SUSTAINABLE MANGEMENT IS IMPORTANT FOR FONTERRA'S TRADING OPPORTUNITIES AND NEW ZEALAND

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The long term success of Fonterra is, in no small measure, affected by the approach we and our dairy farmer suppliers adopt to the management of the physical, natural and biological resources upon which we jointly depend.

The importance to tourism of New Zealand's "clean green" image is such that our approach to sustainability will have effects which extend well beyond the sector.

Our vision is to be at the leading edge of sustainable dairying – from pasture to plate.

To achieve this vision, the Company has applied a number of programmes such as the Dairying and Clean Streams Accord, embarked upon carbon footprint work and adopted a comprehensive Energy Efficiency Programme. All of this now sits within a comprehensive Fonterra Sustainability Strategy.

Drivers for sustainability operate at both the domestic and internationally levels. Domestically, if sufficient progress is not made in resolving issues associated with climate change, nutrient management, water use and similar, negative public attitudes to dairying will grow, our licence to operate will increasingly be constrained, on-farm flexibility will decline and regulatory costs will increase. The net effect will be an incremental erosion of our low cost advantage and value.

At the international and market level, consumers and customers around the world are increasingly exercising their discretion to demand foods with robust environmental credentials. While the environmental footprint of a product may never match price and product quality attributes as the dominant factors affecting purchase decisions, there is no question the environmentally sustainability credentials of a product will become more and more important.

The ambitious ideal is to achieve a premium price for those products which are confirmed as being the product of world leading sustainability practice - at all steps in the supply chain. There is some way to go before that ideal is achieved but it is already apparent that products with proven sustainability credentials will achieve higher volumes of sale than those that do not.

The challenge we face is to be at the leading edge of profitable and sustainable dairying but at a pace and at a price which does not disadvantage our competitive position. This challenge is big but we are well placed to meet it.

THE DAIRY INDUSTRY STRATEGY
- CURRENT SUCCESSES, CHALLENGES
AND FUTURE PROGRAMMES

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The Strategy for New Zealand Dairy Farming (2009-2020), developed by DairyNZ, Federated Farmers and the Dairy Companies Association of New Zealand (DCANZ) was released in May 2009. It updates and replaces the Strategic Framework for New Zealand's Dairy Farming Future (2004), and has a substantially different approach. Whereas, the 2004 Strategic Framework set productivity improvement as the highest priority, the 2009 Strategy takes a much broader farm system approach to maintain farm profitability, sustainability and competitiveness.

Five key outcomes are sought through industry investment and activities:

1. Increasing farm profitability
2. Talented and skilled people are attracted to the dairy industry
3. An internationally competitive milk supply maximises returns to farmers
4. Industry reputation enhanced locally and globally
5. Achievement of shared goals through genuine partnership between industry and government and the wider community

A brief overview of investment and activities in each of these outcome areas will be given, but the focus of this presentation will be the Sustainability programme of work. In particular, the imperative for, and examples of, growing partnerships between industry and local government will be highlighted.

The dairy industry's production and productivity targets have created a real tension in New Zealand with heightened concerns over dairy farming's environmental footprint, and the consequent regulatory controls being imposed on the dairy industry. The primary means for increasing dairy production, either by intensification or conversion of other land uses, both increase the total environmental footprint of dairy farming. The fundamental challenge for the industry and New Zealand as a whole is the question of what the footprint of dairying should be and what trade-offs (i.e., environmental, economic, social or cultural) are required as this footprint varies across a range of scales. We argue that these challenges can be best met with genuine partnerships between the industry, government and the wider community.

WATER QUALITY TRENDS AT NATIONAL RIVERS WATER QUALITY NETWORK SITES IN NEW ZEALAND FOR 1989-2007

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The National Rivers Water Quality Network (NRWQN) in New Zealand commenced in January 1989. The network consists of 44 sites in the North Island and 33 in the South Island at which 14 physical and chemical variables are measured monthly. This paper reports findings from the most recent water quality trend analysis undertaken by NIWA for MfE for the 19-year period 1989-2007.

Formal trend analysis was carried out using Time Trends software. The non-parametric Seasonal Kendall Slope Estimator (SKSE) was used to represent the magnitude and direction of trends in flow-adjusted data. Values of the SKSE were normalised by dividing through by the raw data median to give the *relative* SKSE (RSKSE), allowing for direct comparison between sites. A positive RSKSE value indicates an overall increasing trend, while a negative RSKSE value indicates an overall decreasing trend. Trends were identified as being either significant ($P < 0.05$) or "meaningful" - significant trends with an RSKSE > 1% yr^{-1}. National trends in water quality variables were indicated using a binomial test.

Seven water quality variables were examined: temperature, dissolved oxygen, visual clarity, and four forms of nitrogen and phosphorus. For the 19-yr period (1989-2007 inclusive), trends in water quality were similar to those reported by Scarsbrook (2006). Comparison of the median RSKSE values showed that upwards trends have weakened for visual clarity and dissolved reactive phosphorus, but have become stronger for temperature, total nitrogen, oxidised nitrogen and total phosphorus.

At the national scale, there was a significant increase in visual clarity. We found strong overall increasing trends in total phosphorus and in dissolved reactive phosphorus. There were also strong increasing overall trends in oxidised nitrogen and total nitrogen, all of which indicate deteriorating water quality, mainly attributable to expansion and intensification of pastoral agriculture.

From our analysis of water quality data for 19 years a clear pattern is emerging: the gains from clean-up of point pollution over the past two decades are being overshadowed by increasing diffuse pollution dominated by expansion and intensification of pastoral agriculture.

DELIVERING SOLUTIONS FOR ENVIRONMENTAL MANAGEMENT OF PASTORAL SYSTEMS – KEY MESSAGES FROM THE P21 PROGRAMME ENVIRONMENT

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Under the Pastoral 21 partnership, FRST, DairyNZ, Fonterra and Meat & Wool NZ are jointly funding the P21 Environment programme. This programme aims to reduce the impact of pastoral farming on nitrogen (N), phosphorus (P) and microbial contamination of waterways, by providing farmers, the industry and/or policy agents with tools for:

1. informed decision making on national and catchment scale environmental policy development and target setting
2. understanding the current state and pressures of key catchments
3. improved on-farm decision-making and adoption of mitigation strategies to achieve the required targets

The key component of 1. is an integrative systems deliberative process that makes transparent the economic, social and environmental impacts of environmental policies targeted at the pastoral industry through providing quantitative information of these impacts using a range of catchment, regional and national scale analytical tools. The deliberation matrix helps stakeholders reach a consensus on water quality issues and identifies where in the system interventions would have a large impact. The analytical tools provide quantitative data on the trade-offs between economic and environmental gains and can inform perceptions.

The key components of 2. are i) the best practice dairy catchments programme which is highlighting the beneficial effects of farmer action on water quality at the catchment scale, ii) an inventory of on-farm environmental practices and iii) the refinement of the CLUES model that assesses the environmental, economic and social impacts of land use change within a catchment.

The key components of 3. are a risk-management tool for understanding the environmental impacts of farming, a tile-drain alert and integrated mitigation options for minimising N, P and microbial losses. In terms of on-farm mitigation options the research to-date has indicated that nitrification inhibitors (NIs) and restricted grazing are the key mitigation options for reducing N losses to water. For P and microbial contamination, the research has indicated that, under base-flow conditions, these pollutants can be adequately managed through the adoption of best management practices promoted in the Clean Stream Accord (e.g. stock exclusion and appropriate effluent management strategies).

LAND APPLICATION OF FARM DAIRY EFFLUENT: DEVELOPMENT OF A DECISION FRAMEWORK FOR MATCHING MANAGEMENT PRACTICE TO SOIL AND LANDSCAPE RISK

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The management of farm dairy effluent (FDE) in New Zealand has typically involved the collection of daily wash down effluent in a concrete sump and subsequent immediate application to pasture using a twin boom travelling irrigator. Of late there has been a greater uptake of recently-researched best management practices (BMPs) for FDE application to land, in particular the adoption of a deferred irrigation strategy (pond storage when soil moisture is close to, or at, field capacity) and the use of low application rate sprinkler systems. However, the effectiveness and therefore mitigation impact of these best management practices will vary with the associated risk of land application on each farm based on soil and landscape features. Information on the environmental benefits of applying FDE best practices in New Zealand is required for improved farm system planning to ensure regulatory compliance and nutrient use efficiency and for the development of effects-based Regional Council policy guidelines. A decision framework has been constructed to identify soil and landscape risk categories and provide minimum practice guidance on FDE management and infrastructure requirements. Soil and landscape features such as sloping land, land with artificial drainage and land with either impeded drainage or low surface infiltration rates typically display a high risk of preferential or overland flow of land-applied FDE. Soil types with well-drained, fine structured soils typically exhibit matrix flow characteristics and represent a relatively low risk of direct losses of contaminants due to FDE application. Where critical climate, landform and soil characteristics occur, BMPs are required to mitigate or prevent the direct loss of contaminants from land-applied FDE and keep nutrients and contaminants in the root zone.

USING DURATION-CONTROLLED GRAZING TO REDUCE NITRATE-N LEACHING FROM DAIRY FARMS

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Duration-controlled grazing practices, in conjunction with increased use of cow housing or feedpad facilities, are used in New Zealand to reduce treading damage to pasture and soil, and to shelter animals during wet periods. Removing cows from pasture also reduces the excreta load returned to paddocks. The excreta captured in the standoff facility can be stored and uniformly re-applied to paddocks. Simulation models suggest that duration-controlled grazing can lead to reductions in nitrate leaching, and therefore, has potential as a mitigation option for farms.

A large scale, long-term grazing trial investigating the effect of duration-controlled grazing on the quantities of nitrogen (N), phosphorus (P) and faecal microbes lost in drainage and runoff from grazed pasture, was established at Massey University No. 4 Dairy Farm in 2008. The research site has 14 plots (each ~850m^2), on which pasture accumulation and cow intakes are estimated. Mole and pipe drainage water is sampled from all plots and analysed for N, P and faecal microbes.

