modelling confirmed changes in pasture productivity of approximately the expected magnitude. The extra fixed carbon was preferentially utilised for pasture production and removal in grazing, with less carbon retained on-site and contributing to soil carbon formation.

THE EFFECTS OF DIFFERENT URINARY NITROGEN RATES ON GASEOUS NITROGEN FLUXES AFTER SYNTHETIC COW URINE DEPOSITION

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Ruminant cattle grazing pasture result in urine deposition at high nitrogen (N) rates that can impact the environment including via gaseous emissions. Among those lost pathways, nitrogen gas emission, especially nitrous oxide (N_2O) and dinitrogen (N_2), is the primary way where N can be lost to the atmosphere. There is limited information on the magnitude or fluxes of N_2 losses from grazed-pasture systems after urine deposition due to the method limitation. We used the ^{15}N flux method and high sampling frequency to explore N_2 and N_2O fluxes over time after urine application at two rates (400 and 800 kg N ha^{-1}) on a New Zealand grazed pasture soil. The higher N rate significantly increased daily N_2O fluxes but has no significant effect on daily N_2 fluxes in our study compared with the lower rate. N_2 is the predominant gaseous N form lost from the applied urinary-N which contributed 32.1 ± 4.1% and 14.4 ± 1.7% of the total deposited-N from 400 kg N ha^{-1} and 800 kg N ha^{-1} respectively, over 95 measurement days. Denitrification and codenitrification co-occurred in the pasture system, with denitrification being the predominant N_2 production pathway, contributing 97.9 – 98.5 % of total N_2 production. The $N_2O/(N_2+N_2O)$ product ratio was generally higher during periods of nitrification (the first month after urine application) but with no clear relationship to other measured variables. Contrary to our hypothesis, an elevated urine-N rate did not enhance N_2 loss. This is speculated to be due to enhanced ammonia volatilisation and transfer of N as nitrate, to deeper soil layers. Soil relative gas diffusivity indicated that high N_2 fluxes resulted from entrapped N_2 diffusing from the draining soil.

THE CHALLENGE OF ENSURING GOOD PHYSICAL MIXING OF INHIBITOR APPLIED TO A URINE PATCH

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Nitrification inhibitors have the potential to reduce nitrogen leaching and nitrous oxide (N_2O) emissions from grazed pastures by slowing the transformation of ammonium (NH_4^+) to nitrate (NO_3^-) in soil, thereby allowing more time for uptake by plants. A review by Di and Cameron (2016) found nitrification inhibitors reduced N_2O emissions from urine patches on average by 57% and NO_3^- leaching by 30-50%.

It would be desirable to target inhibitor applications to the urine patches only, to reduce the total amount of inhibitor released to the environment and potentially transferred into animal products. However, this necessitates some delay (i.e., 24 to 48 hours) between the grazing event and inhibitor application. During this time the urine could move down the soil profile and therefore not be physically co-located with subsequent applied nitrification inhibitors.

In this study we created 2 L synthetic urine patches by pouring urine onto soil in a manner intended to simulate natural urine deposition. Then, after a delay of 4 to 48 hours, 40 mL of inhibitor solutions was applied using a spray unit. The inhibitors investigated were DCD (*dicyandiamide*)*,* DMPP (*3,4-dimethylpyrazole phosphate*), and nitrapyrin (*2-Chloro-6-(trichloromethyl)pyridine*) applied at two different sites (one in the Massey University Dairy #4 site in Manawatu and one in AgResearch Hamilton site in Waikato) and two different inhibitor loadings. The soils were then sampled from 0-20, 20-50, 50-100, and 100-150 mm and the urine-N and inhibitor amounts in each layer measured. Pasture samples were also collected to determine the proportion of inhibitors retained by the pasture canopy.

The pasture canopy captured around 30-50% of the inhibitor. Of the inhibitor that reached the soil, ~80-90% remained in the top 20 mm. In contrast, between 60-80% of the urine-N detected was below 20 mm. This suggests that this application method would be less effective at reducing N_2O emissions due to poor mixing between the inhibitor and the urine. We recommend that future studies include a greater volume of water with the inhibitor application to reduce the amount of inhibitor trapped by the plant canopy and improve the transport of the inhibitor in the soil profile.

AN ASSESSMENT OF THE THRESHOLD CONCENTRATIONS OF NITRIFICATION INHIBITORS TO REDUCE URINE NITROGEN NITRIFICATION RATES ON PASTURE SOILS

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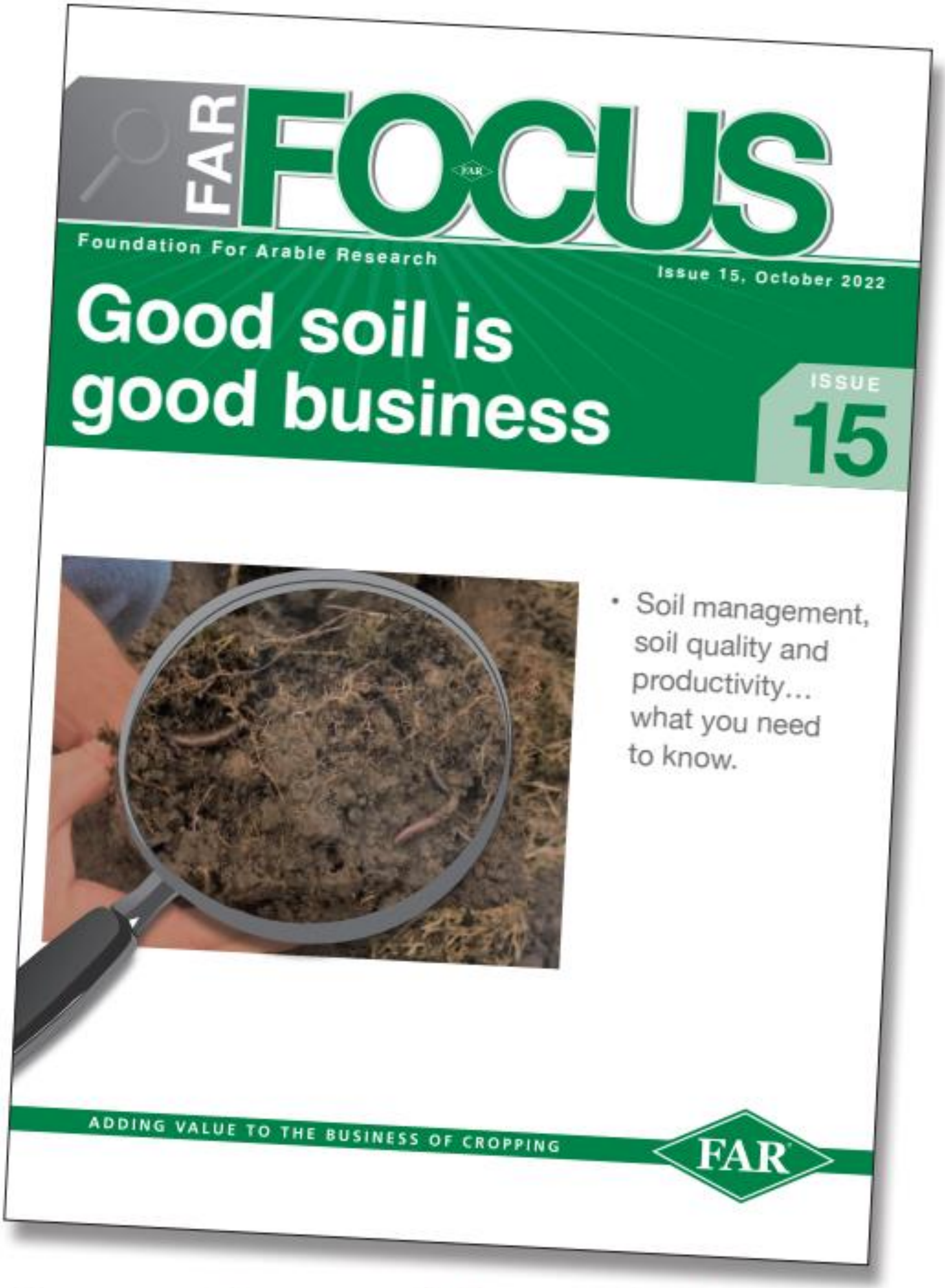
Information on the threshold concentrations of nitrification inhibitors (NIs) to reduce urine nitrogen (N) nitrification rates is required for the targeted treatment of urine patches to mitigate gaseous and leaching losses of N to the environment This study measured the threshold concentrations of three NIs: dicyandiamide (DCD), 3,4-dimethylpyrazole phosphate (DMPP) and 2-chloro-6-(trichloromethyl) pyridine (nitrapyrin) to reduce urine N nitrification rates on two contrasting pasture soils. Four rates of each NI (3–27 mg DCD kg−1 soil, 1–13 mg DMPP kg−1 soil and 1–14 mg nitrapyrin kg−1 soil) were added to urine-amended soils and incubated at laboratory room temperature. The amended soils were sampled periodically to monitor changes in mineral-N concentrations. Under the experimental conditions, the threshold concentrations of the NIs required to reduce urine N nitrification rates on the examined pasture soils are equivalent to 13 kg DMPP ha−1 soil, 5–7 kg nitrapyrin ha−1 soil and 3 kg DCD ha−1 soil, assuming a soil bulk density of 1000 kg m−3 in the top 0.1 m soil depth. Greater NI effectiveness corresponded to greater NI persistence, with higher ($P < 0.05$) half-life values observed for DCD (16 ± 2 days, mean ± s.e.) compared with nitrapyrin (10 ± 2 days) and DMPP (9.2 ± 0.3 days). All three NIs persisted longer ($P < 0.05$) with higher application rates.



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THE EFFECTS OF DIFFERENT PLANTAIN (PLANTAGO LANCEOLATA) PROPORTIONS IN PASTURE ON GASEOUS NITROGEN LOSS AFTER URINE DEPOSITIONS ON CONTRASTING SOIL TYPES

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Nitrous oxide (N_2O) is a potent greenhouse gas. Dairy cow urine patches on pastures are a major source of N_2O emissions from agriculture. Plantain (*Plantago lanceolata*) has been found to exhibit a biological nitrification inhibition (BNI) trait which can potentially mitigate N_2O emissions from. However, there is limited research on the effects of different proportions of plantain and soil types on gaseous N (N_2O and dinitrogen (N_2)) loss from urine patches. In this trial, dairy cow urine was applied in autumn at a rate of 660 kg N ha^{-1} on lysimeters (500 mm diameter x 700 mm depth) with 5 different proportions of plantain in the sward (0%, 15%, 30%, 50%, 100%) (mixed with perennial ryegrass) and 2 soil types (allophanic and gley). A closed chamber method was used to measure N_2O emissions and the ^{15}N flux method was used for measuring N_2 fluxes after urine deposition. Plantain inclusion in the pasture sward reduced cumulative N_2O emissions from some treatments of both soil types. In the allophanic soil, the 30% plantain treatment had the lowest emission factor (EF_3) (0.18 ± 0.04 %) while the lowest EF_3 (0.34 ± 0.03 %) in the gley soil was from the 100% plantain treatment. There was no linear relationship between plantain proportion and cumulative N_2O emissions found in this study. Plantain inclusion increased N_2 production in both soils but to different extents. The allophanic soil had 59.2% of the applied N lost as N_2 in the 100% plantain treatment over the 92 days of the trial while 48.5 % of the applied urine-N was lost in the 0% plantain treatment over the same period. In the gley soil, 60.4 % and 55.9 % of the applied-N was lost from the 100 % and 0 % plantain treatments over the 92 days, respectively. The difference between the two soil types is speculated to result from the difference in microbial activity, especially nitrification capacity, between the two soil types. The higher the nitrification capacity the soil has, the stronger the BNI effect from plantain after urine deposition. More detailed microbial studies should be conducted in the future to better understand the effect of plantain on N_2O emission.

SOIL N STATUS AND MOISTURE AFFECTING THE ABILITY OF PLANTAIN TO REDUCE N_2O EMISSIONS FROM CATTLE URINE

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Plantain (Plantago lanceolata) is known for its potential to inhibit ammonia oxidizing activity in the soil in a process termed biological nitrification inhibition (BNI) and has been actively investigated as an option for reducing nitrous oxide (N_2O) emissions and nitrate (NO_3^-) leaching from animal urine patches. However, the research results to date on the effectiveness of plantain use as an N_2O mitigation tool are variable, and there is a lack of evidence on the drivers of plantain's ability to induce BNI. There is some indication that a plant's BNI trait is a mechanism to conserve soil nitrogen (N) under low N availability. We therefore hypothesized that plantain's ability to reduce N_2O emissions from urine patches reduces as soil N availability increases. A glasshouse trial was conducted using pots containing plantain (Agritonic) or perennial ryegrass (cv. One50 AR37) plants grown in a Wingatui silt loam soil. We assessed the influence of soil N fertility status (Low N, Median N, High N, that were achieved with base fertilization of 0, 100 and 200 kg urea-N ha^{-1}, respectively) and soil moisture content (either maintaining 60% water-filled pore space [WFPS] or applying standard irrigation, mimicking average rainfall in the region) on the effectiveness of plantain to reduce N_2O emissions. A standard chamber method was used to measure N_2O fluxes following cattle urine application at a rate of 534 kg N ha^{-1}. Soil N status influenced the capacity of plantain to reduce N_2O emissions from applied urine when soil moisture content was maintained at 60% of WFPS, reducing 29%, 28% and 44% of N_2O emissions at low, median, and high N status, respectively, compared to ryegrass ($P<0.05$). When the soil moisture content was not controlled (standard irrigation), soil N status did not significantly affect plantain's ability to reduce N_2O emissions compared with ryegrass ($P>0.05$), although there was a similar trend in emission reductions compared to the 60% WFPS treatments. The results rejected our hypothesis that increasing soil N status reduces plantain's ability to reduce N_2O emissions. The results also suggest that any potential plant effect on soil water status was not a determining factor in the effectiveness of plantain to reduce N_2O emissions content as both moisture treatments showed a similar trend towards lower emissions under plantain compared with ryegrass.

COMPARISON OF NITROUS OXIDE EMISSIONS AND SOIL NITROGEN LEVELS FROM PLANTAIN AND RYEGRASS/ WHITE CLOVER PASTURES ON A WAIKATO FARM

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Emissions of nitrous oxide (N_2O), a potent greenhouse gas (GHG), from agricultural soils are a major concern for the sustainability of grassland agriculture. In New Zealand urine deposited by grazing animals is the main source of agricultural N_2O emissions. Recent studies have suggested that pastures containing plantain (Plantago lanceolata) can reduce N_2O emissions from pasture soils.