Grazing treatments, which commenced in September 2008, are alternated between ‘day’ and ‘night’ grazings. The duration of grazing on 7 plots is limited to 4 hours at each grazing (Duration-controlled grazing, *DCG*). Standard grazing practices are employed on the other 7 plots (Standard grazing treatment, SG; 6 hour day graze or 12 hour night graze). The average stocking rate at each grazing is the same for both treatments. Pasture growth rates allow the plots to be grazed approximately 10 times per annum.

There were no differences in drainage water nitrate-N losses between the two grazing treatments during the 2008 drainage season. This was due to the treatments commencing toward the end of the drainage season. However, during the subsequent drainage season, from February to October 2009, the *DCG* treatment reduced nitrate-N leaching by 41% (5.2kg N/ha). During this time, there was 236 mm of cumulative drainage on average. Pasture accumulation and intakes by cows were similar for both treatments for the 2008/2009 lactation season.

The 2009 drainage results show *DCG* reduces nitrate-N leaching losses, and this reduction is more evident in the early parts of the season. Decreased N loss early in the drainage season is consistent with less urine patch-N being deposited on the *DCG* plots in summer and autumn.

CAPTURING URINE ON STAND-OFF PADS WHILE MAINTAINING PASTURE INTAKE, MILK PRODUCTION AND ANIMAL WELFARE OF DAIRY COWS IN LATE LACTATION

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Measurement of nitrogen (N) leaching at DairyNZ's Scott Farm, near Hamilton, showed that the accumulation of N in soil during dry summer and autumn periods is critical for determining N leaching rates during subsequent winter drainage periods. Reducing urinations on pasture during autumn by capturing urine on standoff pads could reduce the risk of nitrogen loss to the environment. This study investigated the effect of 16 h/d removal of cows from pasture to a stand- off pad on the location of urination, milk production, pasture intake and animal welfare from cows grazing fresh pasture in late lactation. During March and April 2009, 48 Holstein- Friesian cows (498 ± 43kg body weight; 225 ± 23 days in milk) were allocated to one of three treatment groups. Cows had access to pasture for either four hours after each milking (2×4), eight hours between morning and afternoon milkings (1×8), or for 24 hours, excluding milking times (Control). When not grazing, the 2×4 and 1×8 groups were stood- off on a plastic- lined, loafing area with a woodchip surface. There was no difference in pasture intake (mean 10.2 kg DM/cow/day, P=0.291), milk production (mean 10.3 kg milk/cow/day, P=0.956) and body weight or body condition score change (mean 3.7 kg/cow/week, P=0.245, and -0.2 units/cow/week, P= 0.354, respectively) between treatment groups. Urinations on pasture and laneways were reduced from 85% (Control) to 56% (1×8) and 50% (2×4) of total urinations (P=0.026). These findings demonstrate an opportunity to maintain performance and welfare of grazing cows in late lactation while capturing a significantly higher proportion of urine. After storage, this urine could be returned to pasture and crops as a fertiliser at a time of year (e.g. late spring) when nutrients are more likely be taken up by actively growing plants, and distributed more evenly across a land area than in urine patches.
Keywords: restricted grazing, urine capture, animal production.

LINKING FARM AND WATERWAY VALUES – THE BOG BURN CATCHMENT

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Maintaining key values in streams and rivers in areas of intensive dairy farming often requires concerted action based on a shared understanding of the links between waterway values, farm practices and stressor mitigations. This paper describes a causal linkage model between practices on dairy farms and on-farm and instream values in Bog Burn, Southland. A stakeholder workshop identified the key values as farm economics, trout in Bog Burn and contact recreation in the Oreti River, and developed an initial conceptual model of system linkages. Subsequent research used a combination of published information, local data, and expert knowledge to develop this into a Bayesian Belief Network (BBN) used to predict the effects on the key values of mitigations (singly and in combination) under simplified conditions.

The BBN predicted riparian fencing and planting had the greatest single-action benefit for trout in Bog Burn, whereas deferred dairy shed effluent irrigation had the best predicted single-action benefit for contact recreation in the Oreti. Optimising phosphorus fertiliser use to soil Olsen P tests results was predicted to have the greatest single benefit for farm economic returns, whereas converting 2.5% of the land to wetlands to treat field-tile drainage had the greatest cost. When used in combination, several mitigations have enhanced effects on the key values by (i) reducing contaminant inputs (e.g., use of wintering pads, optimising P fertiliser use and stream fencing), reducing contaminants transport to water (e.g., deferred and low rate effluent application, the use of DCD, and constructed wetlands on mole/tile drains), or (ii) acting in combination with other drivers of in-stream responses to inputs (e.g., riparian shade influence on nuisance plant growth in Bog Burn in response to nutrient enrichment). Focusing solely on edge-of-field mitigations (riparian management and drainage treatment wetlands) was predicted to have less benefit to both farm and waterway values than combined field and edge-of-field mitigations. The top five mitigations in terms of their overall benefit for the three key values were predicted to be optimising P fertiliser to soil Olsen P, stream fencing and planting, deferred dairy effluent irrigation and/or low rate effluent irrigation, and winter herd shelters.

WATER AND NITROGEN MOVEMENT UNDER AGRICULTURAL AND HORTICULTURAL LAND

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Clean water and healthy soils are essential components of modern agriculture. The challenge to the farmers is to maintain the benefits of irrigation and agrichemical use whilst minimising any adverse effects on the receiving environment. International sustainability standards for water and agrichemicals are being developed. Thus, our farmers will increasingly need to show that their practices are sustainable. They will require tools to monitor, audit and predict the impact of land use activity on the receiving environment, in order to minimise their environmental footprint.

It is difficult to measure unsaturated (vadose zone) water and nutrient flow rates for at least three reasons. First, vadose-zone flow rates span many orders of magnitude; second, spatial distribution of water fluxes are often highly variable over short distances; and third, the placement of water-flux sensors can disrupt the flow, causing either convergent or divergent flow with resultant inaccuracies in water-flux estimates. At present, there is no standard method for measuring soil water flux.

In this presentation we provide a short description of the passive-wick fluxmeters that we have been developing at Plant and Food Research to measure the drainage fluxes. Our drainage flux meters (DFMs) use a hanging water column to draw drainage water out of a lysimeter tube. The drainage flux is measured automatically with a tipping spoon that collects water draining from a fiberglass wick. The wick “passively” controls the pressure head in the soil at a value approximately equal to -60 cm (i.e. the length of the wick). Drainage water is collected in a subterranean reservoir where it can be extracted and analysed for nutrients and co-contaminants.

We demonstrate the use of DFMs under a range of land uses including field crops (potato), tree crops (apple and kiwifruit), and pasture (dairy). We also present a measurement and modelling comparison where nitrate leaching is calculated using Plant and Food’s SPASMO (Soil Plant Atmosphere System Model) model. These comparisons, along with some fine-tuning, are very important to provide growers, industry and regulators with confidence in the quality of the data.

CAMPYLOBACTER, A PATHOGENIC BACTERIA HIDING IN DAIRY HERDS

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Dairy cows, and other ruminants, have been identified as common carriers of the faecal bacteria pathogen *Campylobacter jejuni*. This pathogen is a zoonosis (infectious for both animals and humans) and causes many of the human gastroenteritis cases reported to the NZ Department of Health. Unusually, cows infected with *C. jejuni* do not often develop symptoms of disease.

Because of the large numbers of dairy cows in New Zealand there is potential for the *C. jejuni* excreted in bovine faeces to contaminate streams and rivers with an adverse effect on safety for human consumption and recreational activities. An effective approach is needed to control the spread of *C. jejuni* into freshwaters, and the first step in this control is to acquire a good knowledge of the contribution of the cow reservoir.

The objective of this study was to determine the prevalence of *C. jejuni* in two dairy herds. A collection of faecal samples from 102 of the 238 cows in the milking herd tested on farm A (a traditional grazing farm) and from 74 of 240 cows on farm B (that used a Herd Home as well as grazing) was repeated twice in a fortnight to investigate herd prevalence. Samples were tested for the presence of *C. jejuni* using a combination of microbiological culture and molecular identification techniques.

The prevalence of *C. jejuni* was relatively stable over the two consecutive visits on each farm but varied widely between the two farms: *C. jejuni* was detected in 33-42% of faecal samples from farm A and in 70-88% of faecal samples from farm B. Although the overall percentage recovery from each farm was similar over the two weeks, we found that the excretion of *C. jejuni* by individual animals varied within the fortnight: in both farms, about one third of the cows tested shed *C. jejuni* at only one of the two sampling occasions. Yet, a proportion of the cows, 23% and 64% on farm A and farm B, respectively, shed *C. jejuni* on both sampling occasions. We did not observe any statistically significant effect that could be related to cow age in either overall prevalence or in the variation of *C. jejuni* excretion on the two sampling occasions.

The observed overall stability in *C. jejuni* prevalence at the herd level supports current information obtained by snapshot studies on smaller numbers of cows or by cross-sectional studies at a number of farms in an area. However, variability at the individual cow level reveals the complexity of the dynamics of excretion and demonstrates a need for more in-depth studies.

FROM ENVIRONMENTAL MONITORING TO ON-FARM RISK MANAGEMENT

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Increasingly, New Zealand farmers are expected to manage the environmental performance of their farms to minimize environmental impacts. It is often said that "the ability to manage, requires the ability to measure". And indeed, farmers already use a range of measurements (e.g. pasture production, milk production, time and cash flow) to aid farm management decisions that optimise the performance of their farm system. The Pastoral 21 Environment program was charged with developing tools to measure the environmental impact of farms to aid environmental management decision making.

Environmental impacts on water quality are usually determined by measuring specific pollutants in the water and comparing the results to accepted guideline values. Thus, environmental impact assessment is a two step process of measurement and then interpretation. Reviews were conducted to determine the availability of measurement technology that could be applied at a farm scale to generate water quality measurements on a daily basis. The conclusion was that there was no technology currently available and none likely to be in the foreseeable future that would have a good 'fit' with New Zealand dairy farms. There is also significant difficulty in interpreting water quality measurements into meaningful information for operational and tactical on-farm decision making. This is because diffuse pollution from agriculture is a bit like "death by a thousand cuts": it is very difficult to determine the source and impact of each specific cut. Without being able to make a direct link between stream pollutant concentrations and specific farm management practices, environmental monitoring will not be able to aid on-farm decision making. Furthermore, environmental monitoring will also only act as a feedback loop providing information on what happened after the event. This relies on the farmer learning from past behaviour to make better decisions next time around.