The objectives of this study were to measure and compare N_2O emissions of urine deposition on pastures sown with plantain only (Plantago lanceolata) and on pastures sown with a standard ryegrass/white clover seed mix (Lolium perenne/Trifolium repens) and to increase understanding of the effects of soil N dynamics on N_2O emissions.

This work was carried out in dairy farm paddocks on a gleyed alluvial soil near Te Aroha in the Waikato Region. Pastures had been established following harvest a maize crop in autumn 2022. Measurements coincided with grazing of paddocks by dairy cows from August to December 2022.

A static chamber method was used to measure N_2O fluxes from plots on both pasture types treated with either artificial urine simulating a urinary nitrogen (N) deposition of 600 kg N ha^{-1} or no urine (control).

Measurements of soil N, soil carbon (C) and pH were made on soils at depths of 0-20 mm and 2-75 mm. Soil cores were collected at each N_2O measurement from plots adjacent to each chamber, and from transects across the entire paddocks.

LOWERING FOLIAGE N CONTENT BY CHANGING PASTURE PLANT SPECIES COULD REDUCE N_2O EMISSIONS AND INCREASE FORAGE PRODUCTION: AN ANALYSIS COMBINING EDDY COVARIANCE MEASUREMENTS WITH PROCESS-BASED MODELLING

Lìyǐn Liáng

Manaaki Whenua - Landcare Research

One of the aims of modern agriculture is to maintain production while minimising the environmental impacts. Ongoing research on grazed pastures has suggested a potential option to promote pasture production and reduce greenhouse gas (GHG) emissions by introducing species with low foliage N content like plantain into traditional ryegrass/white clover pastures. However, disagreement exists regarding the effect of lowering foliage N content by changing plant species on pasture production and GHG emissions. Here, we used eddy covariance (EC) measurements to parameterise the carbon and water processes in the process-based model CenW to simulate the effect of lowering foliage N contents on plant production and excretal N deposition. N_2O emissions were calculated from simulated excretal N production using an emission factor-based method. We used different scenarios to explore the effects of varying foliage N content on pasture production and N_2O emissions. We found that species with lower foliage N had increased pasture production but lower annual N_2O emissions. The increase in pasture production for species with lower foliage N content could be a result of reducing the constraint from N limitation, allowing faster growth compared to species with higher foliage N content. Our simulations also confirmed that lowering foliage N contents reduced urine N load and consequently curtailed annual N_2O emissions. Additionally, we investigated the effects of modifying the partitioning of excretal N between dung and urine on annual N_2O emissions. When more N was allocated to dung, it reduced the N allocation to urine, resulting in lower N_2O emissions. Our simulation also demonstrated strong seasonal variations in N_2O emissions, with higher N_2O emissions over the main growing seasons and lower emissions in winter. However, we found that the EF-based method predicted lower cumulative N_2O emissions than EC measurements in a wet year. We also found soil organic carbon (SOC) losses under all scenarios and the loss increased with increasing foliage N contents. However, at present, there are insufficient available measurements to confirm these findings in field conditions. In addition, plant species with lower foliage N content are likely to have other physiological differences which also affect SOC. Further investigation will be required to verify the change in SOC when more field measurements become available.

THE RELATIONSHIP BETWEEN DIETARY INCLUSION OF WHEAT AND PALM KERNEL AND METHANE EMISSIONS DETERMINED USING IN VITRO METHODOLOGY

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

Previous work by Meads *et al* (2019) showed a significant decrease in methane emissions with increasing concentrates in the ration. The current work looked to see if this pattern could be repeated with different diets, especially using wheat.

The effect of feeding increasing levels of concentrate on enteric methane production using an *in vitro* fermentation model (IFM) wase investigated. Three mixed rations (100%, 70% and 55% pasture - plus equal amounts of wheat and Palm Kernel Expeller (PKE)) were fermented in a closed *in vitro* system for 48 hours. Microbial biomass (MBM), volatile fatty acid (VFA) production and total gas production were determined as indicators of ruminal digestion.

Unlike the previous study (Meads *et al*, 2019) the total VFAs were unaffected by the % pasture. However, changes in acetate, propionate and butyrate as a molar proportion of total VFA production changed significantly in a linear fashion with increasing concentrate inclusion. Using a VFA stoichiometric model (Wollin 1960) as a proxy for methane measurement showed significantly reduced methane production with the inclusion of concentrates ($p<0.05$).

Propionate acts as an alternative H+ ion sink, therefore reducing the production of methane. These results would indicate that ruminal digestion of diets with a component of concentrates added feed in the form of wheat and PKM increased propionate production to significantly impact on methanogenesis in an *in vitro* fermentation situation.

LANDPLAN – THE ONLINE TOOL FOR TESTING VIRTUAL CHANGES IN LAND USE MANAGEMENT ON GHG EMISSIONS

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New Zealand has legislated a GHG zero emissions reduction strategy and farmers have been told to 'know their numbers' relating to their GHG emissions. Once they collect those numbers it is not clear what they should do with that knowledge, or how they could alter their overall emissions. LandPlan (LP) is an online tool aimed at helping farmers to investigate the effect of changing their landuses on whole farm net emissions. LP is used to map the whole property by all landuses. LP then takes an insetting approach and sums all emissions and all sequestration to provide an overall index of net emissions on a per hectare basis. Farmers can then test virtual changes while planning future farm landuse scenarios and display the expected effect on their overall emissions.

INCLUSION OF SUPPLEMENTARY FEED IN THE AGRICULTURAL INVENTORY MODEL FOR DAIRY, SHEEP AND BEEF

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The quality of pasture and other feeds consumed by livestock has a significant effect on the quantity of greenhouse gas (GHG) emissions generated by New Zealand agriculture.

Despite the increasing use of supplementary feed in New Zealand (particularly for dairy cattle), the agriculture (GHG) inventory has assumed up until 2022 that livestock are entirely pasture fed. In 2023 the inventory methodology will for the first-time account for non-pasture feed. This improvement will significantly increase the accuracy of emissions reporting.

For dairy cattle, the estimated proportion of supplementary feed consumed increased from 4.0% of total dietary intake in 1990-91 to 18.8% in 2017-18. Supplementary feed usage in beef and sheep has remained relatively constant at 5-7% of total dietary intake between 1990 and 2015.

The estimated effect of supplementary feed was included in the model by changing the pasture values for metabolisable energy (ME) content of feed (expressed as MJ-kg), nitrogen content (N%), and digestibility (DMD) to weighted averages based on the total diet of each livestock type. This methodology assumes the methane yield (amount of methane produced per unit of feed) for all feed types is identical to pasture.

Reported agricultural emissions when including supplementary feed are consistently lower than emissions using pasture values for all livestock. The decreased emissions estimates reflect the higher metabolisable energy, lower nitrogen content, and higher digestibility of supplementary feed compared to pasture.

For sheep and beef, fluctuations over the time series were small, reflecting the consistent use of supplementary feed. For dairy, there is a proportionally larger difference in later years, reflecting the changing composition of dairy cattle diet.

AN INTRODUCTION TO ON FARM SUPPORT, A NEW SERVICE FOR FARMERS AND GROWERS

John Roche

Ministry for Primary Industries, On Farm Support

New Zealand farmers and growers are experiencing unprecedented change, with climate change disrupting traditionally stable production systems and market forces and government regulations requiring farm practices that have a demonstrable smaller environmental footprint. These changes, alongside pandemic-related supply chain issues, labour shortages and an increased cost of debt servicing have led to widespread concern in the primary sector.

In response to these challenges, the Ministry for Primary Industries has created On Farm Support (OFS), which will support farmers through these changes by connecting them with services, funding, and advice that will help in the transition to more sustainable practices, in the planning for climate change and associated adverse weather events, and, in the process, help landowners build more resilient businesses.

OFS is building regional teams throughout Aotearoa, connecting with farmers and growers and those that provide support services to them already. Through connecting with the New Zealand research ecosystem, OFS will ensure evidence-based solutions to on-farm challenges and will liaise with already established community groups to increase the flow of relevant information and strategies for implementable changes to farm systems that meet the landowners' goals and those of the market and wider society.

As Heroclitus putatively said, "Change is the only constant". But, the market fundamentals are sound and people must eat. New Zealand is already recognised for its sustainability credentials and its leadership in the production of nutritious and accessible food. But, we can do better and the discerning consumer is demanding that we do better. On Farm Support will help farmers and growers in this quest.

DANISH EXPERIENCE WITH CATCHMENT OFFICERS AND IMPLEMENTATION OF NITROGEN MITIGATION PRACTICES

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SEGES Innovation, Denmark

To meet the EU requirements of good ecological status in all Danish coastal waters in 2027, there has been a continuous and increasing effort to reduce nutrient loss from agriculture. Initially the regulation has been focused on agricultural practices based on general regulation methods. As the regulation has increased so has the costs for the farming business. To meet the ecological targets without severe economic consequences there has been a gradual shift towards edge-of -field mitigation measures. In the latest political agreement on agriculture, it was decided that the remaining reduction of 4500 tons N could be met with voluntary collective measures based on funding schemes like constructed wetlands, river valley- and peatland restoration projects and afforestation.

If the farmers should avoid further regulation on their individual farms, it will be necessary to establish approx. 8000 constructed wetlands and restore 25.000 hectare of natural wetlands. Each catchment has a specific fixed target of nitrogen reduction to the coastal water. In some of the most vulnerable catchments it will be necessary to apply a drain filter solution on almost every drainage system.

Since 2017 SEGES Innovation has been managing a national network of locally based catchment officers. The catchment officers help the farmers identify potential for measures and assist in the dialogue with authorities. The assistance is free for farmers as the ministry of agriculture and the farmers organization have made an equal funding on the project. Most of the officers are employed within the agricultural advisory service system within plant production, environment, or nature. The catchment officers have initially focused on constructed wetlands, as the farmer himself can apply for EU-funding and is responsible for completing the project according to rather specific design criteria and location in the landscape. To date the catchment officers has applied for funding of 800 constructed wetlands and 300 projects been completed.

To motivate the farmers the catchment officers have tested different approached of communication. Initially it was aimed towards the individual farmer based on letters, webpages, phone calls, social media, and field demonstrations. Gradually it has shifted towards organizing collective start-up meetings for all farmers within a catchment. The joint meetings have several advantages. Initially most farmers are skeptical and rejective towards the environmental targets decided by the government. When the farmers realize that they can decide the type and location of measures their mindset gets constructive. During their discussions the farmers develops a mutual and often positive attitude towards the task. With the combined knowledge it is also possible to locate the best position of measures along each drain within the catchment. In addition, there is instantly recognition by colleagues and neighbors to the farmers who decides to implement measures on their farms to help with the mutual task. This recognition is crucial for maintaining motivation after the meeting and during the often long and complicated project period.

BUILDING CAPABILITY AND CAPACITY FOR RESOURCE MANAGEMENT

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[1]*Element Environmental, Te Aroha*

The Capability and Capacity Builder project focuses on understanding current capability in the resource management sector to support the requirements for implementing freshwater farm plans (FW-FP). Once understood, it will develop processes, structures, training and support, enabling the continual development of national capacity in the sector. This project is a partnership between the Ministry for the Environment (MfE), Regional Councils and the New Zealand Association of Resource Management (NZARM).

The current understanding of the number of advisors, their capabilities, and their work locations to support landowners and regional councils is limited. This creates challenges when individuals are looking to obtain the expertise needed to complete Freshwater Farm Plans or risk assessments relating to the impact of land use on freshwater.

Over a three-year period, which began in July 2022, the capability and capacity builder project will work collaboratively with regional councils, stakeholders and MfE to deliver on building capacity within the resource management sector to help landowners meet New Zealand's freshwater challenges.

This project aims to provide solutions by,

- Gaining a clear understanding of the current capability of individuals within regions.
- Understanding each catchment's capability and capacity needs through working with regional councils, community groups, and Iwi organisations.
- Providing targeted, context-based training to build capability to match the regional needs and support career development.
- Providing a nationally supported register of capability that allows councils, catchment groups, landowners, and mana whenua to connect to the right expertise.

This programme promotes the development of a competent and skilled sustainable land and water management workforce capable of addressing national and regional environmental concerns. In addition, the programme's availability to inform regional councils and landowners looking to facilitate a range of on-farm environmental support tasks will allow individuals' capacity and capability to be matched or developed to meet future capacity and capability needs. The programme will leave a legacy of training resources, formal qualification pathways, digital tools, and capable trainers. With support from MfE, commitment from NZARM, and ongoing regional council support, this project will be self-sustaining for future resource management professionals.

The paper presentation will discuss the program's first year's progress and future prospects.

A CASE FOR AN INTEGRATED ENVIRONMENTAL POLICY FRAMEWORK, AND THE CONSEQUENCES OF NOT HAVING ONE

Erica van Reenen

AgFirst Manawatu-Whanganui

Over recent years, farmers have faced numerous environmental policies (some pending) for the management of freshwater, biodiversity and mitigating greenhouse gases. In a number of cases these policies and regulations have been released, withdrawn and re-released due to a complete lack of practicality in implementing them. Farmers, regional councils, industry bodies, advisors, bankers, accountants, vets, and other professionals are often left struggling to keep pace with the proposed or actual policies and amendments, while supporting farmers to respond and remain sustainable, profitable and viable.

Much of the policy, proposed or in place, requires specialist input which is often in short-supply or carried out by people farmers have never worked with before. Consequently, there is a lack of trust or willingness to invest. The ability to implement practical outcomes to respond to these policies on-farm within a farm system context requires farmers to grapple with a wide-range of complex challenges and often the input from multiple specialists.

There is strong competition for talent between central and local government, industry bodies, rural agribusiness, and advisory/consultancy. Estimates made of the number of people required to implement these policies far exceed the current talent-pool, and the skill sets needed generally require several years of training and experience.

Achieving positive outcomes from these policies will require 30,000+ farmers and the wider agribusiness community to understand, support, and implement. To have any chance of success, this will need to be done in an ***integrated*** way.

An integrated policy framework would reduce duplication for farmers, better reflect the systemic nature of a farm and landscape, reduce administrative cost, and require fewer highly skilled people. Positive outcomes are likely to be achieved more quickly and with less pain and distress to farmers.

An integrated approach to policy is not common and would be difficult, but this paper argues, not as difficult as 30,000+ farmers attempting to do the integration one farm at a time…before they even start to think about implementing changes.

FARM PLANNING: MOVING FROM COMPLIANCE TO STRATEGIC PLANNING

Estelle Dominati, Alec Mackay and Duy Tran

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The NZ government is investing heavily in a national farm planning framework that will make it easier for farmers to meet business and regulatory requirements.