We propose an alternative approach of developing a decision support tool to predict "tomorrow's impact" of "today's decisions". The tool will use key factors that increase N and P losses from farm systems. The factors will be determined through detailed modelling analyses of multiple scenarios. The tool will be based on specific soil and landscape features on a farm, and measurement of soil moisture and temperature, to produce a farm's "current status". Rainfall forecasts will then be used to predict the likely "tomorrow status" of the farm. Tomorrow's status, key N & P risk factors, and management decisions will then be combined to predict the potential N & P loss (high, moderate and low risk) from the farm. The farmer will then be able to incorporate the environmental risk of alternative management decisions into existing operational and tactical decision making processes.

WHY GOOD TECHNOLOGIES GET SHELVED

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The paper discusses the reasons why many apparently good technologies don't get used. Many R&D produced technologies/solutions were created with the designers' underpinning belief that they will be good for and acceptable to potential users. These technologies appear 'good' to the inventors, but don't get used. The paper recognises this particular issue, and draws on a review of New Zealand adoption literature and research over the last decade to discuss the reasons why many of these seemingly good technologies get shelved from the perspective of NZ farmers' internal adoption decision drivers.

Many people believe that farmers are distinctly different to other people, however our research has shown that this perception is misleading. We found that, by and large, farmers' adoption behaviours are driven and constrained by a variety of factors which, from a psychological perspective, closely resemble the drivers of individuals in most other occupations with similar characteristics and incumbent requirements.

For environmental solutions and problems in particular, unawareness may be an issue, followed by denial and lack of willingness to take responsibility for addressing the problem. Secondly, for both productivity and environmental problems, disbelief that a potential solution will actually solve the problem often hinders the use of new technologies. Farmers seek confidence from independent research and peers that a solution works. Also, like other people, farmers can struggle with self-doubt and fear of failure which prevents them from using a new technology. A particularly strong motivating factor is farmers' perception that a technology or solution fits their current farming system and is simple to use. In cases where farming system changes are actually required, this is particularly important. Farmers intuitively or deliberately work out the value proposition of new technologies, considering aspects like cost, time and labour requirements. Technologies with low perceived value are mostly rejected.

WATER QUALITY STATE AND TRENDS IN THE HORIZONS REGION

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Horizons Regional Council is preparing the "One Plan" to support resource management in their region. It addresses four keystone issues – water demand, native biodiversity, unsustainable use of hill country land and surface water quality degradation. This contribution presents an overview of water quality state and trends in the Horizons region, and was used as independent background information to the One Plan hearings.

Water quality state was assessed by comparing the median values of main water quality variables at Horizons State of Environment (SoE) and National River Water Quality Network (NRWQN) sampling sites in the Horizon's region with the proposed One Plan water quality standards, ANZECC trigger values and all NRWQN data. Trend analysis was carried out on flow adjusted data using NIWA's Time Trends software. The influence of land use on water quality was examined by correlating the median values for water quality variables at each SoE and NRWQN site with the percentage pasture and forested land in the catchments.

When data from Horizon's region is compared with guideline values and national data, water quality in the region is poor. In the Manawatu catchment, median nutrient concentrations are among the highest in the country and frequently exceed national and proposed One Plan guideline values. Visual clarity is low, and turbidity correspondingly high, at many sites. Faecal microbial pollution is also often high.

Trend analysis of water quality data for the time period 2001-2008 from Horizon's SoE and NRWQN sites revealed three meaningful decreasing trends in dissolved reactive phosphorus (DRP) concentrations, eight meaningful decreasing trends in soluble inorganic nitrogen (SIN) concentrations, four meaningful decreasing trends in *E.coli* and five meaningful decreasing trends in turbidity. These encouraging short term trends perhaps suggest improving water quality at both Horizon's SoE and NRWQN sites.

Pollution from agriculture appears to have a strong influence on water quality in the Horizon's region. *E.coli*, DRP and SIN concentrations increase, and visual clarity decreases, as the total % land in pastoral agriculture (sheep and beef and dairy farming) increases. In contrast, % land in native forest cover is inversely related to SIN, DRP and *E. coli* concentrations.

MINIMISING THE FOOTPRINT OF PASTORAL DRAINAGE USING CONSTRUCTED WETLANDS: PRACTICAL GUIDELINES

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Practical guidelines on constructed wetlands for treatment of tile drainage flows have recently been prepared for use by farmers, farm advisors, rural contractors and regional council staff. Tile drainage can act as a significant route for contaminant losses, particularly of nitrate-nitrogen, from intensively grazed pastures to waterways. Constructed wetlands are one of the simple, practical tools farmers can use to intercept tile drainage flows to reduce such nutrient losses to waterways and lakes. They should ideally be employed in combination with good fertiliser, grazing and effluent management practices. The new guidelines build on international experience as well as monitoring and modelling results from field-scale trials carried out on farms in the Waikato, Northland and Southland over 3-5 year periods. They provide comprehensive recommendations on choice of wetland location, size, design and construction, inlet and outlet structures, planting and maintenance. The guidelines are available free to download from the NIWA website at: http://www.niwa.co.nz/our-science/freshwater/tools/tile-drain-wetland-guidelines

THE INFLUENCE OF LAND MANAGEMENT PRACTICES ON TRENDS IN N AND P LOSSES TO WATER FROM DAIRY FARMS IN THE WAIKAKAHI CATCHMENT

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The Waikakahi catchment in South Canterbury is part of the Best Practice Dairy Catchments project that monitors farm management practices and water quality trends in five catchments throughout New Zealand. The Waikakahi catchment is characterised by low annual rainfall and is dominated by well-drained soils. The dairy farms in this catchment are predominantly irrigated using border dyke irrigation systems. Continuous monitoring of catchment outlet flows since 2001 (monthly stream sampling for water quality parameters) and the regular completion of detailed farm land management surveys (2001, 2003, 2006, 2009) has (i) monitored changes in water quality in the catchment, (ii) identified (using OVERSEER® nutrient budget modelling) some of the key drivers of changes in nutrient loss and (iii) assessed changes in production efficiency, i.e. nutrient loss per T MS (milksolids). Catchment water quality monitoring of the Waikakahi stream from 2001-2009 shows a significant change in N loss over time but no significant change in P or *E. coli* concentrations. During this time there has been significant farm intensification, with milksolids production increasing by 39%. This has driven an increase in N losses per ha and at a catchment level. Calculated production efficiency (as expressed by kg N leaching/ kg MS produced) has however remained constant throughout the monitoring period. Despite the dairy farm intensification, P and *E. coli* losses from the catchment have remained constant. There has thus been an improvement in production efficiency (with decreasing losses of P and *E. coli* per kg MS produced), due in part to: improved fertiliser management (for P); improved irrigation management (including re-bordering, improved application timings and some conversions to spray irrigation); and improved riparian management, including fencing of streams, riparian planting and the addition of stock crossings and culverts.

QUANTIFYING FAECAL BACTERIA IN A FARM STREAM

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A study was carried out to measure faecal bacteria in a stream system on a dairy-grazing farm located in the King Country region. At the time that this study was carried out, stock had free access to both the stream and to the many shallow swampy areas that surrounded it.

The stream left the farm as a single channel that joined the Mokau River a few hundred metres downstream of the farm boundary. Upstream of the boundary there were a number of tributaries, some of which flowed in from neighbouring properties and others that arose on the farm itself. The stream was sampled monthly for a year (August 2004 – July 2005) at six sites, two of which were at boundaries with neighbouring farms and one at the exit point from the farm. Samples were analysed for the faecal indicator bacterium *Escherichia coli* and the pathogen *Campylobacter*. On 16th January 2006 samples were collected at fourteen sites on the farm and stream flow rate also measured (Global Flow Probe, USA), allowing bacterial yields to be calculated.

Escherichia coli were present in all samples and *Campylobacter* in most. Five sites had relatively similar average *E. coli* concentrations (209 – 457 *E. coli* 100 ml^{-1}; i.e. $\leq$ 0.5 log difference) that exceeded the ANZECC stock drinking water guideline value of < 100 *E. coli* 100 ml^{-1}. The concentration was lower (but still non-complying) at the seep: average 129 *E. coli* 100 ml^{-1}. On any sampling day *E. coli* concentrations varied widely reflecting that location of stock and direct faecal input was more important than rain-related transport of bacteria to the stream. At the stream exit point the average bacterial concentrations were 457 *E. coli* 100 ml^{-1} and 19 *Campylobacter* 100 ml^{-1}.

On the day that bacterial yields were measured the water leaving the farm boundary contained 3.6 x 10^7 *E. coli* per second and 9.0 x 10^4 *Campylobacter* per second. This exceeded the yields in water entering the farm from the neighbouring properties (3.2 x 10^6 – 1.5 x 10^7 *E. coli* and 3.0 x 10^3 – 4.1 x 10^4 *Campylobacter* per second) allowing the contribution from the study farm to be demonstrated.

As a consequence of poor water quality in rural waterways authorities are requiring individual farmers to take steps to decrease their impact. In this study the stream system was impacted by neighbours before it reached the study farm. However by quantifying the loads of incoming and outgoing bacteria it was possible to determine the additional input from the study farm. Since this preliminary study the streams have been fenced and a programme of riparian planting is underway. Over the next few months the stream will be sampled again and it is hoped that the information obtained will demonstrate the effectiveness of the costly interventions that were put in place by the farm owner for water quality improvement.