This poses important questions:

- Is there a danger of the farm planning process being hijacked and used as a compliance tool to address single issues (greenhouse gas emissions, freshwater…), when the power of the planning process is in its ability to handle complexity?
- How do we assist farmers in their understanding of the complexity of their farm's landscape, in a way useful for farm planning and farm system design?
- How do we demonstrate the underlying role of soils and biophysical resource information in the farm planning process?
- How can we help farmers see farm planning as an opportunity to start a redesign process for their farms?
- What are the steps required to move beyond Freshwater farm plans towards integrated farm planning?

Prerequisites that underpin freshwater farm plans are national regulations as well as catchment context, a spatial map that sets outs the farms major land management units, a risk and impact assessment of each land management unit (i.e., erosion, critical source areas, fodder crop management, intensive grazing wetlands), and putting in place actions to reduce those risks (i.e., strategic fencing of waterways, wetland restoration, winter grazing paddock plan) to freshwater.

To move towards strategic and integrated planning, farmers would need good knowledge of all farm resources (starting with soils and including natural, human and built capital), breaking the farm down into land management units based on land resource information, measuring the current condition of resources and current flows of ecosystem service and emissions, assessing potential opportunities in addition to constraints and setting prioritised, time-bound actions in the work plan.

Such process must be driven by the farmer's personal, family, business, and financial goals for the farm.

This paper, using a hill country sheep and beef farm in Manawatu, will explore how a geo-design framework combined with an ecosystem-based management (EBM) approach can be used in an integrated farm planning process to help plan and design a sustainable multifunctional landscape at the farm scale, and priorities actions on different parts of the farm.

CHALLENGES TO ENABLING OPEN DATA: A FARM SYSTEMS CASE STUDY

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Many farm systems research projects begin with very specific data collection and analysis goals in mind. These goals are often focused on specific research questions to answer and do not necessarily consider longer term use cases or future interest in the data beyond the scope of the original project. While initial data collection and storage for the duration of the project may be well composed and considered, this careful organisation of data may not necessarily carry forward as expertise involved in the original use case for the data moves on or as interest in the initial research question fades.

A recent farm systems research project seeks to understand how the movement of animals in response to weather conditions on Waipori Station in Otago, affects water quality in the area at different times of year. This project, and the numerous sources of data required to answer the research question at hand, has presented a unique opportunity to investigate and implement data architecture with the intent to ensure that all data relevant to the site and the farm systems begin considered is stored in an open and usable both in the present and for future research.

In this case study, we have worked towards a goal of creating a robust and open data lifecycle to preserve the data that has been collected for the longer term. We detail how the goal of enabling open data access has evolved from internal data collation and sharing for a small and specific set of data sources, to interest in collecting and collating a much larger set of disparate data that can be openly accessed to answer novel research questions both now and in future. We discuss how this evolved dataset has required different thinking in terms of chosen approach to data storage and access solutions. We identify challenges to this goal of open data including ensuring FAIR, CARE, and NZISM data principles are adhered to, identifying and gathering complete datasets, extensibility and usability of the data storage solution, and questions around data governance and balancing interests in use of the data.

ACCOUNTING FOR CHANGE: A PIONEERING APPROACH TO OPTIMISED CATCHMENT ACTION PLANNING USING THE FRESHWATER MANAGEMENT TOOL

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Auckland Council's long-term plan (2018–2028) set aside $452 million for targeted water quality improvement, including for actions targeting contaminant reduction in urban and rural streams. To ensure this investment contributes to better water quality outcomes in an efficient and targeted manner, Healthy Waters is developing the Freshwater Management Tool (FWMT)—an accounting tool for freshwater quality which guides actions to achieve water quality improvement at least cost.

While used to inform water quality management overseas (USA, Canada), the FWMT's pioneering approach to optimised action planning and freshwater accounting is new for Aotearoa New Zealand. The FWMT is comprised of two established US-EPA models (LSPC and SUSTAIN) that have been adapted specifically for the Auckland region's streams, land cover and use, soils and climate. The approach allows assessment of present and future water quality (under altered land management, use or climate) as well as feasible, least-cost actions (for an objective or to ensure greatest environmental return on investment). The FWMT v1 spans six major contaminants (nitrogen, phosphorus, sediment, E.coli, copper and zinc), is process-based and fully integrated across Auckland's rural and urban landscapes (5,465 catchments, 100+ activities, 15-minute dynamic output).

The FMWT programme is underpinned by a robust evidence base drawn from statistical analyses, published studies and "grey" literature (including State of the Environment Monitoring, device efficiency information, and complete 50-year lifecycle costings). An external peer-review panel has also been established to scrutinise both the tool as well as its decadal development programme.

The FWMT advances farm environment planning and the broader goals of central government's Essential Freshwater work programme in two ways:

First, enabling process-based modelling to account for actions in farm environment plans (FEPs)—overcoming traditional barriers to successful adaptive management by linking each FEP to local and downstream instream effects. The FWMT supports adaptive management by overcoming monitoring and empirical modelling constraints (e.g., not subject to marked response delays, hysteresis instream, able to disaggregate individual FEP benefits on contaminants and environmental flows).

Second, the tool uses lifecycle optimisation and intervention modelling to derive least-cost strategies for remediating catchments. Combined, the FWMT offers farm environment planners and farmers more direction on actions to prioritise and credit for action taken.

This paper will demonstrate the FWMT's application to rural catchments and farm environment planning, including optimised action and catchment context information (e.g., broader water quality information). Finally, the paper will highlight key areas of focus for the FWMT's continuous improvement programme (see also, Improved understanding of horticultural grower systems within the Pukekohe area to inform the Freshwater Management Tool).

IMPROVED UNDERSTANDING OF GROWER SYSTEMS WITHIN THE PUKEKOHE AREA TO INFORM THE FRESHWATER MANAGEMENT TOOL

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Auckland Council's Freshwater Management Tool (FWMT; see *Accounting for change: A pioneering approach to optimised catchment action planning using the Freshwater Management Tool*) has been developed to improve how water is managed throughout urban and rural Auckland.

The FWMT is a novel regionwide accounting framework, combining process-based (causative) and continuous (high-resolution) modelling to generate water quality information and identify actions to achieve water quality objectives (including costs, distribution of costs and least thereof for targets) by sub-catchment, integrating across the rural-urban divide for numerous contaminants (N, P, sediment, E.coli, Cu, Zn).

FWMT outputs include region-wide information on contaminant yield (from land) and in-stream concentrations across 106 distinct "land types," representing key physiochemical (e.g., soils, slope, climate, land cover) and anthropogenic (e.g., imperviousness, land use) factors that influence variation in water quality across the Auckland region.

A robust evidence base underpins the tool's predictive current and future water quality and catchment action planning abilities. Information on land use "impacts" help to inform baseline water quality predictions. Likewise, estimates of generalised environmental benefit, detailed economic costs, as well as opportunity estimates for a range of source controls and devices, inform the suite of interventions available within the tool. Feasible actions are explicitly mapped, optimised for their footprint (cost) and effect (benefit) whether within or between catchments (urban and rural).

In the first stage of the FWMT's development, an approach of "defensible simplicity" was taken to adopt increasing model complexity only where required and supported by evidence. This approach was endorsed by the FWMT's expert peer-review panel and by various sectoral groups.

This paper explores how Auckland Council (Healthy Waters) partnered with Horticulture NZ and the Pukekohe Vegetable Growers Association to better characterise commercial vegetable growing for water quality effect and management choices. Outputs include detailed rotational typologies for commercial vegetable production, contaminant generation information and costed mitigation choices representing good practice.

Five "typical" crop rotations are presented along with associated environmental footprint estimates determined for nitrogen, phosphorus, and sediment losses using both APSIM (for nitrogen) and the Erosion Sediment Calculator (for phosphorus and sediment). A summary of estimates of mitigated losses are also shown (also modelled using APSIM or the Erosion Sediment Calculator) and include both edge-of-field and practice-based options. Gross margins were developed for each crop (and rotation) based on a range of data sources, including direct grower guidance. This information will be used to improve optimised catchment action planning within the FWMT to support better decision making and water quality outcomes.

PRINCIPLES OF SUCCESSFUL SUSTAINABLE CHANGE SOLUTIONS – A CASE STUDY

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Freshwater quality in New Zealand has been under pressure from the accumulated effects of intensification of agriculture for over 30 years, particularly on the Canterbury Plains. New national regulations to manage these effects have yet to be fully implemented, however the Canterbury Land and Water Regional Plan (LWRP) have been managing diffuse discharges from farming activities since 2012.

Barrhill Chertsey Irrigation Limited (BCI) is a relatively new mid-Canterbury irrigation scheme, delivering up to 13 m^3/s to over 190 covering approximately 60,000 ha of the Canterbury Plains between the Rakaia and Rangitata Rivers from 2010. Farms within the scheme are predominantly arable, with some dairy, dairy support and sheep and beef operations.

In 2013, BCI were granted a resource consent to manage the nutrient losses from all farms receiving their water, which was renewed in 2021. The nutrient discharge consents set up an Audited Self-Management Programme (ASM), with a collective cap on nitrogen losses reported annually. The consents required every property to have a Farm Environment Plan (FEP), audited to standards set by ECan.

The renewed consents have added in controls on land use change, effects on sensitive receptors, water quality monitoring and adoption of "Advanced Mitigations", a step beyond Good Management Practice (GMP) to address water quality issues in our catchment.

Over the past 7 years, farms within the scheme have significantly improved their practices and resource use efficiency. Over 96% of shareholder farm now meet GMP, compared to 10% when the programme started and we have seen reductions in N loss of 21% and Simple N Surplus of 25%.

From our experience, we found the following principles were key to the success of our programme:

1. Focus on continuous improvement, working with farmers to support them on their own journey to GMP and beyond
2. Set clear catchment goals and expectations
3. Building strong, trusted relationships
4. Ensure policies and processes reflect their collective values
5. Enable the sharing of ideas and practices

Incorporating these key principles into regulatory frameworks to improve water quality will enable the development of programmes which are more likely to succeed in the long term.

ŌTŪWHAREKAI – ASHBURTON ALPINE LAKES ADVANCED FARM PLANNING

Shane Gilmer

Environment Canterbury

The area known by manawhenua as Ōtūwharekai is an alpine location with an extensive lake system between the Rangitata and the Rakaia Rivers.

The wider Ōtūwharekai area is of immense cultural significance to Ngāi Tahu Whānui – not only within their oral history but also being both an important seasonal mahinga kai area and a major travelling route between the settlements on the eastern coast of Te Waipounamu (the South Island) and those on Te Tai Poutini (the West Coast). Its restoration is of huge importance to rūnanga.

Over the past 10-years lake water quality has degraded significantly in most lakes. There are eight key lakes the project is seeking to understand the nutrient origin and find solutions that return lakes to health.

High country stations in Ōtūwharekai are within the Sensitive Lakes Zone of the Canterbury Land and Water Plan. This means a farm operation needs a Farming Land Use (FLU) consent which has a Farm Environment Plan that is audited. Farm audits have resulted in multiple A-grade results reflecting operation management at or above the good management practice.

In 2021 the Cawthron Institute completed analysis of the catchment loads by utilisation of catchment monitoring data. Good statistical relationships were observed between total nitrogen (TN) and total phosphorus (TP) loads calculated using the national CLUES (Catchment Land Use for Environmental Sustainability) model and in-lake nutrient concentrations. Measured in-lake concentrations and modelled loads were then used to identify load reduction targets for each lake and in turn provided the framework for the advanced farm plan process.

To work with landowners a high degree of trust was required upfront to build relationships to establish engagement and willingness to explore the mitigation process beyond the current regulatory requirements to ensure longevity of lake health for future generations.The advanced farm planning process began with a detailed risk assessment to identify nutrient pathways at paddock scale. Overseer was used for analysis of farm systems and nutrient foot printing along with calculations of seasonal mob locations. This enabled accuracy of nutrient load distribution in the catchment at certain times of the year.

Farm environmental mitigation scenarios were scaled and analysed to calculate their nutrient load reduction at the farm sub catchment level then compared with modelled catchment load targets.
Mitigation options and load reduction calculations were peer reviewed by Agresearch to ensure accuracy and integrity. Agresearch found the approach to follow best practice and accurately utilised national literature for accurate load reductions in the project area.

Reduction scenarios were costed and evaluated by the landowners and the multi-agency working group. The group are collaboratively working toward a catchment action plan that will ensure good lake water quality outcomes in the future.

LAND USE FEASIBILITY STUDY FOR NGĀTI TAHU NGĀTI WHAOA (WAIKATO)

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WSP carried out a high level land use feasibility study, to assess alternative land use options for land owned by Ngāti Tahu Ngāti Whaoa iwi within the Upper Waikato River catchment, in the Orakei Korako and Ohaaki areas. Ngāti Tahu Ngāti Whaoa has title to roughly 4,500 hectares of land in this catchment, comprised of multiple blocks administered by various trusts and several individual hapu and whanau. This whenua is rich in history and is home to many taonga, including geothermal resources. Existing land uses include dairy, sheep and beef, forestry, geothermal energy, and tourism. The blocks host a diversity of landscapes and there is extensive existing infrastructure which could be accessed to facilitate high energy land uses. Therefore, there is much potential to develop and diversify these land holdings further.

For this study, WSP investigated the natural resources (water, soils, climate, topography, and land use capability classes) and existing infrastructure available within five selected blocks. In particular, water was identified as a key consideration for land use options, which will enable and drive land-based businesses.

Potential options for land development included a range of horticultural, pastoral and aquaculture operations, as well as potential improvements for the existing land use. A multi-criteria analysis approach was used to outline the opportunities that the different land use options could create for Ngāti Tahu Ngāti Whaoa. This approach ranked the suitability of each land use for the five blocks based on operational, economic, social/cultural, regulatory, and environmental criteria.

Recommendations were outlined specific to each land block. Irrigation was recommended for some blocks to improve the productivity of the existing pastoral land use, as well as retiring some marginal areas into exotic or native forest. Some areas used for cow dairy were suggested to transition to high value sheep dairy. Other areas were identified as suitable to transition to horticultural operations such as potatoes and taewa, and hazelnuts; and others identified as suitable for supporting infrastructure-based enterprises, such as aquaculture, greenhouse crops, or mushroom production facilities, to link with existing geothermal power plants and a proposed solar farming operation.

The next steps for this project will require decisions by Ngāti Tahu Ngāti Whaoa around which land uses to explore in greater depth for each block. This will require a more detailed investigation of the viability of the selected short-listed options, including more detailed soils, microclimate, and hydrological analyses; economic analyses and an investigation of potential markets; identifying specific resource consent requirements; and determining the governance structure and potential partnerships for the business operations.

NEW DESIGN GUIDE FOR RIPARIAN BUFFERS TO MEET WATER QUALITY OBJECTIVES

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Riparian buffers are often used to separate agricultural activity from a waterway. Many livestock farms have invested in riparian buffers, typically a combination of livestock exclusion fencing and planting of native grasses, shrubs, and trees. A new guide has been developed which discusses design principles and provides high-level information about the water quality performance of riparian buffers.

This presentation will provide an overview of the guide and illustrate how the guide can be used to predict contaminant removal by riparian buffers.

The guide is based on a review of New Zealand and international performance data and preliminary technical guidelines. It shows how riparian buffers may be used to reduce the inputs of suspended sediment (SS), nitrogen (N) and phosphorus (P) from agricultural lands to surface and groundwater (principally on dairy farms) under pasture and during pasture renewal and cropping.

The guide describes the steps required to develop a riparian buffer that meets water quality objectives. It outlines how they function, discusses landscape suitability, and provides contaminant removal estimates and design checklists for filter strips and planted riparian buffers.

The guide can be accessed and downloaded from the NIWA website:
https://niwa.co.nz/freshwater/management-tools/riparian-buffer-design-guide

The guide will assist farmers, farm advisors, rural contractors, and regional council staff to appropriately size, design, construct and maintain effective riparian buffer zones designed for water quality outcomes. It complements existing guides focused on planting for biodiversity and habitat enhancement.

METHANOL DOSING INCREASES NITRATE REMOVAL IN WOODCHIP BIOREACTORS WITH NO SUBSTANTIAL ADVERSE EFFECTS: LABORATORY AND FIELD EVIDENCE

Reza Moghaddam

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Woodchip bioreactors are well-established technologies for removing nitrate from a wide range of wastewaters, including agricultural tile drainage. Nitrate removal in bioreactors diminishes with time as it is dependent on the declining availability of carbon from woodchips. The current study aimed to assess the effects of methanol dosing on nitrate removal in bioreactors as well as quantify the adverse effects of such an approach on both bioreactors and receiving waters.

The first phase of the project involved methanol dosing in a pilot-scale bioreactor located in an agricultural catchment in Waikato, New Zealand. To investigate a pragmatic management-based approach regardless of the input nitrate loads, the bioreactor received a constant rate of 8% methanol solution during the drainage seasons of 2020 and 2021. Volumetric nitrate removal rates in the bioreactor were approximately 1 g N m-3 day-1 (2018) prior to methanol dosing and increased after methanol dosing to 8 g N m-3 day-1 in 2020 and 5 g N m-3 day-1 in 2021. There was a significant decline in methanol concentrations along the bioreactor length with removal rates ranging from 24 to 180 g C m-3 day-1, with an overall removal efficiency of greater than 99%.

The second phase of the project was the establishment of a long-term mesocosm experiment to evaluate methanol dosing in bioreactors under controlled hydraulic and laboratory conditions. Methanol dosing increased nitrate removal rates from 7 g N m-3 day-1 to 28 g N m-3 day-1. A C:N ratio of 0.7 was determined to be optimal for increasing nitrate removal while minimizing sulfate reduction, a potentially adverse effect of methanol dosing which occurs under excessive reducing conditions .

The third phase of the project was to determine the hydraulic performance of bioreactors following carbon dosing. Methanol dosing reduced the hydraulic conductivity of field bioreactor from approx. 4600 m day-1 to 1600 m day-1. Conservative tracer tests on mesocosm bioreactors revealed that methanol-dosed bioreactors had a 30% shorter hydraulic retention time (HRT) than the control treatment. Conservative tracer experiments, however, demonstrated that methanol dosing had no significant effect (p-value > 0.05) on any hydraulic parameters of bioreactors, and bioreactors could still accept hydraulic loads without bypass or overflow even after 1.5 years of operation.

The study's findings provide critical design information for using methanol dosing to maximize nitrate removal in bioreactors while minimizing the potential adverse impacts on the bioreactor operation or the downstream receiving waters.

BIOGEOCHEMICAL PATHWAYS FOR PHOSPHORUS REMOVAL IN WOODCHIP BIOREACTORS

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Woodchip bioreactors are passive anaerobic systems for the removal of nitrate in agricultural drainage. However, little is known about phosphorous (P) dynamics in these systems, limiting our ability to maximise environmental gains from this technology. We investigated the aqueous biogeochemical conditions in an established woodchip bioreactor (Tatuanui, Waikato, New Zealand), in order to elucidate the processes leading to P source/sink behaviour observed elsewhere. Using two drainage seasons (DS) of monitoring data and supplemental in-field measurements (Fe^{2+} and HS^-), we demonstrate coupled Fe-P biogeochemical cycling in the reactor, resulting mainly from the reductive dissolution of soil-derived iron oxides (and adsorbed P) incorporated during bioreactor installation. Outlet P and Fe concentrations were initially closely correlated (R^2 = 0.858), but as outlet Fe:P ratios declined from DS1-DS2 the correlation disappeared, suggesting preferential P removal (over Fe) along the flow path. Since outlet P concentrations exceeded inlet concentrations in DS1, it was necessary to infer the mass of P generated by internal dissolution of Fe oxides. Hence, we used the inlet Fe:P relationship (R^2 = 0.935) to infer the native stoichiometry of P binding to Fe oxide particles, and the outlet Fe concentration to infer the amount of *in-situ* dissolution of Fe oxides; then estimating P removal using the observed outlet P concentration. Based on this analysis, we conclude that P removal rates can reach ~0.6 g P m^3 day^{-1} when not limited by P-supply and/or low hydraulic retention times. Based on equilibrium geochemical modelling, we further suggest that the incorporation of Fe-based media close to bioreactor inlets would allow for P adsorption, whilst minimising the potential for reductive Fe-dissolution.

Thinking about freshwater farm plans?

Don't forget Horizons Regional Council has a website dedicated to freshwater information, including maps and specific data for each freshwater management unit in the region.

Visit freshwater.horizons.govt.nz to view these as well as updates on how policy changes will impact the One Plan.

HAVE YOUR SAY

While you're there you can also share your thoughts about top swim spots and outstanding water bodies before 28 February.

Oranga Wai OUR FRESHWATER FUTURE

SIMULTANEOUS PHOSPHORUS REMOVAL AND REDOX BUFFERING OF DENITRIFYING BIOREACTORS USING ORGANO-MINERAL COMPOSITES

Dorisel Torres-Rojas

University of Waikato

Agricultural runoff often transports excessive amounts of nutrients such as dissolved inorganic nitrogen (N) and phosphorous (P), resulting in the eutrophication of waterways. Diffuse pollution control technologies include denitrifying bioreactors, which act as an organic carbon (OC) source to reduce high nitrate loading (NO_3^-) from agricultural runoff to receiving waterways by supporting heterotrophic denitrification. Although denitrifying bioreactors are designed to treat N, there is interest in the simultaneous removal of P using iron oxide activated bio-media. In previous studies by our group, P removal by Fe(III) (hydr)oxide activated charcoal was confirmed to operate at the acidic-neutral pH of typical denitrifying bioreactors. However, in anaerobic systems, such as bioreactors, redox reactions also reduce other components, including iron, manganese oxides, and sulfate.

Consequently, under electron-acceptor-limiting conditions (i.e., low NO_3^- supply), pollution swapping can occur, for example, by phosphate release coupled with iron reduction. This reaction pathway would, therefore, also limit the efficacy of purposefully introduced iron oxides (which serve as P adsorbents). One approach to prevent the release of P into drainage waters is to poise redox conditions in the bioreactor above the E_h level associated with iron or sulfate reduction.

In this study, we sought to test this theory by adding manganese dioxide (MnO2), an electron acceptor with intermediate properties between NO_3^- and $Fe(OH)_3$. Using laboratory-scale bioreactors and agricultural drainage water, we demonstrate that iron oxides effectively remove P in drainage water and remain present despite prevailing reducing conditions (influent P of 3 mg L^{-1}, effluent P < 0.5 mg L^{-1}). Continuous removal of P by the iron oxide containing treatments would suggest that despite the high level of initial P, we see continuous adsorption of P following a proposed multi-layer adsorption mechanism. Additionally, the presence of MnO_2 in the bioreactors consistently enhanced the removal of NO_3^--N from the influent compared to the woodchip-only treatments, suggesting that manganese (Mn^{2+}) serves as an alternate electron donor for the reduction of NO_3^-. Furthermore, Mn reduction operated throughout the experiment, limiting Fe-reduction and preserving the introduced Fe oxides.

FILAMENTOUS ALGAE NUTRIENT SCRUBBERS FOR AGRICULTURAL DRAINAGE TREATMENT AND NUTRIENT RECOVERY

Rupert Craggs and Harizah Hariz

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Filamentous Algae Nutrient Scrubbers (FANS) are a novel agricultural drainage treatment system that grow filamentous algae to recover nutrients for beneficial reuse. Filamentous algal systems have been used to treat agricultural drainage in the USA, where they have also been used to treat various agricultural effluents and wastewaters.

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

This talk will discuss the potential to use FANS systems for agricultural drainage water treatment in New Zealand and present the results from MBIE funded research on the performance of FANS at mesocosm-scale. Results of outside mesocosm experiments have shown annual nutrient removal rates in excess of 130 g Nitrate-N m^{-2}.y and 20 g DRP m^{-2}.y which are in line with removal rates obtained with systems in the USA (90 g TN m^{-2}.y and 10 g TP m^{-2}.y respectively). The nutrient removal rates of FANS are at least double those of Constructed Wetlands for N (40 g TN m^{-2}.y) and four times those for P (3 g m^{-2}.y).

We are investigating different options for attached algae systems including along-side or within existing freshwater bodies (streams, rivers, lakes).

Algal biomass production varies seasonally between 5-15 g m^{-2}.d. Beneficial reuse of the nutrients that are recovered as algal biomass that are culturally acceptable to Māori will also be determined (e.g., fertilizer, animal fodder).

Annual results from pilot-scale demonstration trials conducted in consultation with iwi partners have shown similar performance and provided valuable insights into the operation and maintenance requirements of FANS

SINGLE VERSUS MIXED SPECIES ASSEMBLAGES ON THE PERFORMANCE OF FILAMENTOUS ALGAE NUTRIENT SCRUBBERS (FANS) FOR THE TREATMENT OF AGRICULTURAL DRAINAGE

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Filamentous algae nutrient scrubbers (FANS) have potential as a novel on-farm treatment system to remove and recover diffuse nutrients from agricultural drainage water. FANS use attached filamentous algae that grow and assimilate nutrients from the water which are removed when algal biomass is harvested for beneficial use (e.g. biofertilizer, animal feed supplement). This study assessed on-farm performance of pilot-scale FANS over seven months, comparing the effects of seeding methods (controlled seeding vs. natural establishment) and seeded species (single target species vs. mixed algae assemblage). Controlled seeding promoted faster biomass establishment on FANS than the natural establishment method. However, environmental conditions had a stronger effect on biomass productivity and nutrient removal than the difference in seeding method and seeded species (single species vs. mixed species). Crucially, these experiments demonstrated that FANS seeded with a single target species have the potential to be operated with a higher relative abundance on the FANS for a longer period of time compared to FANS seeded with a mixed species assemblage, enabling the recovery of high-quality biomass for on-farm FANS. This study demonstrated that FANS can be successfully used to treat nutrients in agricultural drainage water, and therefore could be implemented as a novel tool to assist in mitigating diffuse pollution in New Zealand.

A CONSTRUCTED WETLAND RECEIVING DAIRY FARM RUN-OFF: EFFECTIVENESS DURING HIGH FLOW EVENTS COMPARED WITH BASEFLOW

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The efficacy of constructed wetlands (CWs) during storm events has been questioned, due to the short residence time for treatment. While it is recognized that CWs can efficiently remove nitrate via denitrification during baseflow, their performance is less well studied during high flow events when high loads of particulate associated pollutants and faecal bacteria are typically mobilized. A multi-celled, CW receiving runoff from farmland and a major laneway on a dairy farm was monitored for performance during two drainage years (2017 and 2019). The 2017 season had the highest precipitation since 2000 (25 events, 989 mm), while the 2019 season had the fourth lowest precipitation (7 events, 467 mm). Wetland outflow was even more extreme, at 96,500 m^3 and 10,500 m^3 respectively. During baseflow, runoff was primarily from upslope natural wetlands and direct groundwater inputs. Removal of nitrate appeared low during the 2017, as the upslope wetlands had already reduced nitrate in the surface inflows, while groundwater monitoring wells had not been installed. In 2019, when groundwater inputs were monitored in four piezometers, the reduction in incoming nitrate loads was able to be accurately estimated at ~70%. During rain events in both the years monitored, high loads of particulate associated pollutants washed off the laneway and into the CW, far exceeding inputs during baseflow. The initial cells of the CW acted like sedimentation basins, effectively capturing much of the sediment and associated pollutants. Removal efficacy of pollutants such as TSS for the two years was 80% and 65% respectively, with similar removals of TP and *E. coli*. In most instances, removal of other monitored pollutants exceeded 50%. The study confirmed:

- The importance of laneways as point sources of particulate-associated pollutants,
- The need to monitor groundwater inputs to adequately characterize nutrient processing in constructed wetlands,
- The influence of seasonal and inter-annual variability in CW input loads, and
- The efficacy of sedimentation basins where inputs to CWs carry significant particulate loads.


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MITIGATING THE POTENTIAL FOR CONSTRUCTED WETLANDS TO RELEASE DISSOLVED REACTIVE PHOSPHORUS

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Constructed wetlands (CWs) are one of the tools being utilised to mitigate agricultural diffuse pollution losses to waterways. However, in some situations they may be sources rather than sinks of dissolved reactive phosphorus (DRP). This is likely due to their creation on drained, fertilized areas where local, carbon rich top-soils have been added to the wetland to increase rates of denitrification and increase initial macrophyte growth rates. Draining of swampy soils for agriculture increases the rate of organic matter mineralisation and the conversion of organic phosphorus into DRP. This DRP can bind to soils in forms that are unavailable to pasture grasses and crops in aerated soils but can be mobilised if these soils become inundated and anoxic, through Fe and Mn reduction. Here we investigate the risk of DRP release following inundation for gley soils, an often-drained soil type that is common to lowland agricultural regions of New Zealand. To assess DRP release risk we have; 1) measured degrees of phosphorus saturation (DPS) in a range of gley soil types with different total P concentrations and chemical characteristics indicative of DRP binding potential, and 2) conducted assays to measure DRP release after inundation and subsequent deoxygenation 3) tested a range of potential mitigation measures. We have identified a critical DPS threshold for DRP release from gley soil and identified some potentially effective mitigation measures.

DIVERSE SOLUTIONS FOR MITIGATION OF DIFFUSE CONTAMINANT LOSSES: WHICH GOES WHERE FOR WHAT?