NUTRIENT CAPTURE BY EXPERIMENTAL WATERCRESS BEDS, LAKE ROTORUA

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Aquatic plants can scavenge nutrients down to remarkably low concentrations in the water column and harvesting the plant biomass can permanently capture nutrients. Limited information is available on aquatic plant uptake in different seasons, whether harvesting can be used to maintain plant uptake and issues of biomass quality. Watercress was grown in troughs, supplied by nitrate rich water from Waingaehe Stream and the inflow and outflow nutrient concentrations (total nitrogen (N), nitrate-N, ammonium-N, total phosphorus (P), dissolved reactive P) were measured fortnightly. Watercress was chosen as it is a luxury feeder and can to strip water column nutrient concentrations to low levels. Water flow through the troughs was set at two different flow rates (low flow $0.057L.s^{-1}$ and high flow $0.57L.s^{-1}$). Plant cover was higher in the active growing season (>40%, Oct-May) than the senescent winter months (<20%, Jun-Sep). Both harvested and unharvested areas of troughs showed similar die-back in winter. Nitrogen in the inflow was dominated by nitrate-N (average $1438mg.m^{-3}$ or 84% of incoming total N). Average removal of nitrate-N and TN were greater in the low flow treatment (32% and 31%) than the high flow treatment (12 and 19%). On a net daily removal basis, this equated to 1.637 (high flow) and $0.267g.TN.m^{2}.d^{-1}$ (low flow). There was a strong seasonal component of total nitrogen removal, with rates twice as high in the growing season than in winter. Around half of the total P in the inflow was DRP (range $82\text{-}120mg.m^{-3}$). Dissolved reactive phosphorus removal was higher in the high flow treatment (33% or $0.016g.m^{-2}.d^{-1}$) than the low flow treatment (15% or $0.0074\ g.m^{-2}.d^{-1}$). Removal of total phosphorus was higher, at 51% (high flow) and 58% (low flow), probably associated with settling of particulate phosphorus in the troughs. Arsenic accumulation by watercress is a potential concern in geothermal areas. At our trial, plant arsenic concentrations were low (max $0.44.mg.kg^{-1}.DW$). However, some wild harvested watercress from the region would exceed the NZFSA weekly arsenic intake in a single 230g serve ($79mg.kg^{-1}.DW$). Our work demonstrates that watercress can successfully remove major dissolved and particulate nutrients from streamflow, particularly in summer. Trials at a larger scale would help determine practical flow rates and nutrient removal potential of this technology at the farm-scale.

PASTORAL AGRICULTURE, WATER QUALITY AND MICROBIOLOGICALLY SAFE MĀORI FOOD

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A study was carried out to determine whether the impact of pastoral agriculture on the microbiological quality of waterways affects the quality of traditional Māori food. Two foods were investigated, watercress to be eaten raw as a salad vegetable and a fermented food, Toroi.

In all 65 bunches of watercress were harvested from four streams (2 on pastoral farms and 2 in scenic reserves). The watercress, and samples of water collected at the same time, were analysed for two species of faecal bacteria, the widely used faecal indicator, *Escherichia coli* and the pathogen *Campylobacter jejuni*. Additional bunches from the farm streams were given either a "household" or a simulated 'commercial" triple-wash to determine whether washing would ensure that the watercress was safe to eat.

Ten batches of Toroi were prepared from mussels purchased from retail outlets (5 with watercress and 5 with puha). To ensure consistency in the level of contamination, which would be difficult to obtain using mussels harvested from the wild, the Toroi was then artificially contaminated with laboratory-grown *E. coli* at low (c.10^2 *E. coli* 100 g^{-1}) and high (c.10^3 *E. coli* 100 g^{-1}) levels, then capped and stored in a refrigerator for up to 56 days. These levels were chosen to reflect "good" and "poor" quality natural shellfish respectively.

Most watercress from the reserve streams was satisfactory (assessed against New Zealand Food Standards Authority – NZFSA- guidelines for ready-to-eat foods) but watercress from farm streams was marginal at best and often unsatisfactory. Household washing failed to produce "satisfactory" watercress. Triple-washing was more effective but only 6 of 15 bunches became "satisfactory", probably because the remaining *E. coli* was firmly attached to leaves.

There was little change in pH during Toroi storage, demonstrating that true fermentation, with the accompanying food safety benefits, did not become well established. *E. coli* numbers declined with refrigerated storage so that for the Toroi contaminated at low level *E. coli* numbers were "satisfactory" (NZFSA guideline level) within 14 days. However, none of batches contaminated at high level were satisfactory after 14 days and *E. coli* could still be recovered some batches after 56 days.

Overall our findings are that pastoral farming does affect the ability of Māori to gather traditional foods as it introduces faecal microbial contamination into water. If watercress is to be eaten raw it should not be gathered from farm streams. If "wild" mussels are gathered from areas impacted by faecal contamination, including that sourced from farms then they should not be used in the preparation of Toroi.

INVOLVEMENT AND DECISION MAKING ON-FARM: THE USE OF WINTERING FEEDPADS AND NITROGEN INHIBITORS ON DAIRY FARMS IN NEW ZEALAND

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Dairy farming has the potential to pollute waterways through the loss of nitrogen (N), Phosphorus (P) and Faecal Indicator Organisms (FIO). Two on-farm management actions that can reduce losses of N, P and FIOs are the use of wintering feedpads, and the application of nitrification inhibitors. In this research we used the concept of involvement to explore the adoption of these amongst dairy farmers in New Zealand. Involvement, from social psychology, is used extensively in consumer behaviour research. It is a measure of the intensity of an individual's motivation in regard to a decision (Verbeke & Vackier, 2004). High involvement implies that something is important, often expensive, rarely or infrequently purchased, closely tied to self-image and ego, and that time and effort will be devoted to considering alternatives. Low involvement implies something that is relatively unimportant, inexpensive, routine, with little risk and that little, if any, time and effort is put into considering alternatives. Thirty-five semi-structured qualitative interviews were undertaken in 2008/09. Thirty-two farmers were interviewed about the use of nitrification inhibitors and 22 were interviewed about the use of wintering feedpads. Care was taken to interview a range of farmers, from different regions, as well as adopters and non-adopters. The results indicate that the decision to adopt a wintering feedpad is a high involvement decision dependent on three critical issues; the use of supplements, winter milking and the condition of the soil over winter. However the decision to adopt nitrification inhibitors is less involving and so is dependent on personal triggers. In addition, the impact of using nitrification inhibitors was hard to observe. The results of this research suggest that involvement influences the type of decision making used by farmers; context influences high involvement decision making; and that different strategies are needed to promote adoption under low involvement compared to high involvement.

THE EFFECT OF LONG-TERM USE OF THE NITRIFICATION INHIBITOR DCD ON REDUCING N_2O EMISSIONS FROM COW URINE

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The nitrification inhibitor DCD is a novel and effective N_2O mitigation technology and recent research has shown that DCD can substantially reduce N_2O emissions from urine patches and grazed grassland. However, the research to date has been largely conducted on soils that received DCD for only one or two years. Uncertainty exists whether the reduction potentials measured in these short-term studies continue to occur when DCD is applied in the long-term. This paper presents the results of a study that determined the effect of 4 or 5 years of DCD use on its effectiveness to reduce the N_2O emission factor from animal urine applied to soil.

The study was conducted at two experimental sites, Lincoln University and Tussock Creek Southland, which included plots that had received DCD applications for 4 and 5 consecutive years, respectively. In May 2009, the following treatments were applied to long-term DCD plots and to plots that had not previously received DCD: Control, Control+DCD, Urine, Urine+DCD. The trial thus consisted of eight treatments, which each were replicated four times. N_2O emissions were measured between May and November 2009, using a standardised soil cover technique. At the Lincoln site, long-term DCD application did not significantly affect total N_2O emissions from cow urine, nor the effectiveness of DCD to reduce these emissions. DCD application reduced the average N_2O emission factor from 1.4 to 0.4% of urine applied for the non-DCD plots and from 1.2 to 0.5% for the long-term DCD plots. The results from the Southland site showed relatively large within-treatment variability but the N_2O emissions from the cow urine (without DCD) were consistently lower from the long-term DCD blocks compared to the non-DCD blocks. DCD application reduced the average N_2O emission factor from 1.4 to 0.9% of urine applied for the non-DCD plots and from 0.9 to 0.7% for the long-term DCD plots. The higher urine emission factor from the non-DCD plots (1.4%) compared with that from the long-term DCD plots (0.9%) could indicate that there is a memory effect of long-term use of DCD. However, further work is required to verify this.

MITIGATING NITRATE LEACHING IN DAIRY SYSTEMS – WHICH PERIODS OF URINE DEPOSITION SHOULD WE BE TARGETING?

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Management options for decreasing nitrogen leaching from cattle urine deposition often focus on the late autumn/early winter period, for example use of nitrification inhibitors or stock removal from paddocks.

To test whether this is the critical period, small plots (2.5 m x 1.5 m) were established on a paddock at DairyNZ's Scott farm (Horotui soils series). Artificial urine was applied to separate plots at monthly intervals from March to August 2009. The urine was applied at a rate of 800 kg N/ha at the start of each month and individual plots received only a single application, with 5 replicates at each application time. Leachate was sampled using porous ceramic cups installed at 60 cm depth and was analysed for nitrate- and ammonium-N. Nitrogen loads leached below 60 cm were calculated using the measured N concentrations and drainage measurements obtained from nearby lysimeters housing the same soil type.

Drainage started late May and continued until late October. Rainfall was 794 mm in the months of March through to October inclusive, which yielded 413 mm drainage. Not surprisingly, there was a highly significant effect of application time on nitrate-N leached during the drainage period ($P<0.001$), with the following losses (kg N/ha): 332 (March applied); 264 (April); 306 (May); 233 (June); 76 (July); 12 (August).

Nitrogen leached from the urine patch will be a balance between the amount of N deposited and the amount of N removed from the leachable pool by uptake by the pasture, gaseous losses and immobilisation into the soil. The indication from this experiment is that urine deposited in March is as great or greater a risk to nitrate leaching as urine deposited in May or June, albeit the results are from one season and one soil-type in the Waikato region.

Further experimental and modelling work is required to extend these data to different soil and climatic conditions and to also test the effects on N leaching of urine deposited before March.

MANAGING METHANOTROPHS IN AN ON-FARM BIOFILTER TO REDUCE METHANE EMISSIONS

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Methane (CH_4) is New Zealand's major agricultural greenhouse gas, mainly sourced from enteric fermentation (85–95%) and waste ponds (5–15%) on dairy farms. Nationally, CH_4 represents about 37% of our total emissions on a CO_2-equivalent basis, and effective mitigation options have yet to be developed. Mitigating this potent gas has become more urgent as it appears to have a much greater warming effect on the atmosphere than previously thought. Biofilters, in which methanotrophic bacteria convert CH_4 to CO_2, are widely used to reduce CH_4 emissions from landfills and coal mines. However, to date little research has focused on the application of biofiltration to treat CH_4 generated from farming activities. This paper reports on the development of biofiltration technology to reduce New Zealand's dairy farm CH_4 emissions.