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Edge-of-field and flow path mitigation options can complement in-field management of agricultural land-use to reduce diffuse contaminant losses to surface waters. They can provide farmers and land managers with an additional range of tools to manage contaminant losses and achieve nutrient limits.

The pathways by which run-off and associated contaminants travel from land to water determines the types of contaminants mobilised, their form (e.g., dissolved or associated with particulates), where they can be intercepted and the suitability and suitability of different mitigation options. Each mitigation option has its niche in terms of contaminant(s) and flow path(s) able to be targeted, efficacy, cost, longevity, operation and maintenance requirements, ancillary benefits and disbenefits, landscape fit, and consenting requirements. However, it is often not clear to users which mitigation option is appropriate for their situation, where it could be located, what contaminant reductions and benefits can be achieved, and what it would cost to implement, maintain and operate.

This talk will overview these factors for 7 mitigation options that have wide applicability on pastoral farms in New Zealand; grass filter and planted riparian buffers, constructed wetlands, woodchip bioreactors, filamentous algal nutrient scrubbers, sediment traps and detainment bunds. Practical guidance will be provided to help land managers identify an appropriate suite of mitigations for their specific situation and needs.

A COMPARISON OF THREE DIFFERENT EDGE-OF-FIELD NITRATE MITIGATION PRACTICES, AS REALISED FROM FIELD TRIALS

Lee Burbery[1], Phil Abraham[1], John-Paul Praat[1], Vern Brasell[1], Aidan Bichan[1] and Murray Close[1]

[1]DairyNZ

Constructed wetlands and woodchip denitrifying bioreactors are developing edge-of-field mitigation practices, for reducing contaminant loads from pastoral land in New Zealand (NZ). We provide a research update on, and make a comparison of, three edge-of-field nitrate-mitigation technologies we have trialed over the past seven years. These being a denitrifying:

i) constructed wetland,
ii) in-stream woodchip bioreactor,
iii) woodchip denitrification wall in a shallow gravel aquifer.

We have evaluated the treatment performance and estimated the cost-effectiveness of nitrate removal for each method. Such information is useful for assessing the feasibility of the different mitigation methods. A constructed wetland (5,000 m^2) in the Wairarapa region is an example of an off-line, multi-celled, surface flow treatment wetland of serpentine design. The wetland was constructed in 2015. Praat et al. (2015) reported on its design and treatment performance after 6 months when wetland plants were still establishing. The nitrate removal efficiency at that early time was 48%. The wetland has since had water quality monitored monthly, for seven years. From analysis of the long-term monitoring data, we detected no change in the wetlands' nitrate removal efficacy and estimate that, on average, it has removed 490 kg NO_3-N/year.

A large (430 m^3) ´in-stream' woodchip denitrifying bioreactor at Woodbury, Canterbury, was completed in 2020. Details of its construction and commissioning were described by Burbery et al. (2022). Following the initial flush of labile carbon that occurred over 2021, the bioreactor has averaged nitrate removal 504 kg NO_3-N/year.

A woodchip denitrification wall (375 m^3) was entrenched within the alluvial gravel aquifer at Silverstream Reserve, Canterbury, in 2018. Unlike the other denitrifying devices, the woodchip wall intercepts shallow groundwater, not surface drainage water. Details of the wall's construction and performance over its first year of operation (when we estimated it removed 542 kg N/year) are described by Burbery et al. (2020). The treatment performance of the wall has since declined significantly. The trend in four years of monitored groundwater nitrate data, suggests a half-life of 3.3 years.

Based on actualised and projected costs, we determine the constructed wetland to be the most cost-effective of the three nitrate mitigation practices compared, and estimate that the long-term cost of nitrogen removal to be no less than NZ$28 /kg N.

DETAINMENT BUNDS AS A TOOL FOR MITIGATING THE HYDROLOGICAL IMPACT OF POST-SETTLEMENT AND DISTURBANCE AND CLIMATE CHANGE

John Paterson[1], Andrew Hughes[2], Katherine Glasgow[3] and Natalie North[4]

[1]The Phosphorus Mitigation Project Inc., Rotorua, [2]NIWA, [3]The Bay of Plenty Regional Council, [4]Landpro

The post-settlement removal of forest and replacement with pastoral land uses from much of New Zealand has significantly impacted the hydrology of many catchments. Forest removal and other pastureland development practices e.g., extensive drainage, has reduced rainfall interception and buffering and as a result has increased stream flows and the size of runoff events. These human-induced impacts will be further exacerbated by the increased frequency and magnitude of runoff events that are forecasted under future climate change. Detainment Bunds^{PS120} have been demonstrated to effectively delay the delivery of pasture derived runoff. The catchment-wide placement of DBs may therefore be a potential tool to mitigate the hydrological impact of both land development and future climate change impacts.

As well as applying good practice to limit the loss of water contaminants from the farm in the first instance, an additional option for pastoral farmers is to target storm run-off mobilised contaminants along their escape pathways. Three of the contaminants to off-farm water bodies; phosphorus, sediment, and pathogens, are generally only lost from the farm during episodic high intensity rainfall events. It makes sense to intercept and treat this conduit of multiple contaminant losses from the farmed landscape. A group of farmers formed the Phosphorus Mitigation Project Inc. (PMP) in 2016 to source funding and direct applied research on validating and refining the novel concept of treating episodic farm storm water run-off events with Detainment Bunds^{PS120} (DB).

This has been successful to date with positive results via a completed MPI/Sustainable Farming Fund project enabling the 2020 B Levine PhD on DB performance and the ongoing MPI/Sustainable Land use and Climate Change funded project in collaboration with NIWA to trial the DB concept pan NZ (A. Hughes FLRC 2023). While PMP's initiative and original primary target was treatment of contaminants from runoff events, this paper discusses another important potential benefit of temporarily detaining stormwater on-farm particularly for climate change outcomes. The multiple benefits of farm pasture run-off interception include mitigation of losses of phosphorus, sediment and pathogens, as well as dampening flooding peak flows, and contributing to aquifer re-charge.

This paper examines a 'what if' strategy. What if we could regenerate today's farmed landscape hydrology to a storm water buffered status similar or better than the pre-settlement hydrology of the predeveloped landscape? The applicability rate of high capacity (≥120m³/ha) DBs to whole catchments can be severely limited by some topography classes e.g., 'Flat' and 'Steep Hill'. However, developed pasture land on the intermediate topography classes of 'Rolling' and 'Easy Hill' can readily accommodate 50 – 70% applicability rates for DB installations.

Using GIS with LiDAR data we present possible scenarios for three whole catchment DB application scenarios and consider the benefits of their runoff buffering as proxy to the lost buffering of former indigenous spongy covers. We calculate what applicability rates of DBs and what 'roll-out' conditions would be needed for such a transformational change to the farmed pastoral landscape to benefit amelioration of climate change driven storm events.

HOW EFFECTIVE ARE DETAINMENT BUNDS^{PS120} AS A POLLUTANT MITIGATION TOOL IN NEW ZEALAND?

Andrew Hughes[1], Rebecca Stott[1], James Sukias[1], Chris Tanner' and John Paterson[2]

[1]NIWA, Hamilton, [2]The Phosphorus Mitigation Project Inc, Rotorua

Detainment Bunds^{PS120} are 1-3 m high constructed earth ridges across hillslopes that temporarily impede overland flow in a ponded area. Detainment Bund^{PS120} locations are determined with GIS software and high-resolution LIDAR data to achieve at least 120m³ of runoff ponding per hectare of upslope contributing area. Hillslope runoff is detained in the ponds for up to three days. While ponded, contaminants such as sediment, phosphorus and faecal matter can settle out, thereby reducing their delivery to downstream receiving environments. Previous research has demonstrated that Detainment Bunds^{PS120} effectively reduce contaminant runoff from free-draining soils of the volcanic-based Central North Island region. The soils of the central North Island are not, however, typical of the heavy, less-free draining soils that dominate the rest of New Zealand. In a collaborative project (funded by the MPI Sustainable Land Management and Climate Change (SLMACC) fund) NIWA and the Phosphorus Mitigation Project will extend trials of the mitigation potential of Detainment Bunds^{PS120} to two additional sites with poorly draining soils in the Auckland and Otago regions. To date, bunds have been constructed and instrumented. Monitoring of storm events at these two sites will take place over the next two years.

Other aims of this project include: i) determining whether non-toxic flocculants can be added to Detainment Bunds^{PS120} to augment their contaminant retention ability, and ii) determining how effective Detainment Bunds^{PS120} are at reducing faecal microbial contaminant loads and floating debris. Work to address these aims has been ongoing at two previously studied Detainment Bunds^{PS120} sites within the Rotorua district. To date we have sampled storm events to provide data for the performance of Detainment Bunds^{PS120} before the application of any flocculants. Devices for automatically introducing the flocculants into the water entering the Detainment Bund^{PS120} ponds are being developed and will be installed during the next year.

Results from our monitoring of confirm previously recorded high contaminant (suspended sediment, total phosphorus (TP) and total nitrogen (TN)) attenuation ability of Detainment Bunds^{PS120}. Our results indicate that, while their mitigation effectiveness varies by event, they can remove over 90% of the sediment, TP and TN delivered to them. Our measurements of the faecal indicator bacteria, *E. coli*, also indicate that the bunds can reduce *E. coli* loads (and hence potentially pathogen loads) by up to 90%.


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Woodchip bioreactors: For nitrate removal from artificial drains by denitrification.
Constructed wetlands: Reduce sediment, nutrients and microbes like E.coli from runoff and drainage waters.
Riparian buffers: Filter contaminants from runoff and shallow groundwater before entering streams.
Filamentous algae nutrient scrubbers: Farming algae to treat nutrients in agricultural drainage waters.
Detention bunds: For treatment of flashy, sediment-laden surface runoff.
NIWA can provide guidance, research and technology for the best mitigation system for diffuse pollution management to suit a range of farmed landscapes.
To learn more, visit:
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HYDROLOGICAL MODELLING FOR DETAINMENT BUNDS

Linh Hoang

NIWA

Detainment bunds (DB) are a type of storm water retention structure constructed in low order ephemeral streams to temporarily retain surface runoff generated by intense storm events. DBs were first implemented in the Lake Rotorua catchment as a strategy to address Phosphorus losses from pastoral agriculture. In this study, a detainment bund within Lake Rotorua catchment with high frequency and continuous measured data over numerous storm events was used as the case study. The study aims at developing a dynamic hydrological model to simulate hydrological processes occurring in the detainment bunds (DB). The model concept is based on a simple water balance. The inflow of DB includes: flow from upstream area based on both measurement and estimation for the ungauged area; and direct rainfall on ponded area based on rainfall data and temporal estimates of ponded area. Surface flows exit the DB by a combination of overflow from the upstand riser or spillway when the ponds capacity is exceeded, leakage during the ponding period and release after a three-day retention period. Ponded water can also be lost through infiltration and evaporation, but evaporation loss is usually insignificant due to the short detention period. The model is run at five-minute time step and calibrated for 14 monitored storm events which comprises three different event types: (i) overflow events (2) occurring at extreme rainfall with water overflowing the upstand riser, (ii) release events (11) during intermediate-sized storms with water releasing after 3-day treatment; and (iii) no-release events at relatively small storms where all the water is lost during the 3-day treatment. The model was evaluated by comparing the time series of simulated ponded height with observed data. The results show that the model could predict the ponded height very well with overall average values of Nash Sutcliffe Efficiencies (NSE) and coefficient of determination (R^2) for 14 events at 0.93 and 0.96. The model indicated that infiltration and leaking are two important processes affecting water volume in the bunds. Approximately across 14 events, 34% of water inflow is lost through infiltration while about 26% is lost through leaking. The positive modelled results on water quantity imply that the DB model gives a relatively good representation of hydrological processes and can be used as the basis for modelling of contaminant attenuation in DB.

SPATIAL DISTRIBUTION OF DUNG UNDER REGENERATIVE AND CONVENTIONAL GRAZING PRACTICES

Zachary Dewhurst

AgResearch

Regenerative agriculture is attracting a lot of interest amongst farmers in New Zealand and globally. Two of the pasture management practice prompted by the regenerative agriculture movement involves the use of a greater diversity pasture species and a shift in grazing to maintaining higher than currently recommended pasture covers in rotational stocking systems (both pre- and post-grazing), in conjunction with high stocking intensities during grazing. The impact of a change to a higher stocking density on the return of animal excrement and nutrient cycling is relatively unknown.

Drones have previously been used to locate urine patches in both dairy and other intensive grazing, however, drones haven't been used to locate and map the spatial distribution of dung patches before. This research has a focus on using aerial imagery captured by a drone to identify and map the spatial distribution of dung and then validate the approach with a more traditional ground-based approach.

The research study is located in Central Hawkes Bay, on Mangarara Farm, which has been working towards regenerative agriculture management for 20 years. The grazing study is in a 9-ha paddock that has been planted with poplar trees protected by single wire fences, that has created multiple (15) lane ways in the paddock. For this study the laneways have been spilt into 67 cells with each cell being approx... 0.12 ha. The paddock has been grazed with R1 and R2 heifers under an adaptive grazing practice (higher pre-and post-graze pasture mass, and higher instantaneous stocking intensity during grazing) for the last 12 months. Within this paddock 12 individual cells have been removed from the current adaptive grazing practice and replaced with a grazing regime with lower pre and post grazing herbage masses and lower stocking intensity during grazing (control) using two, small, independent groups of beef cattle. Each of these cells is paired with a cell that has been grazed by the adaptive group

Once the heifers finish grazing a DJI Mavic 3 drone was flown over the cells and multiple images taken of the dung distribution in cells from the two grazing systems. Using the program pix4dreact these images are then joined together into one image. ArcGIS pro and image J were used to locate the dung patches within the images. The dung location in the images were then validated using a survey grade GPS Trimble to locate the dung patches on the ground under the two grazing practices. The number and distribution of dung patches identified by the drone images were compared with the numbers those collected as part of the ground truthing.

In addition to presenting the findings comparing the use of the drone and ground-based methods, data on the dung patch distribution (i.e. density and location) collected using the two methods under the two contrasting grazing practices is also presented. The comparison of dung distribution under the two management approaches will add to our understanding of the nutrient cycling and potential for nutrient hotspots under these two contrasting grazing systems.

NITROGEN LEACHING IN A DAIRY FARMLET GRAZING STUDY AS AFFECTED BY USE OF SPIKEY®

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Nitrogen (N) leaching from livestock farming is an important environmental issue in New Zealand (NZ) due to degradation of water quality. Research has been focused on developing and testing mitigation options to decrease N leaching. One potential mitigation option is the use of Spikey® technology which identifies animal urine patches after grazings and uses targeted application of a NitroStop™ product to treat the urine patches.
A farmlet grazing trial was set up at the Dairy Trust Taranaki Stratford dairy farm with paired 25 ha farmlets involving standard farm practice (Control) compared to use of Spikey® on paddocks after each grazing (Spikey®). The study commenced in Spring 2020 and is ongoing. Nitrogen leaching is being measured using 150 ceramic cup samplers (60 cm depth) in each farmlet, spread across twelve paired paddocks. Nitrate and ammonium N concentrations are being measured regularly and linked with drainage data from lysimeters (and water balance calculations) to determine N leaching.
There are now two years of measurements of N leaching and both years have shown a strong temporal pattern with highest nitrate concentrations in winter. During late-winter and spring of both years, the nitrate concentrations in leachate were significantly lower ($p<0.05$) in the Spikey® farmlet. In year 1, the average nitrate leached was 54.0 and 45.0 kg N/ha (SE 9.2 and 9.8, p=0.12) for the Control and Spikey® treatments, respectively. Corresponding estimates for year 2 were 38.2 and 35.0 kg N/ha (SE 5.5 and 7.2, p=0.45). Additional data on pasture and cow production will also be presented.

REDUCING NITRATE LEACHING AND IRRIGATION BY BRINGING USER-FRIENDLY, PHYSICAL AGRO-HYDROLOGICAL MODELS TO THE FARMING COMMUNITY

Joseph Pollacco

Manaaki Whenua – Landcare Research

Inefficient use of irrigation is widespread in pastoral farms. Agricultural Farm Management Platforms, AFMP, are powerful tools for improving water efficiency. The proposal is to implement a more precise, stable, and physically based hydrological agro-model, HyPix, into an AFMP to recommend precise agricultural practices. This approach has been demonstrated to be more precise than using traditional simple soil water models and will enable farmers to accurately predict the optimal irrigation rate to avoid plant stress, minimise losses, and comply with environmental limits.

The hydraulic parameters of HyPix are parameterised by applying novel, cost-effective methods to data generated by soil moisture, θ, sensors readily available on farms. This is performed by coupling HyPix with the Multistep Optimisation Algorithm, (MOA), which estimates the hydraulic parameters of every soil layer from θ-time series. HyPix can successfully simulate θ profile (concordance correlation coefficient CCC=0.71) and cumulative drainage very closely through observation by using the novel developed MOA. Moreover, we plan to expand the MOA to incorporate remote sensing-based evapotranspiration.

Scheduling irrigation with physical models is more accurate because it allows irrigation to be triggered when a critical pressure-head threshold is reached rather than a θ threshold with no explicit link to plant water availability. Also, using HyPix will enable farmers to maintain soil water deficits, leading to reduced nitrogen losses and water consumption with little effect on productivity.

The proposed monitoring set-up for farms, derives real-time data stored in the cloud via a cellular network. Data are automatically input into the HyPix model stored in super computers, which derive the hydraulic parameters using the MOA algorithm. These hydraulic parameters can be constantly updated in the background so that the farmer can quickly make predictions on optimal irrigation, depending on weather predictions, crop stage, and limits for drainage and ponding.

The advantage of the proposed methodology is that farmers will gain confidence that the model is performing as expected, because the simulations can be checked in real time by monitoring θ time series.

Precision agriculture offers the possibility of using a variety of crops on several different soil types under one irrigation system. The irrigation prescription map which provides real time recommendations on when, where, and how much to irrigate would be computed by a gridded HyPix model, which would require spatially distributed hydraulic parameters. The number and location of measurement points where hydraulic parameters need to be derived depends on soil heterogeneity, which can be rapidly determined using geophysical methods.

Depending on budget constraints, farmers can derive the hydraulic parameters by combining different cost-effective techniques recently developed: (i) calibration from θ data as described above; (ii) infiltration method; (iii) particle-size distribution; (iv) deriving a spatial time series θ profile by using electromagnetic induction surveys, using a quasi-2-dimensional inversion model, enabling a soil profile image of the true electrical conductivity which will be linked with. The hydraulic parameters can then be derived using the HyPix model, with the MOA using the derived time series θ with depth.

DEVELOPING A SUCCESSFUL NITROGEN MITIGATION STRATEGY IN A MAIZE GRAIN - CATCH CROP PRODUCTION SYSTEM

Rowland Tsimba[1], Brendon Malcolm[2], Tania Gunn[1], Ian Williams[1], David Densley[3], Jen Corkran[4] and Greg Edmeades[5]

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Two small plot replicated trials were initially established on two Waikato soils (clay and ash) in 2019 to evaluate the success of 11 catch crop cultivar species and timing combinations after maize grain harvest. Maize plots were planted in spring and catch crop treatments were applied at V5 maize development stage, brown husk and after maize silage harvest. The catch crop options were selected on their ability to grow in winter, "mop up" surplus rather than add to soil N, and for their use as stockfeed. The species included perennial ryegrass, Italian ryegrass or oats, and were either direct drilled, disc and drilled, or broadcasted as a monoculture, or in a mix with plantain. The five best-performing catch crop species and timing treatments were then selected for further trialling in 2020 and 2021. These consisted of Italian ryegrass and oats that were either interseeded at V5 maize development stage, broadcast when 25% of the maize leaf foliage had senesced, or either direct drilled or disc and drilled after maize grain harvest. The most consistent catch crop treatments were further tested at 15 on-farm sites across four North Island regions of New Zealand to demonstrate commercial feasibility. The amount of N leached from each treatment to 120 cm depth was measured at the clay site in 2020 and 2021 using suction cup samplers (measuring N concentration of soil water), in combination with a corresponding set of monolith lysimeters that were used to measure drainage volume.

The most successful catch crop treatments from the replicated trials were the 25% senescence broadcast Italian ryegrass, direct drilled oats, and disc and drilled Italian ryegrass options. The V5 treatment was the most inconsistent, resulting in either the greatest or least amount of soil N removal, depending on soil type, crop establishment and season. Over both years, catch crop N removal rates from the various treatments tested were greater on ash than clay soil (by 0.2–3.1 and 2.2–7.5 fold in 2021 and 2022, respectively). On the ash site in 2022, the catch crop cultivar had a greater impact on success than establishment method, and oats significantly outperformed Italian ryegrass options in terms of N removal, by up to 81%. However, under the same establishment method in 2021 the amounts of N removal were similar between species. On the clay soil site in 2022, establishment method had the greatest impact on N removal, whereby direct drilled oats and ryegrass broadcasted at 25% maize senescence outperformed the disc and drill options by almost 50%.

Even though there were generally greater N leaching losses (by up to 3.4 kg N/ha) in fallow plots compared to catch crop plots, total N leaching losses over both years were very low N (<4 kg N/ha/year). This was attributed to N applications that were consistent with plant uptake. Across the on-farm trials, conditions were particularly wet making post-harvest establishment of catch crops difficult. Consequently, the 25% maize leaf senescence tended to outperform the direct drilled oats in terms of N removal. The lower amounts of N removed by the oats was attributed to the lower N content, rather than biomass yield. These results show that catch crops can be successfully adopted into maize grain rotations to reduce the risk of N leaching. Importantly, the methodology and choice of catch crop should be selected on a case-by-case base by considering the soil type and climatic conditions. Both broadcast Italian ryegrass at 25% maize senescence (particularly on clay soils) and drilled (direct drilled or following discing) oats or Italian ryegrass (or a combination of both) post-maize harvest can improve the sustainability of maize silage systems.

BEST PRACTICE MANAGEMENT OF NITRATES IN PROCESS CROPPING

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This project arose from industry desire to retain the right to successfully grow process vegetable crops in Hawke's Bay. Proposed changes to policy and restrictions to nutrient use threaten the continuing operation of large vegetable processors in the area. If restrictions are placed on the use of nitrogen, the ability to profitably produce vegetables for processing may diminish. These are high volume, low margin businesses competing on a global stage, and are at risk from rising costs of production. Our goal is to have accepted best nutrient management guidelines for beetroot, sweetcorn, tomato, and bean crops that optimise production and nitrogen fertiliser use efficiency, whilst minimising nitrogen leaching and $CO_2^{\text{-equivalent}}$ emissions

The primary focus of the project is to validate test procedures and recommendations for management of nitrate in key process crops produced in New Zealand. Industry best management practice currently draws from the Horticulture New Zealand published guidelines in "*Nutrient Management for Vegetable Crops in New Zealand*" (2019) by J. Reid and J. Morton. Previous trial work suggested the recommended rates may result in over or under supply of nutrients, leading to adverse environmental risk or yield penalty in some crops. If the information in this book is used as a regulatory tool as 'best management practice' in the future, it is important to understand what changes to grower practice will mean for on farm productivity and profitability as well as any noting environmental impacts.

This project will test the outcomes for crop production and soil nitrogen under different nitrogen management practices and will develop updated best practice recommendations. The tools we are using for the project are all available to growers; soil testing (particularly Potentially Available N and Mineral N tests), Nitrate Quick Tests, and the FAR Nitrate Mass Balance Calculator, and *Nutrient Management for Vegetable Crops in New Zealand* guidelines. This in-field trial compares two rates of nitrogen applied; the grower standard rate as determined by their own advisors, and an 'alternative rate'. The alternative rate is the rate recommended in *Nutrient Management for Vegetable Crops in New Zealand*, based on Potentially Available N to depth of 15cm. All other nutrients and other grower practices are kept the same. Growers are consulted throughout the season and are given up-to-date soil nitrate N information to support their own decision making. Both McCain Foods and Heinz-Watties are active in all key process cropping regions and will actively transfer lessons from this project across New Zealand through their field reps and agronomists.

First year results indicated minor yield differences when fertiliser rates were reduced, but data did not establish statistical significance. Data collected did add to questions about the appropriate depth of soil to test, the tests to use for nutrient budgets, and the use of pre-side-dressing tests using the Nitrate Quick Test. Year Two has been off to a wet start, with delays to planting and side dressing for growers.

The paper details results from year 1, and results gathered so far for year 2.

CHARACTERISATION OF HYDROLOGY AND DENITRIFICATION POTENTIAL IN HILL COUNTRY SEEPAGE WETLANDS

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Seepage wetlands is a potential nitrate mitigation tool in the pastoral hill country landscapes. These small wetlands are characterised by saturated and organic matter-rich sediments and located at the convergence of the important surface and subsurface nitrate-N flow pathways from the catchment that result in their high denitrification potential. However, our understanding of how seepage wetland sediment and hydrologic characteristics influence nitrate-N removal via denitrification is limited. This study characterised seepage wetland sediment and hydrology for nitrate-N mitigation with the objectives to (1) assess the spatial gradient of the denitrification-influencing sediment properties, and (2) investigate the wetland's surface and subsurface hydrologic features that influence nitrate-N removal. Seepage wetland sediment properties and their denitrification enzyme activity (DEA) were quantified using the acetylene inhibition technique, and their spatial gradients were assessed vertically (within sediment column) and horizontally (within and between wetlands) at four seepage wetlands in the lower North Island of NZ. The hydrologic characterisation involved monitoring (1) the stream flow and the nitrate-N load in and out of one of the selected wetlands for 2 years (June 2019-June 2021), and (2) the shallow groundwater quality at the 0.5, 1 and 1.5 m depths for 1.5 year (November 2019-June 2021). Within the sediment columns, the highest DEA values were measured at the surface 0-15 cm depths. The surface DEA values varied widely (560-5371 $\mu g\ kg^{-1}\ h^{-1}$), based on which the sites were categorised into the High-DEA (>3000 $\mu g\ kg^{-1}\ h^{-1}$) and the Low-DEA (<1000 $\mu g\ kg^{-1}\ h^{-1}$) sites. Major DEA-influencing sediment properties were identified as water content (WC), nitrate-N, %total carbon, %total nitrogen, C:N, dissolved Fe^{2+} and Mn^{2+} ($p \leq 0.05$). The wetland positions with high WC also measured high DEA ($p \leq 0.05$). However, the sediment properties accounted for only 53-68% of the variance in DEA, suggesting additional wetland characteristics influenced denitrification in the seepage wetlands. The hydrologic characterisation found a surface flow-dominated hydrology in the study wetland, in which precipitation played a key role in nitrate-N removal. The annual nitrate-N removal in the wetland varied from 0.5% in year 1 (winter precipitation of 345 mm was ~40% of the annual precipitation) to 41% in year 2 (winter precipitation of 193 mm was 21% of the annual precipitation). The winter high flow events and the low flow events, possibly influenced by stock grazing, were identified as the critical periods for nitrate-N losses, while spring resulted in nitrate-N attenuation. The positive influences of high WC and diffuse flow on nitrate-N removal suggests that drainage manipulation has the potential to improve nitrate-N removal in seepage wetlands in the pastoral hill country landscapes.

MULTI-LAYER SOIL HYDROLOGY MODELLING IN OVERSEER

Donna Giltrap[1], Joseph Pollacco[1], Scott Graham[1], Sam Carrick[1], Linda Lilburne[1] and Jean-Paul Tavernet[1]

[1]*Manaaki Whenua – Landcare Research*

Overseer is a decision support tool used widely by councils and farmers to manage nitrogen leaching, amongst other environmental impacts of farming. Originally, soil water was simulated using a single “layer” to represent all the soil water within the 0-600mm depth range. This led to some limitations in Overseer’s ability to simulate situations such as changing soil properties with depth or to simulate soil moisture and drainage at other depths.

In this project we modified the soil hydrology model so that the soil is represented as a sequence of 100mm layers with water flowing from layer to layer. Most of the water transport equations remained largely unchanged. However, the evapotranspiration equation needed to be modified to account for the change in root density with depth in the soil.

The performance of the multi- and single-layer Overseer versions were compared over a range of soil types and rainfall conditions. The multi-layered Overseer model on average simulated less evapotranspiration than the single-layer version, resulting in the annual drainage being on average 7.5% higher in the multi-layer model. Comparisons of the two models with measured drainage indicated that both models had similar precision, but the multi-layer model had a positive bias. Subsequent refinement of the evapotranspiration parameters reduced this bias.

With these changes the multi-layer soil hydrology model could easily be extended down to 1000mm using S-Map data, and potentially deeper with some assumptions, to represent deep-rooted forage crops such as lucerne. However, it should be noted that the nutrient distribution model still uses a single layer and that the empirical relationship between drainage and nitrate leaching has only been established at 600mm depth.

While the introduction of a multi-layer soil profile is a conceptual improvement, the Overseer model still has limitations in its ability to simulate the saturated conditions that occur in poorly-drained soils and further improvements in the soil hydrology model would be needed to address this.