Volcanic soils collected from landfill caps (<2 years and 8 y-old) containing active methanotrophs form the basis for our biofilter. Automated laboratory chamber experiments have revealed that both cap soils consume very high amounts of CH_4 (>95%) at high inlet CH_4 doses (15 000 ppm). This indicates rapid adaptation of methanotrophs to high CH_4 concentrations. Preliminary molecular analysis of *pmoA* and *mmoX* genes shows that mainly Type II methanotrophs appear to be involved in oxidising the elevated CH_4 concentrations in the chambers. Furthermore, enrichment of CH_4-oxidising bacteria has been successful up to three transfers in a Nitrate-Mineral-Salt-Medium, and should provide further evidence of the types of methanotrophic bacteria present in the landfill cap. Our ability to culture these methanotrophs will assist in the future introduction of biofilters on dairy farms.

The most active landfill soil identified in our laboratory trials, mixed with an inert support medium, is now being tested in a prototype field biofilter to oxidise the high CH_4 emissions from a section of a dairy farm effluent pond. Oxidation rates of up to 99% are currently being observed, suggesting the filter could be effectively scaled-up to treat CH_4 emissions from the entire pond. To our knowledge, this is the first field-operating biofilter treating CH_4 produced by dairying. In the next stage in the work we will assess the feasibility of using CH_4 biofilters to treat emissions from housed cattle, which represent the largest CH_4 source on dairy farms. Overall, it is envisaged that the findings of this research can be used to assess whether biofiltration is an effective and economically viable technology for treating dairy farm CH_4 emissions.

OVERSEER® NUTRIENT BUDGETS
- WHEN DEVELOPING A DECISION SUPPORT TOOL, IS IT POSSIBLE TO PLEASE ALL OF THE PEOPLE ALL OF THE TIME?

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'On-farm decision support tool' is a frequently used term and generally means something that will assist a farm manager in achieving the best outcome for a set of goals, be they 'personal/business' (e.g. farm productivity or financial targets) and/or 'imposed' (e.g. N leaching targets). Decision support can operate at a range of spatial scales (e.g. paddock, farm) and temporal scales (e.g. daily irrigation need, annual nutrient balance). Advice can also be delivered in a number of formats including booklets and leaflets, and not necessarily as a computer model. Computer models offer a way of synthesising complex information and can be an efficient way of interacting with the user (but with many provisos).

OVERSEER® Nutrient budgets (*Overseer*) provides users with a tool to examine the impact of nutrient use and flows within a farm on nutrient use efficiency and on possible environmental impacts. *Overseer* has a wide range of users, being used for on-farm decision support or for policy support and implementation. Users have widely differing needs from *Overseer*; at one extreme being an expert user fully conversant with its functioning (e.g. farm consultant); at the other extreme, a general awareness of its capability (e.g. policy maker). A further challenge is added by the fact that *Overseer* is trying to represent complex farming systems with a high variability between farms in their structures and management options.

This paper uses *Overseer* as an example of a continually developing decision support tool and highlights some of the key scientific and operational challenges in building and maintaining such a tool, hopefully providing food for thought for other researchers embarking on this path, as well as for end users. Some of these challenges include:

- Maintaining a strong science base, for example: ensuring that the model is regularly updated with the best available science; making judgements on when there is sufficient data to develop a new feature; extrapolating the model to extreme scenarios.
- Maintaining the balance between simplicity and complexity to that the model is relevant and useful for users but is also not so complex in input demands that it is unusable.
- Matching data availability and scales with model requirements.
- Maintaining and upgrading the software to ensure reliability.
- Avoiding 'rubbish in – rubbish out' - user competence, support, training and accreditation.

DESCRIPTION OF A CUT AND CARRY PASTURE MODEL WITHIN OVERSEER® NUTRIENT BUDGETS

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A new 'cut and carry' model has been added to the OVERSEER® Nutrient Budgets model (*Overseer*) to allow blocks to be set up that are used solely for growing supplement. It is based on the previously upgraded and validated crop model combined with a pasture growth module. This paper describes validation of the drainage and N leaching components of the model.

A review of the international literature and the few NZ measurements collated 15 data sets, comprising mainly ryegrass/clover swards, where sufficient information was provided to allow detailed data input into *Overseer*. These experiments were all independent of the data used to develop the model. The median annual N leaching loss from the reports was 12 kg N/ha.

Agreement between modelled (*Overseer* 5.5 beta version) and measured N leaching was good for 13 of the 15 sites. One site was sown to pure ryegrass with nil N fertiliser; *Overseer* assumes ryegrass/clover and would have overestimated N supply. In an experiment on the Central Plateau measured losses were much smaller (19 kg N/ha) than modelled (38 kg N/ha), even though the N fertiliser inputs were relatively large (230 kg N/ha) and reported yields small for the inputs (8 t DM/ha). Two other experiments in the same area gave good agreement (15 and 14 kg N/ha for measured and modelled, respectively, as a mean of the two sites).

A paired t-test for the dataset of 15 sites showed no significant difference (P=0.6) between measured (mean 13 kg N/ha) and modelled (mean 15 kg N/ha) N leaching. When modelled data were plotted against measured, excluding the two sites as described above, there was a highly significant linear regression (P<0.01), with 53% of the variance explained. Comparison of reported drainage data and *Overseer* modelled results was even better (slope 0.99, intercept not significantly different to zero and 98% variance explained).

We can conclude that the cut and carry model within *Overseer* adequately represents N leaching and drainage in situations where paddocks are used solely for growing pasture based supplements, especially for ryegrass/clover swards.

EFFECTS OF SOIL TYPE AND CLIMATE ON N LEACHING — AN APSIM MODELLING EVALUATION

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Intensive dairy farming with high fertiliser input, biological fixation of N in legume-based pastures, and very high concentrations of N under urine patches, far in excess of what can be utilised by pasture plants, has been found to contribute to elevated groundwater nitrate concentrations in many regions of New Zealand and worldwide. Apart from farm management practices, climate and soil type are major drivers of N leaching. The APSIM (Agricultural Production Systems SIMulator) model was used to assess the effect of soil type and climate variables on the risk of nitrate leaching from urine patches. The simulations were run over a period of 20 years using climate data from 37 stations from around New Zealand spanning a range of temperature and rainfall conditions. Two soil types, a heavier soil (Horotiu silt loam) and a lighter soil (Oropi sandy loam) and standard farm management practices were used in the simulations. A high-concentration urine patch was simulated by applying an equivalent of 1000 kg N/ha every four years. To assess the effect of temperature and rainfall at the time of and in the period following urine application simulations were run with urine applications in either January of July.

The model was first tested with results from lysimeter experiments. Potential nitrification and ammonium adsorption were found to be different for the two different soils. The effects of soil type and climate variables on N leaching were determined by classification and regression tree (CART) analysis.

Of the 1000 kg N/ha applied between 1 and 76 % leached. The timing of urine application had a larger effect on the total amount of N leached in the Horotiu soil and in the lower South Island (latitude ≥-43.575) compared with the Oropi soil. Average annual drainage or rainfall explained most of the variance in N leaching. Other climate variables found important to predict the risk of N leaching were average annual temperature and amplitude. Dry matter production was most highly correlated with average temperature amplitude, followed by average annual rainfall, average annual temperature, and total amount of N leached.

The above results are an initial step to identify indicators of areas with high risk of N leaching and help to develop management strategies to reduce such losses. Further analyses are however needed to fully understand the determinants of the magnitude of N leaching. These include a wider selections of soils plus different urine-N deposition rates and timing.

NITROGEN PROCESSES AND NITROGEN USE EFFICIENCY IN PASTURE SYSTEMS UNDER DIFFERENT MANAGEMENT – A MODELLING ANALYSIS

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A pasture model was developed and integrated in APSIM (Agricultural Production System Simulator) aiming to provide a flexible/versatile tool for simulating pasture production and its environmental impact under various farm conditions and management scenarios. Model performance in predicting pasture production were validated against long-term pasture measurements at multiple sites across New Zealand. Here, we briefly present the model and its validation analysis, plus preliminarily analyses of the nitrogen (N) processes built in the model. The objectives were: (1) to examine the sensitivity of model prediction to management-related parameter settings; and (2) to demonstrate how the changes in pasture management affect pasture production and its environments.

The model was run using a set of management parameters, including the N harvest by animals and N partitioning between animal products and excreta (urine and faeces). Effects of grazing management were simulated against the actual management of a pasture at Winchmore, Canterbury - a sheep grazing trial on dryland versus irrigated pastures. The simulation was run for a period of 10 years, all the N fluxes were traced (plant N fixation, plant N uptake, plant N return, animal N and N return as faeces and urine, N leaching and gaseous N losses), and annual N fluxes were calculated. Results showed that pasture production was very sensitive to grazing management parameter settings, especially those related with N return from animal excreta. It is also shown that grazing significantly increased N cycling rate or N use efficiency in the system. For example, under rotational grazing management, the simulated pasture fixed 36 or 81 kg N/ha/yr in average under dry or irrigated conditions, but plant could uptake about 303 or 599 kg/N/ha/yr due to fast N cycle by animal excreta. Also, for the simulated pasture, plant N fixation under grazing was about half of that under hay-making (cut & move), while plant N uptake was about two times higher under grazing. Grazing increased pasture N uptake and supported a high herbage production, but also slightly increased N-leaching risks. The model may be used to explore the consequences of various management scenarios to support management decision-making.

UPPER WAIKATO NUTRIENT EFFICIENCY STUDY

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A study to look at the economic returns of nutrient efficient farming systems was funded by DairyNZ, Fonterra, Ballance and Environment Waikato in 2008.

This study set out to investigate the costs of change for farming businesses to increase nutrient efficiency. It used case studies of 10 South Waikato dairy and 4 sheep and beef properties. Historical economic and production data from 2008-09 was used. Changes to systems to become more nutrient efficient were done using a combination of Farmax and Overseer.

Winter grazing off was not used as an option to reduce leaching in any models. The dairy farms averaged 45 kg N leached and this was reduced on average by 40% to an average of 25 kg N leached for the study. The sheep, beef and deer farms were modelled to reduce leaching to a target of 12 kg N leached per ha.

There were mixed economic results for the sample group as a result of the changes. Some farms were more profitable, some were less profitable. When modelled for a low nutrient system, the average Waikato dairy farm showed improved profitability. The models assumed farmer skill was not a limiting factor.

The most intensive dairy farms in the case study were affected the most, with a drop of 10% in their return on assets (ROA), the average and low intensity farms when modelled for nutrient efficient systems showed only a small change in net ROA. This can be compared with the impact of a $1.00 change in milk price, which can affect the ROA by up to 30%.

Green house gas emissions were reduced by 12.5% on the nutrient efficient models.

A combination of reduced N use, better effluent capture and management, graze able forage crops and slightly lowere stocking rates had the greatest impact in reducing N leached from the case study farms. There was a variation in the degree of response to each mitigation tool by individual farms.

The study also found that in a lot of cases, a nutrient management plan will be helpful, but where farm systems changes are involved, a full farm systems analysis is necessary, considering the owners goals, and the impact on profit, risk, efficiency and physical parameters.

DESCRIPTION OF THE HOUSE BLOCK MODEL WITHIN OVERSEER® NUTRIENT BUDGETS

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A house block has been added to the OVERSEER® Nutrient Budgets model for completeness of land use units within a farm. Losses of nutrients to waterways from house blocks from 3 primary sources are considered within the model, namely the sewage system, vegetated area (lawns and flower and vegetable gardens), and 'miscellaneous' losses.

The contribution of septic tank effluent can be an important contributor to stream N loading. For example, Hoare (1984) noted that nitrate concentrations in urban streams were consistent with the loads discharged to septic tanks in the stream catchment. Within the model, estimates of loadings are based on average nutrient concentrations in septic tank water reported by the USEPA and assuming a typical water usage of 180 l/day/person. Thus, the number of people years is an input into the house block model. Lower emissions (1 kg N per person/yr) are set within the model for new advanced septic tank systems been developed. Composted and reticulated systems are estimated to have low losses (0.5 kg N per person/yr).

Although there are several references that suggest that house lawns can be a significant contributor to water nutrient loadings, the measured data found indicated losses were in the range of 1-4 kg N/ha/yr. In a school science fair project, losses of 4, 87, and 258 kg N/ha from lawn, flower and vegetable garden were measured in Hamilton, with a weighted section average of 22 kg N/ha/yr. These values were not inconsistent with running the model using a cut and carry system or cropping system.

'Miscellaneous' losses are considered as nutrient losses from hard surfaces such as drive and roofs via their drainage systems. From an analysis of runoff in urban areas, base losses of about 0.5 kg N/ha/yr were estimated for the NPlas model for the Rotorua region. As this region has an average rainfall of about 1400 mm, this figure was also adopted as the value at 1400 mm rainfall for the house block model.

For large farms, the losses from the house block are normally insignificant and can be ignored. However, in small blocks, particularly those with cultivated areas and/or older style septic tank systems, the N leaching losses per ha can be similar to losses from dairy farms.

DEVELOPING A CONCEPT FOR ASSESSING THE PESTICIDE FOOTPRINT OF HORTICULTURAL PRODUCTS

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Increased environmental awareness and changing consumer attitudes have motivated major retailers to label their products with carbon footprints. This allows consumers to choose products according to their global warming potential. Public concern is also targeting pesticides. Heightened customer sensitivity to pesticide residues in food and water has already led to the ban on using certain pesticides by some European retailers. However, pesticides play a vital role in modern horticulture. Often less than 0.1% of the applied mass of these inherent toxic compounds reaches its intended target, so assessing a pesticide's environmental performance is important. Established life-cycle assessment criteria of food commodities include 'pesticide use' alongside global warming potential, primary energy use, and others. However, the concept for including pesticides' impacts into these frameworks is not yet well advanced. Often, the amounts of active ingredient of all pesticides applied are lumped in a single figure regardless of the compounds' specific environmental fates and ecotoxicological profiles. A tool for assessing the actual environmental impact of the pesticides used for producing a specific good is missing.

Our pesticide footprint (PFP) is filling this gap. The PFP estimates the total loss of pesticides, and their respective impact on humans and ecosystems, per unit of horticultural product in a life-cycle framework. The impact assessment considers how the pesticide losses affect humans through the consumption of the product containing residues, and ecosystems through the exposure to residues in the environmental compartments of the soil, water, and air. The PFP includes the production of the pesticide, its application in the orchard, and the final disposal of pesticide containers.

The PFP typically consists of three steps:

1. **Life Cycle Analysis**: Estimate pesticide residues in the product at harvest date and in the soil, water, and air associated with producing a unit of a horticultural product

2. Life Cycle Impact Assessment: Assess and classify the ecotoxicological impacts of pesticide residues. While the impact on humans is directly associated with the product, impacts on soil, water, and air rather relate to the total amount of pesticides applied per hectare

3. Life Cycle Management: Develop mitigation strategies to minimize the PFP.

DEVELOPMENT OF BEST NUTRIENT MANAGEMENT PRACTICES FOR DAIRY GOAT FARMING SYSTEMS

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New Zealand has approximately 36,000 milking goats, on farms ranging from 15 to 130 hectares. Most dairy goats are milked by farmer shareholders of the Dairy Goat Co-operative (N.Z.) Ltd (DGC). DGC has 51 farmer shareholders and focuses on the production and processing of goat milk into high quality branded nutritional powders.

Goat milk production is estimated to have increased an average of 15% each year for the past five years, with over 16 million litres of goat milk processed by DGC in the 2008-2009 supply season. This increase has been driven both by increases in goat numbers, and increases in per goat production as farmers have moved to more intensive indoor systems.

DGC has taken a proactive role in establishing benchmarks for milk harvesting, animal health and welfare, and environmental impact of dairy goats in New Zealand. With funding from the Sustainable Farming Fund, DGC is undertaking the development of a dairy goat specific module within the OVERSEER® Nutrient Budget Model (*Overseer*) to enable farmers to understand and better manage nutrient losses and greenhouse gas emissions.

Alongside the development of *Overseer* for dairy goats, best management practices (BMPs) have been developed for nutrient management. While BMPs for nutrient management for other farm types are well developed, these do not allow for the different systems used in farming dairy goats. The key differences are:

- About 70% of the dairy goats are kept indoors all year round. Forage is cut and carried to housed goats and fed with other supplements.
- On indoor farms, large amounts of shed manure are produced. Effluent absorbed onto bedding of housed goats is high in nutrients but requires careful management.
- Dairy goats are extremely fussy about feed quality and acceptability. This has implications for spreading effluent or shed manure on pasture.
- Dairy goats produce less effluent than dairy cows at milking, but water volume used for washing down is similar.

This paper describes the development of nutrient best management practices for dairy goats, with particular regard for management of milking shed effluent and shed manure from indoor farms with cut and carry feed systems.

EFFECT OF SOIL HETEROGENEITY ON THE UNCERTAINTY IN MODELLING N LEACHING

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Farmers are under increasing pressure to demonstrate that their activities are not harmful to the environment. Because nutrient losses, either via leaching or in gaseous forms, are difficult and expensive to measure on a farm scale, they are increasingly being estimated using computer models. Measurements cannot be done without errors and are subject to natural variability; similarly modelling always has uncertainty associated with its results. These uncertainties arise from both the use of a simplified representation of reality and the use of uncertain parameters and input data.

Soil properties are major inputs to most agro-ecosystem models and therefore can have a significant impact on the model performance. Soils are naturally highly variable and this is one reason for deviations between measurements and modelling results. A single paddock can have different soil types, but variations can also be large even within a single soil type. Furthermore, farm management can change some soil characteristics.

As the use of models for evaluating farm performance increases, issues associated with model parameterisation and uncertainty will inevitably rise. The use of generic soil descriptions is generally considered sufficient for regional or even farm scale modelling, but for a more detailed analysis, this general description may not be acceptable. Thus, it is important to know the likely effects of soil heterogeneity on the models performance. These effects vary considerably with the type of model. Semi-empirical models have quite simplified descriptions and, despite being good at larger scales, they are likely to have higher uncertainty at small scales. Process-based models capture with more detail the variability in the modelled environment but they require more parameters and inputs which are sources of uncertainty.

Using the APSIM model framework with a detailed soil module (SWIM), we have investigated the effect that different soil descriptions have on the estimates of N leaching from pastoral farms. The simulations comprised a factorial combination of different descriptions of two soil types, different climate data, and N inputs. We present in this work the relation between soil variability and the uncertainty on the estimates of N leaching and the ways to use this information to improve decision making.

MODELLING THE EFFECTS OF SPATIAL DISTRIBUTION OF URINE PATCHES ON N_2O EMISSIONS USING NZ-DNDC

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The New Zealand specific version of the process-based Denitrification-Decomposition (NZ-DNDC) has been used to model greenhouse gas emissions in New Zealand dairy- and sheep-grazed pastures. The model assumes that excretal-N inputs from grazing animals are uniformly distributed across the grazed area. In reality, excretal-N inputs are deposited as patches of dung and urine of relatively small area. Urine patches contain high concentrations of mineral N (ammonium and nitrate) and are major sites (hot spots) of N_2O emissions from grazed pasture. It is not known how modelling emissions from this 'patchy' excretal-N deposition will differ from the modelled emission estimates obtained assuming 'uniform' distribution of excretal-N. This paper examines the effect of modelling nitrous oxide (N_2O) emissions from highly concentrated urine patches and non-urine patches, and compares this with the predicted emission obtained using the uniform N distribution.