IMPACT OF USING DIFFERENT CLIMATE DATASETS IN THE OVERSEER MODEL

Jean-Paul Tavernet

Overseer

OverseerFM is a farm management decision support tool that uses a combination of inputs including climate datasets provided by NIWA (National Institute of Water & Atmospheric) to determine N-loss estimates at a block and farm scale. This study investigated the impact of using climate datasets with different temporal resolutions on the N-leaching estimates generated by the Overseer science model, without increasing data input requirements for the end-user.

The study focused on the impact of using daily resolution data within the hydrology sub-model in the first instance. The presentation will show the comparisons of anonymized N-leaching estimates determined by the Overseer model using

- the existing 30-year long-term average *monthly scale* climate dataset (v6.4.3)
- the average of 30 individual climate years of N-loss estimates using *monthly scale* climate data
- the average of 30 individual climate years of N-loss estimates using *daily scale* climate data.

The overall findings on the impact of using different climate datasets will be discussed in the context of recently calculated estimates of model output uncertainty relating to climate inputs.

ACCOUNTING FOR DEEP ROOT N UPTAKE IN OVERSEER

Hamish Brown[1] and Jean-Paul Tavernet[1]

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Overseer currently assumes roots only go to 600 mm in the soil. This is too shallow to accurately represent many crop, tree and pasture species. A modelling exercise was conducted to determine the extent of additional nitrogen (N) uptake that crop and pasture simulations could achieve if their roots are allowed to grow and extract nitrogen below 600 mm depth. Simulations representing wheat, maize and pasture were conducted in factorial for a range of root depths (600, 700, 800, 900, 1200, 1500 mm), initial soil mineral N contents, fertiliser N inputs (N supply factors), potential yields (N demand factor), irrigation scenarios and years (1999–2015) using the APSIM (Agricultural Production Systems Simulator) model. The proportion of N that leaches below 600 mm that deep roots may capture (DeepRootEffect) varied between 0 and 1.0 for individual simulations with increasing root depth showing a clear increase in DeepRootEffect. N demand showed a clear effect with increasing demand increasing DeepRootEffect and increasing N supply showing the opposite effect. Overall, there is clear justification for the need to modify Overseer to take account of the effects of deep roots (> 600 mm depth) on crop N uptake and leaching.

A mechanism is proposed where a "pseudo layer" is added to Overseer that represents the mineral N that has leached below 600 mm but has not yet leached below 1500 mm. Crop uptake from this layer ($Nuptake_{600\text{-}1500}$) is calculated monthly along with leaching into the top and out the bottom. Any $Nuptake_{600\text{-}1500}$ is N that is not leached so this is summed for the year and deducted from Overseer's prediction of N leaching. A function for predicting $Nuptake_{600\text{-}1500}$ is proposed that uses root depth, along with the amount of N in the deep layer and the crop/pasture demand for uptake below 600 mm. This provides a pragmatic solution to account for the benefit of deep rooted species without a need for substantial change to the Overseer code base.
The presentation will cover the theory and analysis for improving deep root representation and provide an update on implementation testing of the proposed improvements

IMPROVEMENTS TO THE OVERSEER CROP MODEL

Hamish Brown[1], Edith Khaembah[1] and Jean-Paul Tavernet[1]

Plant and Food Research

Overseer is able to model the nutrient and water balances of most farm types in New Zealand. Plants are represented in the model by their green cover (affecting transpiration and evaporation), nutrient uptakes (nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg), chlorine (Cl)) and return from residues. There are a substantial number of crops that must be represented in Overseer and all Arable, Forage, Fodder, Vegetable, Fibre and Bulb crops are represented by the same simple generic plant model described by Cichota et al. (2010). Since the inclusion of this model in Overseer, the underlying N balance approach has been adopted for the background model for all block types in Overseer, with alternative plant models used for Pasture and Trees. There have been a few minor upgrades to the crop model in Overseer with the addition of fodder crops (Chakwizira et al. 2011) and recently the addition of Hemp for seed and fibre, Tulip bulbs, a number of new seed crops and the revision of a number of seed, grain and vegetable crops (Brown and Michel 2021; Brown et al. 2021). These recent improvements put a concerted effort into the process of describing the meaning of Overseer parameters to experts in specific crops and using expert opinion to estimate and refine crop parameters. This process yielded a number of additional crops for Overseer and highlighted some structural issues with the crop model. These can be separated into issues with the crop model's core equations and issues with the structure and categorization of crop coefficients. A follow up project was conducted to address these issues

Model code changes recommended use a standard set of crop biomass, cover and root depth curves that are scaled between planting and harvest dates to give realistic predictions of these variables. This has facilitated a rationalization of the crops listed in Overseer as there is no longer any need for variants such as spring/winter or short/medium/long to be listed. Presently the length of their duration is taken from user-provided planting and harvest dates. Changes are also recommended to biomass predictions to take account of the effects of field and dressing losses of harvested product.

Coefficient table changes include the use of full botanical names and end uses for each crop. This has facilitated a review and expansion of crop parameters to fix a number of erroneous values and to extrapolate parameter values for incomplete crops from closely related family members. In addition, a parameter certainty score is added to each crop to identify if parameter values have been extrapolated from related crops, determined from expert opinion or based on measured data. The simplified and tidied layout of the crop parameter table will facilitate faster review and improvement of crop parameters

A summary of the proposed changes and current progress with implementation and testing will be presented.

SENSITIVITY AND UNCERTAINTY ANALYSES FOR N-LOSS ESTIMATES BY THE OVERSEER MODEL

Jean-Paul Tavernet

Overseer

Sensitivity and uncertainty analyses help provide information that aids in understanding a science model's performance and outputs. As the first step to better understanding N-loss estimates generated by the Overseer science model, sensitivity and uncertainty analyses were undertaken to identify key input parameters, and interactions, that significantly alter model estimates for dairy, beef and sheep, and cropping farm systems.

This work utilised real world anonymized farm setups to carry out local and global sensitivity analyses on a minimum of 30 parameters for different farm systems in OverseerFM. It confirmed that Overseer's N-loss estimate was most sensitive to changes in key climate and soil parameters with minimal parameter interactions. Uncertainties for these inputs were propagated through the model and the combined output uncertainties in the N-loss estimate relating to soil and climate, average 27±9% across all the farm systems, is consistent with other models in the field. The predicted uncertainty of other parameters identified in the sensitivity analyses, due to independence from parameter interactions, will also be discussed

ON-FARM SOIL HEALTH ASSESSMENT TO AID DECISION MAKING

Nicole Schon

AgResearch

Soil is a farms greatest asset. When the soil ecosystem is working effectively it is the provider and regulator of many ecosystem services. However, soil is vulnerable to degradation, and this can reduce its ability to provide ecosystem services. In order to maintain a healthy and well-functioning soil, we require methods for assessing its health. Currently, on-farm soil assessment is typically limited to soil fertility to inform nutrient management plans. The addition of indicators of soil organic matter, soil physical condition and biological activity can provide a more complete picture of the health of a soil.

We detail a method extending current monitoring of soil fertility to also include elements of soil quality indicators used for State of Environment reporting, Visual Soil Assessment and an additional measure of soil biology to assess soil health on-farm. The soil health assessment protocol has been designed to utilize existing soil fertility monitor transects used to track soil nutrient status. The use of specific indicators with target ranges that can also be linked to management recommendations, provide opportunity for improving soil health. The information is brought together in radar plots to show the aspects of soil health that may be lacking. We apply the soil health assessment protocol to case study farms with different soils. In instances where indicators are not at target, management changes can be recommended to improve soil health. However, aspects of soil health can be difficult to manage and slow to respond to management changes. By linking soil health to the farm system and environmental impacts will help to realise the value of soil health assessment and its management.

APPLYING ADVANCED GEOSPATIAL TECHNOLOGIES TO QUANTIFY SOIL HEALTH VARIATIONS IN AGROECOLOGICAL LANDSCAPES: A CASE STUDY IN NEW ZEALAND HILL COUNTRY FARM

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Clearance of native vegetation for agricultural production coupled with agricultural practices, such as fertiliser use and grazing with livestock on recent and poorly structured soils and on medium and steep slope has the potential to significantly affect the soil health and quality. To protect and where necessary improve soil health, the necessary course of action requires an adaptive management strategy, which is one which can apply the appropriate land use practices for each part of the targeted areas. Identifying and quantifying the spatial variation on soil health is a key role in this process, as this provides spatially explicit and detailed information on the condition of soil health across the landscape. Soil health is an aggregate of indicators including measures of nutrient fertility, biological activity, organic matter content and physical condition. In addition, pastoral agricultural landscape is far from homogeneousness, but a diversity of soils, topographies and vegetative covers and there is a diversity of land use and management practices. As such, mapping soil health in this landscape is a challenging process. This study aims to quantify the spatial variation in soil health in complex agroecological landscapes using modern geospatial analysis tools and technologies. A wide range of components of soil health such as soil organic carbon (SOC) concentration, soil fertility, bulk density, and earthworm abundance, and underlying factors presenting the topographical characteristics including the land surface biophysical information, and land use management practices, were utilised to model the spatially explicit pattern of soil health quality. Various machine learning techniques were applied to predict soil health at a pixel-level across the whole landscape from a limited number of soil samples collected from specific locations. Performance assessment was carried out to evaluate the model's outcomes and results obtained from the most effective model were used for further analysis. Overall soil health was quantified using a Composite Soil Health Index (CSHI), which was calculated from the mean value of the standardized individual soil health indicator obtained from the scoring functions for each grid cell. The farmlets that make up the long-term P fertiliser and sheep grazing experiment located near Woodville that is in the southern North Island of New Zealand was selected as a case study. Results from our study reveal that the soil health quality is highly different across the farmed landscape and varies between soil health indicators. Among various machine learning techniques that were applied to model soil health in this study, the Ensemble method that combines the predictions from multiple learning algorithms was found to be more effective than the individual method. This study demonstrates that advanced spatial statistical analytics and remote sensing can be an effective solution to tackle the challenge facing the modelling of biophysical processes in complex agroecological landscapes. Applying such an approach enables providing more detailed information on soil health and therefore, can advance the farm's environmental planning and management in New Zealand.

RECOVERY OF SOIL AFTER OVERIRRIGATION WITH DAIRYSHED EFFLUENT

Matthew Taylor

Waikato Regional Council, Hamilton

Overirrigation of dairyshed effluent to land along with fertilisation lead to extremely high Olsen P values at a soil quality monitoring site. New ownership, about 2008, lead to changed land management, which, in turn, impacted soil quality. Not only was nutrient chemistry affected, but interesting dynamics were also observed for pH and soil carbon. Soil quality monitoring has continued at this site with the latest samples currently undergoing analysis. Will these latest samples show soil quality has continued to improve?

MATCHING SOILS AND IRRIGATION AUTOMATION FOR SUSTAINABLE USE OF WASTEWATER

Katie Beecroft[1], Brian Ellwood[1] and Cathy Campbell[2]

[1]Lowe Environmental Impact, [2]Fonterra Co-operative Group Limited

Fonterra operates a dairy processing plant at Tuamarina, north of Blenheim within the Marlborough region, whereby dairy plant wastewater (DPW) is produced. The wastewater is predominantly irrigated to farmland at a series of properties surrounding the plant. When soil conditions are not suitable for land application and the Wairau River is above 60 cumecs flow, it discharges to the river. Lowe Environmental Impact (LEI) was engaged by Fonterra to undertake site investigations, and to assess and recommend future irrigation management.

It was found that the soils' field capacity values vary between 12% and 53% moisture content between sites. Available water holding capacity of the soils across the sites showed large variation mostly due to soil texture. The current irrigation application depth of 25 mm/event (250 m3/ha) is similar to or less than 50% of most of the soil's Profile Available Water (PAW), which is a normal maximum application criteria for fresh water. However, applying this volume at a high instantaneous rate at two sites which have very high Ksat rates was likely to result in significant macropore bypass flows. This is not appropriate for wastewater application. The soil saturated hydraulic conductivity (Ksat) values retrieved were moderate to high, while soil unsaturated hydraulic conductivity (K-40mm) values for most sites were low which reflect both the particle size distribution and presence of macropores which varied across soil types.

These soil findings were used to redesign the irrigation regime and irrigation was customised depending on the property and soils present. Innovative use of automated valves was proposed to upgrade the existing irrigation systems so that the irrigation application rates could be matched to the soils, with frequent smaller applications during the irrigation day used to allow time for the soil to absorb the dose volume, minimising bypass flow.

Water balance modelling showed that the total land area available is greater than that required to apply all wastewater sustainably, the revised irrigation application regime avoided soil moisture constraints and would allow the system to operate with no discharge of DPW to the river.

REDOX-INDUCED PHOSPHORUS RELEASE IN CRITICAL SOURCE AREAS UNDER SHORT-TERM SUBMERGENCE IN WINTER

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Critical source areas (CSA) contribute significant nutrient loss from pastoral lands in New Zealand. The potential contribution of phosphorus (P) from these areas due to short-term but repeated submergence of soils during winter seasons is not well studied. A field study was conducted to explore P dynamics under short-term submergence of two dairy farm soils (Recent Soil and Pallic Soil) at Massey University, in ephemeral flow pathways which act as CSAs during wet weather. Ten sampling stations were installed in each field enabling the sampling of porewater from 2 and 10 cm depths below the surface. Porewater and floodwater samples were collected within 24 hours after five rainfall events from July to August 2022. Soil texture, Olsen P, Mehlich extractable P, and anion storage capacity (ASC) of the initial soils (0- 10 cm depth) were measured. Redox potentials of the two soil depths were measured in situ. Dissolved reactive phosphorus (DRP), pH, dissolved organic carbon, selected cations, and alkalinity of the collected water samples were measured. Sand and clay percentages for the Recent Soil was 39 and 18%, respectively, and 14 and 32% for Pallic Soil, respectively. Olsen P (69 and 66 mg P/L) and Mehlich 3 extractable P concentrations were similar (147 and 133 mg P/L, for Recent and Pallic, respectively) between the two soils. The Pallic Soil showed higher ASC (29%) than the Recent Soil (19%). The pH of water samples was in the neutral range in both soils. The average DRP concentration in porewater (2 cm) varied from 0.65 to 1.03 mg/L in the Recent Soil, and the range was from 0.26 to 2.31 mg/L in the Pallic Soil during the study period. The average floodwater DRP concentration varied from 0.13 to 0.87 (Recent Soil) and 0.19 to 1.08 mg/L (Pallic Soil). The average redox potential of both depths for the two soils showed less than 33 mV, indicating that both soils were reduced enough to release P associated with Fe and Mn oxy(hydr)oxides, enhancing the risk of P loss to water. The study continues with P fractionation modelling to explore the mechanisms and relationships behind P release upon submergence in the CSAs.