To run 'uniform' and 'patchy' N deposition simulations, a grazing scenario was constructed using the soil, climate and grazing intensity data from a recently published study on a North Canterbury dairy-farm (Saggar et al. 2010)[1] with 200 cows/ha depositing 34.8 kg urine-N/ha in 24-hour grazing. The 'uniform' simulation treated the urine-N as evenly distributed over the paddock, and in the 'patchy' simulation urine-N was treated as unevenly deposited only over 3.5% of the paddock. Results of model simulations show that over a 50-day period 'uniform' simulation predicted 273 g N_2O-N/ha and 'patchy' simulation 413 g N_2O-N/ha emissions. The control soil produced 49 g N_2O-N/ha. The emission factor using the 'uniform' simulation was lower (0.65%) than the 'patchy' simulation (1.05%). Our results demonstrate that the non-linearity of N_2O emissions processes with respect to N-application rates could cause different N_2O emission predictions and emission factor estimates.

MODELING OF THE EFFECT OF COMBINED DCD AND UREASE INHIBITORS ON THE POST-DEPOSITION SIZE OF URINE PATCHES - IMPLICATIONS FOR DECREASED N LOSSES AND INCREASED PASTURE PRODUCTION USING THE 'TAURINE' TAIL-ATTACHED DISPENSER

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The high concentration of N in urine patches from dairy cows reduces the efficiency of conversion of N to dry matter. Improvements in this efficiency can be made by the use of both nitrification inhibitors (e.g. dicyandiamide and DCD), and/or urease inhibitors such as NBPT. The application of DCD reduces the environmental loss of N both as nitrous oxide emission and leaching as nitrate, and has shown increases in total pasture production of 5-20%. The co-application of DCD and NBPT has been shown to decrease ammonia volatilisation along with reductions in nitrate leaching and nitrous oxide production, which increases the potential N conversion efficiency.

The mechanical application of inhibitors requires that the total area of pasture is treated, while the affected area of pasture is small (perhaps 5 -10%), which must be treated within an hour of deposition to prevent the conversion of urea to ammonium. The simple and low-cost 'Taurine' tail-attached device dispenses both urease and nitrification inhibitors at the time and location of every urination, thereby maximising the potential production area of urine patches, reducing ammonia volatilisation, nitrate leaching and nitrous oxide emission.

The application of NBPT increases the time urea (an uncharged molecule) is present in the soil and permits lateral diffusion, therefore producing an increase in the area of pasture able to recover urine-N. The main limitation to lateral distribution of urine-N in the soil is the conversion of urine-urea to ammonium ions, which are strongly adsorbed by many soils, thereby inhibiting diffusion and leaching.

The application of a simple transverse and hemispherical model shows that the application of urease inhibitor to increase the lifetime of urea from 3 to 14 days can increase the area of pasture affected by at least 50 kgN/ha by 36% and 44% for hemispherical and concentric-cylinder geometries respectively.

CLUES – LINKING LAND USE TO WATER QUALITY

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CLUES (Catchment Land Use for Environmental Sustainability) is a GIS-based modelling system for predicting mean annual loads of nutrients, E. Coli, and sediment in streams throughout New Zealand. The software is available through MAF (http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/clues/), and includes modules from AgResearch (a reduced version of OVERSEER for nutrient sources), Crop and Food (SPASMO predictions of nutrient sources), Harris Consulting (farm profit and GDP), Landcare Research (nitrate leaching risk), and NIWA (SPARROW model for catchment-scale accumulation, stream attenuation, E. coli and sediment).

Recent additions to and applications of CLUES, made with Envirolink and Pasture21 funding, include the prediction of median nutrient concentrations and an application to identify critical catchments in the Waikato Basin. The Waikato work identified stream reaches that are predicted to exceed EW 'report card' criteria for total nitrogen and total TP, and the distribution of nutrient yields within impact catchments leading to such critical reaches. Predictions were made for the current land use and for a hypothetical scenario of dairy conversions for certain LUC classes throughout the catchment. Current work includes the application of CLUES to predict land use change under land use and intensification scenarios predicted with regional economic models, and prediction of the effects of mitigation measures applied in specified areas within the impact catchments.

REFERENCING WATER FOOTPRINTS TO INDICES OF WATER RESOURCE IMPACTS

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The growing scarcity of fresh water relative to human demand is now evident in many parts of the world. Fresh water is a renewable resource, but it is also finite. Around the world, there are now numerous signs that human water use exceeds sustainable levels. Groundwater depletion, low or nonexistent river flows, and worsening pollution levels are among the more obvious indicators of water stress. Sustainability of fresh-water use is thus increasingly becoming a topic of global concern.

Indicators can be used to evaluate the vulnerability of fresh-water resources. The first part of this paper reviews three fresh-water scarcity indicators, and discusses their advantages and limitations. Indicators related to water resources vary in content and complexity. A simple indicator like Falkenmark's is easy to use, but it fails to provide accurately a comprehensive picture of water scarcity. The Water Scarcity Index just considers total water withdrawal and does not account the quality of water and consumptive usage. The Water Poverty Index covers wider aspects of water scarcity. However, its complexity limits discrimination in international comparisons. The utility of indices depend on how well they assess water demand and supply of a country.

It is understood that water traded between nations in the form of 'virtual water' of product and services is an important component of conserving the world's water, but none of the three indices above takes this into account. The Water Footprint (WF) concept brings consumption-based indications of water use and accounts water traded in virtual form and the water polluted during usage. However, measuring of water use and trade by water volume alone is an inadequate guide to environmental impact and to the sustainability of water use. The sustainability of water use depends upon the impact of water use and this varies spatially and temporally. For international comparisons to be valid they need to take into account the localized impact of water use. The key is to link the WF of a product and services with an appropriate index on water resources and impact at the place of the production of those goods and services.

Latter part of this paper discusses about the fresh-water status of New Zealand. According to key indicators, New Zealand is well endowed with fresh water resources, but its high levels of water use reveal the need for vigilance to protect the country's valuable and renewable water resources.

CARBON STORAGE IN KIWIFRUIT ORCHARDS OF NEW ZEALAND BASED ON ABOVE- AND BELOW-GROUND BIOMASS

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The terrestrial carbon balance is influenced by soil, climate, vegetation and its management. Vegetative growth of kiwifruit vines in New Zealand tends to be vigorous (i.e. high photosynthetic fixation of atmospheric CO_2) due to warm and moist climatic conditions. Recently, the impact of kiwifruit production on greenhouse gas emissions was estimated in New Zealand with an LCA-based carbon footprint analysis following the PAS2050 framework. However, this framework does not consider the soil or the kiwifruit vines as a source or sink of atmospheric CO_2. This was the objective of this project. We estimated the carbon storage in kiwifruit orchards in New Zealand based on above- and below-ground biomass of organic, biological, and conventional management systems and in three agro-ecological zones: Katikati, Tauranga and Te Puke. The above-ground biomass was measured as standing stable dry matter (kiwifruit vines) plus litter dry matter (ground biomass: vine pruning, leaf and grasses). The below-ground biomass was measured as secondary and tertiary kiwifruit roots and sward roots in the 0-15 cm depth. Kiwifruit vines biomass carbon content ranged from 9.01 to 11.79 t ha^{-1} for organic, 6.56 to 12.61 t ha^{-1} for biological and 6.35 to 12.20 t ha^{-1} for conventional management systems. Most below-ground biomass was at 10-15 cm depth and there was a large variation among the orchards. The below-ground biomass carbon content ranged from 45.06 to 63.15 t ha^{-1} for organic, 39.37 to 64.88 t ha^{-1} for biological and 38.35 to 56.34 t ha^{-1} for conventional management systems in the 0-15 cm depth. Below-ground had higher carbon storage than above-ground with the ratio (below-ground: above-ground) ranging from 2.73 to 5.57. The total carbon storage in kiwifruits orchards of New Zealand varied with agro-ecological zones, with 54.66, 66.95 and 56.96 t ha^{-1} in Katikati, Tauranga and Te Puke, respectively. Regardless of management and zones, the total carbon storage was 67.59 t ha^{-1} in kiwifruits orchards in New Zealand. Our study highlights that soil contributes more than other variables in carbon storage in kiwifruit orchards. The differences in carbon sequestration in different management systems and agro-ecological zones indicate the necessity of estimating carbon emissions due to anthropogenic activities in order to allow us to identify management practices that best protect and enhance carbon in kiwifruit orchards, and to predict the contribution of kiwifruit production to the global carbon cycle.

A COMPARISON OF DIFFERENT METHODS FOR THE SEPARATION OF PARTICULATE ORGANIC MATTER FROM SOILS

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Particulate organic matter (POM) is defined as soil organic matter (SOM) that is greater than 50 µm in diameter. Research has shown that POM is a dynamic SOM fraction, which responds rapidly to changes in management. Recent work has shown that soils may also contain labile, POM-like organic matter that is less than 50 µm (5-50 µm). POM is separated by first dispersing the soil to break down aggregates into primary particles. Our objective was to evaluate chemical (Calgon) and physical (ultrasonic) dispersion methods to identify a procedure that can be used to isolate conventional POM (>50 µm) as well as the new POM-like (5-50 µm) fraction in weakly- and strongly-aggregated soils. Two contrasting soils (an easily-dispersible Pallic soil and a strongly-aggregated Allophanic soil) were dispersed by overnight shaking in Calgon solution or by treatment with an ultrasonic probe at an energy output of 132 W (ultrasonic treatment times of 30, 60, 90, and 120 sec were evaluated). After dispersion, the (>250, 50-250, and 5-50 µm) fractions were separated by sieving and sedimentation. For each soil, the mass of the >250 and 50-250 µm fractions was similar for the Calgon and ultrasonic dispersion methods. However, the 5-50 µm fraction mass was greater when dispersed with Calgon as opposed to ultrasonic treatment, particularly in the Allophanic soil. Furthermore, the 5-50 µm fraction mass tended to decrease as duration of ultrasonic treatment increased. These results suggested that micro-aggregates were still present in the 5-50 µm fraction after using Calgon and short-duration ultrasonic treatments, due to incomplete dispersion. Calgon and ultrasonic dispersion methods yielded similar values for POM-C in the conventional > 50 µm size fraction. However, due to the presence of micro-aggregates resistant to Calgon, C in the 5-50 µm fraction was ~ 70% greater than with a 90-sec ultrasonic treatment. We conclude that Calgon gives adequate dispersion for the recovery of conventional POM-C (> 50 µm), but a more vigorous dispersion method (e.g. ultrasonic treatment for 90-sec; energy output 132 W) may be needed to isolate "POM" in the 5-50 µm size fraction.