FIELD TRIALS OF MULTISPECIES PASTURES AND ACTIVE BIOLOGICS TO ENHANCE PRODUCTIVITY AND NUTRIENT UPTAKE

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The recent *Essential Freshwater* reforms have placed increased scrutiny on nutrient use within farming systems to maximize nutrient use efficiency and minimize losses to the environment. A total allowable cap on nitrogen fertilizer use of 190 kgN/ha/yr has been applied to pastoral agricultural systems. Additional drivers to reduce overall nutrient inputs are the rapid rises in fertilizer prices and increased scrutiny on their contribution to farm level greenhouse gas emissions.

Lower intensity regenerative production systems may offer alternatives that can be incorporated into existing farming systems to various degrees, depending on farm goals. Multispecies pastures, involving ryegrass amongst other grass species, various clovers, multiple herbs such as plantain and chicory, and even radish plus sunflowers are being widely investigated. Benefits may include higher overall dry matter production throughout an entire season and broader nutritional properties. Soil bio-amendments also occupy the regenerative systems toolbox. Respond® is a proprietary mix of beneficial soil bacteria and fungi, designed to improve soil health, plant nutrient uptake and boost agricultural productivity.

Large, replicated plot field trials conducted in 2018/19 on an effluent block compared existing ryegrass/clover pasture, existing pasture plus Respond®, multispecies pasture and Respond®+multispecies pasture. Respond® boosted existing rye/clover pasture dry matter production by 12%. Over the 6-month trial, the multispecies pasture alone performed similar to the existing ryegrass pasture. However, the Respond®+multispecies combination boosted dry matter production by 37%.

Full scale paired paddock field trials of the Respond®+multispecies versus existing ryegrass/clover pastures began in December 2020. The Respond®+multispecies paddocks on average produced 96% higher dry matter. Herbage testing showed no significant differences in nutritional properties between the conventional and multispecies pastures. Cows enthusiastically grazed the multispecies sward. Of interest regarding nutrient use efficiency, was that the higher multispecies sward growth rates resulted in nitrogen uptake of around 400 kgN/ha/yr and 60 kgP/ha/yr for phosphorus, with only relatively minor effluent inputs. The combination of the multispecies sward and active biologics may provide a useful tool for 'growing more from less', thereby helping to implement *Essential Freshwater*.

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STARTER NITROGEN AND PHOSPHOUS TO ESTABLISH CLOVER SWARDS

Jeff D Morton

MortonAg, Christchurch

In previously undeveloped areas with low levels of available soil N, clovers may benefit from the use of starter N in addition to starter P fertiliser in the period between drilling and the commencement of N fixation. To investigate this concept, white and red clover was sown at two sites with medium total soil N levels (0.4 – 0.5%) in Central Canterbury and drilled with no fertiliser, N (urea), P (TSP) and N + P (DAP) to supply 30 kg N and P/ha. At neither site did N affect establishment or early growth of the clover. One site with a high Olsen P of 28 also showed no response in early clover growth to P. The other site with an Olsen P of 10 showed a large yield response to P at 3 months after sowing but this response was not present when pasture DM mass was measured at 6 months after sowing. It can be concluded that for a medium soil N status, fertiliser N is not required to assist early clover growth. At a low soil Olsen P level, starter P is beneficial for early clover growth but this effect may only last until the roots can access soil P.

CLOVER TEST STRIPS FOR IDENTIFICATION OF MOLYBDENUM DEFICIENCY

Jeff D Morton

MortonAg, Christchurch

Because of issues such as lack of clover in the spring and interpretation of the results of plant analysis, the concept of applying Mo to a small area and monitoring the vigour and cover of the clover compared to where no Mo had been applied was investigated at 21 sites on the east coasts of both Islands. There was no significant response in clover vigour and cover to 100 g/ha of liquid sodium molybdate any of the sites as observed 2-3 and 12-15 months after application. Clover Mo and N content were also measured as adequate (> 1 ppm Mo and 4.5% N) at nearly all of the sampling times for each site. Therefore this approach has been shown to be of practical application using GPS to locate a 5x2m strip in 3-5 paddocks with at least 10% clover cover where 500 g/ha of molybdic superphosphate has been applied in early to mid-spring. If an increase in clover vigour and cover is observed in the test strip compared to the pasture outside then 100 g/ha of Granular Mo or 50 g/ha of sodium molybdate should be added to the fertiliser application.

INFLUENCE OF SHELTER ON THE SPATIAL BEHAVIOUR OF EWES DURING LAMBING

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Lamb mortality rates in New Zealand range between 5 and 25% with the two main causes of lamb death being dystocia and the starvation/exposure complex. Lamb deaths due to starvation/exposure generally occur during the first three to seven days of life due to either insufficient nutrition or an inability to maintain their core body temperature. The rate at which heat is lost to the environment is influenced by lamb size with small light weight lambs being at greater risk of starvation/exposure than larger lambs. Temperature, wind speed and rainfall can all impact the rate of heat loss of the lamb. Thus, providing shelter during the lambing period can provide lambs an area with reduced wind exposure. Shelter as small as clumps of reeds or tall grasses have been shown to reduce lamb deaths due to starvation/exposure by up to 10% (Hinch et al. 2014). Studies examining the impact of shelter including provision of hay bales, topographical shelter and trees have reported decreases in lamb mortality rates of between 10 and 25% (Pollard 2006; Hinch et al. 2014). Until recently, however, it has not been possible to monitor ewe and lamb behaviour 24 hours a day in areas with undulating terrain.

New technologies such as global positioning systems (GPS) and triaxial accelerometers can now allow 24-hour a day observation of the patterns of movement by livestock and the influence of paddocks features such as natural and artificial shelter. Our aim was to determine how shelter impacted ewe movement using GPS units and the interaction of twin-bearing ewes with their lamb(s) using accelerometers. Ewe and lamb behaviour observations are still being coded from recorded video footage. An example of the GPS data collected will be demonstrated in this paper.

FACTORS AFFECTING GRAZING AND RUMINATION BEHAVIOURS OF DAIRY COWS IN A PASTURE-BASED SYSTEM IN NEW ZEALAND

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This study investigated the variation in daily time spent grazing and rumination in spring-calved grazing dairy cows (*n = 162*) of three breeds, Holstein-Friesian (HFR), Jersey (JE), and KiwiCross (KC) with different breeding worth index, and in different years of lactation (1st, 2nd, 3rd, 4th). The cows were managed through a rotational grazing system and milked once a day at 05:00 a.m. The cows grazed mainly pasture and received supplementary feeds depending on the season. Automated AfiCollar device continuously monitored and recorded grazing time and rumination time of the individual cows throughout the lactation period for three study years (Year-1, Year-2, Year-3) with 54 cows per year. A general linear mixed model fitted with breed × lactation year with days in milk (DIM), breeding worth (BW) index value, individual cow, season, and feed, and their interactions was performed in SAS. Variance partitioning was used to quantify the effect size of study factors and their interactions. Individual cows, DIM, and BW (except Year-3) had effects on grazing and rumination times throughout the study years. Grazing time and rumination time were different for different seasons due to varying supplementary feeds. Grazing time varied among breeds in Year-2 and Year-3, and among lactation years only in Year-1. Although rumination time differed among breeds in Year-3, it remained the same within different lactation years. Grazing time and rumination time had a negative relationship with each other, and their regression lines varied for different seasons. The total variance explained by the model in grazing time was 36–39%, mainly contributed by the individual cow (12–20%), season (5–12%), supplementary feed (2–6%), breed (1–5%), and lactation year (1–6%). The total variance explained in rumination was 40–41%, mainly contributed by the individual cow (16–24%), season (2–17%), supplementary feed (1–2%), breed (2–8%), and lactation year (~1%). These findings could contribute to improving the measures for feed resource management during different seasons over the lactation period for a mixed herd comprising JE, HFR and KC breeds in different years of lactation management in New Zealand and other countries that exhibit similar issues.

INCORPORATING COMPOSTING SHELTERS ON FARM: FINDINGS FROM RECENT FARMER CASE STUDIES

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[1]Perrin Ag Consultants

Dairy farmer investment in composting shelters is being driven by a desire to tackle environmental challenges, improve animal welfare, and provide a more labour-efficient and satisfying farm working environment. This paper consolidates learnings from a recent composting shelter case study project, and interactions with farmers considering or already operating with the system.

Composting shelters are a unique animal housing structure in which cows spend a proportion of time under a covered structure where they lie on a deep (c. 600-800 mm), plant-based bedding material. Aerobic composting, aided by daily tilling and ventilation, mixes the bedding with urine and dung to create in situ composting. The heat generated from composting keeps the bedding warm and dry, allowing it to remain in place for one year or more before it is replaced and applied to land.

While the economics of composting shelters are proving sound for those operating the system, it is not typically financial performance that is driving investment. Farmer interviews with existing composting shelter farmers throughout the country identified that it was the intangible, or harder- to-quantify benefits that were valued most highly by farmers and were the key motivator behind the initial investment.

For farms where the colder climate poses challenges for grass growth and wintering stock, composting shelters are being used as an alternative solution to intensive winter cropping with stock generally wintered 24/7 within the shelter from dry off through to calving. The dry, warm environment within the shelter provides benefits to farm working conditions and animal wellbeing, while the stabilised climate provides significant winter feed savings typically in the order of 35-45%. A centralised location for farm activities also provides opportunity for reduced labour requirements.

Where shelters are incorporated in the system year-round, improvements to grazing management including the avoidance of pugging and over-grazing are possible through the implementation of a hybrid indoor-outdoor system. During the warmer months, the provision of shade alleviates the impact of heat stress on the cows, and where supplementary feed is used, the shelters can enable improved feed utilisation (c. 95%). For a South Waikato case study farm where the shelters were incorporated year-round, the improvements to the farm system were modelled to increase milk production by 14% (+57 kg MS/cow).

Significant reductions to nitrogen (N) loss are also possible by reducing time on pasture, with the same Waikato case study farm achieving a 45% reduction (51 kg N/ha/yr to 28 kg N/ha/yr; OverseerFM v6.4.3). In this system, time spent in the shelter by the cows averaged six hours per day throughout the year. In contrast, a farm in Canterbury using the shelters for wintering only (24/7 from 15 May to 15 August) was able to achieve a 22% reduction in N loss. The actual N reductions possible will be farm and system-specific. It is not just determined by the specific hours and seasons of use of the shelter, but also other farm aspects (e.g. soil type, cropping, irrigation) which can impact on the potential of the shelters to reduce N loss.

THE QUANTIFICATION OF RELATIVE STOCK UNITS FOR HORSES WITHIN A PASTURE-BASED PRODUCTION SYSTEM

Yin Ying Chin

Massey University

Overseer® is the primary software tool used to estimate farm level nutrient cycle and management for regulatory purposes in New Zealand. The software uses a modification of stock unit system (standard ewe), the revised stock unit (RSU) to estimate the relative feed demand from different livestock classes and species. For horses, the RSU are upscaled in the model based on bodyweight difference of the horse from the standard ewe. This method does not consider allometric scaling of metabolism to bodyweight and the biological differences between mono-gastric hindgut fermenter and ruminants. As a result, this can lead to overestimation of feed and nutrient intake which can have implication on the farm level nutrient leaching estimation on equine properties. Due to the large scale of the thoroughbred breeding farms in New Zealand (300-600 mares and >500ha), even small over estimations could have significant implications for stock management and economic viability. Bodyweight data for commercial equine stock classes were obtained from a structured literature search and weighted mean bodyweights were obtained. These bodyweights were used to estimate the daily and subsequently annual DE intake based on nutrient requirements for the horse published by the national research council. These annual intake values were subsequently used to develop predicted RSU and compared against the default values for equine stock classes within Overseer.

For all equine livestock classes, the RSU was greater than the predicted RSU (range 2.7 – 6.8 RSU), with the overestimation driven by an assumption of linear increases in RSU with bodyweight. The overestimation of pasture intake with the RSU would translate to a 52-84% overestimate in mean Nitrogen intake. If these values were used in Overseer for regulatory decisions this could have a major impact on stock numbers and stock density, particularly during the breeding season. The predicted RSU presented reflected metabolic scaling and therefore should provide a more accurate estimation of pasture consumption to be included in the overseer model.

SEASONAL FLUCTUATION OF LIVESTOCK NUMBERS ON EQUINE STUD FARMS AND THE IMPACT ON MODELLING OF FARM LEVEL NITROGEN LEACHING

Yin Ying Chin

Massey University

Overseer® is the primary software tool used to estimate farm level nutrient cycle and management for regulatory purposes in New Zealand. On Thoroughbred breeding farms, livestock numbers fluctuate seasonally, with an approximate doubling of the number of mares on the farm during the breeding season due to influx of non-resident breeding mares. At farm level this results in substantial fluctuation of feed demand and livestock numbers across the year. Currently, this fluctuation is not considered within Overseer® due to the inability for user to allocate equine stock class to grazing months, which can impact the feed demand estimations within the model. Previous modelling has demonstrated that even small over estimation of feed demand can significantly impact the nutrient intake estimation. Therefore, there is a need to identify simple correction factors for equine livestock numbers to account for seasonal variation associated with the thoroughbred breeding production system.

Published data and prospective data captured on a model farm estimating feed consumption and the seasonal fluctuation of livestock were used within a model to generate monthly and annual feed demand (pasture consumption) for a commercial breeding farm. To reflect Overseer input data whole farm annual feed demand was also estimated using the *equine*RSU (revised stock unit modelled using equine specific model) with and without adjustment for the seasonal fluctuation in broodmares numbers. To adjust for the seasonal fluctuation of broodmare numbers, an annual stock total was generated using the weighted average of the monthly stock numbers.

The model farm consisted of 116ha with 120 resident mares and 35 non-resident mares on farm between September – December thus a total of 140-155 mares on the farm during the breeding season (September – December). Twenty-four resident dry mares (non-pregnant mares) were grazed off farm between March – July. Pasture growth and consumption for the whole farm was subsequently allocated to the respective stock classes. The estimated annual farm feed demand for equine livestock was 84822872MJ ME (8482287 kg pasture DM, assuming pasture energy content of 10MJ ME/kg DM).

To reflect input data for Overseer the *equine*RSU was used in conjunction with the maximum number of mares on the breeding farm during the year. Failure to account for the seasonal fluctuation of broodmares resulted in the estimated feed demand (pasture DM) being 27% greater than true feed consumption. Use of the weighted average monthly broodmare stock numbers reduced the over estimation of feed consumption to 8%.

This modelling demonstrated that the seasonal fluctuation of broodmares on commercial thoroughbred breeding farms could be easily accounted for in an Overseer model by use of the weighted average of the monthly broodmare numbers in conjunction with the *equine*RSU. Failure to use the weighted average value or the *equine*RSU will result in overestimation of nutrient leaching and may provide unfair regulatory constraints on equine livestock management for this sector of the equine industry.

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