EFFECT OF SLOW-RELEASE BORON FERTILISER ON PINUS RADIATA GROWTH, BORON UPTAKE AND PHOTOSYTHESIS

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The effect of different fertiliser boron (B) levels on growth, B uptake and photosynthesis of *Pinus radiata* was studied under greenhouse conditions. Results showed that the B concentration in needle, stem and roots increased with increasing rates of B fertiliser. At the highest rates, B reduced net photosynthetic rate and diameter growth, however increased growth and photosynthesis rate were observed for lower rates of 4-8 kg B/ha. Soil dehydrogenase activity, an indicator of soil microbiological activities, was significantly reduced by B application at the rate of 16 and 32 kg/ha.

EFFECT OF SPECIES AND MANAGEMENT ON ROOT DEVELOPMENT IN SRC WILLOW

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SRC *Salix* using two clones *Salix schwerinii* 'Kinuyanagi' and *S. viminalis* 'Gigantea' was trialled at formerly pastoral sites near Taupo as an alternative land use to reduce nitrogen use and leaching. In their first year of growth from cuttings at the trial in Taupo, both species suffered retarded growth from water shortage. Many more 'Kinuyanagi' than 'Gigantea' cuttings died. "Gigantea' responded to water stress by shedding leaves, but 'Kinuyanagi' did not. This partly explained differences in survival. We hypothesised that under soil water limitation differences in the root system may also contribute to 'Kinuyanagi' showing more stress than 'Gigantea'.

To investigate the root response to coppicing and siting root excavations were carried out for each clone and root length, root dry mass and extension of the longest roots measured.

The two species, grown in short rotation coppice willow trials in New Zealand, differed in root extension and coarse and fine root distribution. *Salix viminalis* 'Gigantea' roots occupied a greater volume of soil than did roots of *S. schwerinii* 'Kinuyanagi' at stool age 3 years. Coppicing reduced fine root length and mass in both species. Coarse root response following coppicing differed between the species. *Salix viminalis* 'Gigantea' showed increased coarse root extension following coppicing whereas for *S. schwerinii* 'Kinuyanagi' the longest roots extended less in coppiced plants than in uncoppiced plants of the same age.

Siting of *Salix* in sites where depth and nature of soil and slope reduce plant available water is likely to disadvantage survival and growth in the establishment year just as it might for any other crop. This is likely to be more pronounced with *S. schwerinii* 'Kinuyanagi' than with *Salix viminalis* 'Gigantea' because of the differing rooting behaviour. Coppicing of SRC willow stools following the first season's growth is recommended management practice. However the differing effects of coppicing on root development in different clones may result in differing production in marginal sites
Knowledge of rooting characteristics of Short Rotation Coppice (SRC) willow species can contribute to understanding of species performance in changing environments, especially moisture deficit conditions, and inform choice of clone in marginal environments.

AGRICULTURE AND FORESTRY IN THE NEW ZEALAND EMISSIONS TRADING SCHEME: THE LEGISLATIVE FRAMEWORK

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The Climate Change Response (Moderated Emissions Trading) Amendment Bill passed into law on 25 September 2009. The Amendment Bill made a range of substantive changes to the agriculture and forestry provisions of the New Zealand Emissions Trading Scheme (NZETS), which has been operating since 1 January 2008.

The NZ ETS is the price-based mechanism for addressing greenhouse gas emissions (GHGs) and is a key part of New Zealand's overall climate change policy. It covers all GHGs and all sectors of the economy. The principle behind the NZ ETS is that participants must monitor their GHG emissions and surrender New Zealand Units (NZUs) to cover those emissions on an annual basis. Participants can obtain NZUs by purchasing them from the marketplace or earning them through forest sequestration. Some participants will also receive some NZUs for free from the Government (free allocation).

The agriculture sector (agricultural methane and nitrous oxide) fully enters the NZ ETS on 1 January 2015. However, participants may voluntarily report their emissions in 2011 and are required to report their emissions from 2012 through 2014.

The legislation sets the point of obligation at the processor level, meaning that meat processors, dairy processors and fertiliser companies will surrender NZUs for emissions that occur on farms. The government may change the point of obligation to the farm level by Order in Council. In choosing to move the point of obligation to farm level, the Minister must have regard to the costs and benefits and the ability to enforce compliance with the scheme.

The forestry sector entered the NZ ETS on 1 January 2008. Owners of post-1989 forest land are eligible to register as participants in the NZ ETS and receive NZUs for the carbon that their forest sequesters. However, post-1989 participants must also surrender NZUs whenever the carbon stocks in their forest falls below a previously reported level.

Owners of pre-1990 forest land will automatically become participants in the NZ ETS if they deforest more than 2 hectares of non-exempt forest land in any five year period, starting 1 January 2008. As participants, they will have to calculate and report their deforestation emissions and surrender emissions units equal to those reported emissions.

EXTENSION OF CLIMATE CHANGE TO THE PRIMARY SECTORS – A PARTNERSHIP APPROACH

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There is inevitably debate with such a complex issue as climate change. However, the scientific consensus is that it is now unequivocal that warming of the climate system is happening. The evidence continues to grow that human activity is contributing significantly to this warming. In 2007 the Government established the Sustainable Land Management and Climate Change Plan of Action which includes two main responses: mitigation and adaptation. Pragmatic farmers and growers tend to see mitigation and adaptation responses as ways of making their businesses more resilient and sustainable. Many of the actions that help respond to climate change issues also address other issues of environmental, economic and social sustainability. This paper will present some of the key findings from a July 2009 survey of 1000 farmers and growers on their attitudes to climate change and the actions they are already taking and plan to take to increase their resilience and sustainability.

A partnership approach between dairy, forestry, sheep & beef, horticulture, arable, Maori, Federated Farmers, FertResearch, Local Government and MAF is being used to develop a five year action plan for climate change extension and upskilling. This plan will address the impacts of climate change (both mitigation and adaptation). The purpose of this plan is to promote more resilient land based businesses by supporting and co-ordinating sector and government initiatives and providing up to date, relevant information, resources and upskilling on climate change issues to land managers and their advisers. The MAF Climate Change Technology Transfer Sub Group (CCTTSG) is taking the lead on developing this plan.

A series of seven sector workshops will develop sector specific targets, actions, identify drivers of uptake and get commitment from the sectors. The first workshop was run in December 2009 for the arable and process vegetable sector and came up with a series of practical actions. The other workshops will be completed by the end of February 2010. This paper will also outline where this work is heading.

TO TREE OR NOT TO TREE
– PROJECTED FARM BUSINESS ANALYSIS

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The passing of the moderated Emissions Trading Scheme into law in November 2009 may provide options for landowners who are interested in integrating sustainable land management with carbon management and managing business risk. We describe the financial impact of the Emissions Trading Scheme on a livestock farm business. The potential interaction of commodity prices and farm forest management will be analysed to provide some insight into possible future farm business models where carbon management is of fiscal importance.

N DYNAMICS UNDER ELEVATED CARBON DIOXIDE IN THE AUSTRALIAN FACE EXPERIMENT

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The Australian Grains Free Air Carbon Dioxide Enrichment (AGFACE) facility was established to compare wheat growth, yield and development under ambient (~380 ppm) and elevated (~550 ppm) carbon dioxide (a[CO_2] and e[CO_2]). Experiments on fertilizer N recovery, straw decomposition and greenhouse gas production have been undertaken to estimate how e[CO_2] and a changing climate could affect crop production systems.

Elevated [CO_2] increased crop biomass at the end of tillering, anthesis and maturity. Although plant and grain N contents declined, crop N uptake was 24% higher with e[CO_2]. Stubble C:N ratio was not affected by e[CO_2].

Wheat was grown with ^{15}N enriched urea in PVC microplots at 50 kg N/ha in the AGFACE facility. Harvest biomass increased by 23% and N uptake increased by 17% under e[CO_2]. Like the main experiment, C:N ratio of the stubble was not affected by e[CO_2] and it had no significant effect on the proportion of N derived from fertilizer (%Ndff) for grain, stem and root. There were no significant effects of e[CO_2] on ^{15}N recoveries in soil and total fertilizer N losses.

The effects of e[CO_2] and irrigation on straw decomposition and soil respiration was also undertaken within the AGFACE experiment. Pure cotton cloth, wheat straw and pea straw were decomposed using litter-bag method for 140 days. The mass remaining was the highest for cotton cloth (90%), then wheat (73%) and pea (50%). Total C content of wheat and pea straw and total N content of pea straw were reduced only under e[CO_2] and irrigated conditions. Soil CO_2 emissions were increased by e[CO_2] only under irrigation.

In these experiments, the C:N ratio and degradation of organic residues in the wheat crop is not affected by carbon dioxide levels, although large amounts of residue would enter soil nutrient cycles. These data indicate that e[CO_2] increases plant N demand but does not increase the efficiency with which fertilizers are used nor the likely supply of N from residues. Further research is planned to investigate mineralization and N fixation under e[CO_2] and these data will be used to develop N strategies for future cropping systems.

IS ANTHROPOGENIC CLIMATE CHANGE REAL?
A PERSONAL VIEW BASED ON THE SCIENCE

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Much of the research being conducted today in agriculture is predicated on the basis that human-induced emissions of greenhouse gases are the main cause of global warming. It appears that many agricultural scientists accept this to be the case, excusing themselves on the basis that they are not specialist in this field and therefore must defer to those who are. This approach under normal circumstances is appropriate but should it be applied to Anthropogenic Global Warming (AGW). This paper questions the veracity of the AGW hypothesis based on assessments of published science. It is hoped that it will stimulate discussion on this important topic.

Climate science is very complex and covers very many disciplines. It is doubtful than there is any one person who has a complete grasp of the all aspects of climate science. The approach adopted in this paper is that of a layman in terms of climate science – albeit a scientist by training – searching for robust scientific evidence, either for or against human-induced global warming. This approach cannot and does not rely on a detailed study and knowledge of all that is climate science. Rather the approach is to apply some simple scientific tests to some of the questions which are fundamental to the AGW hypothesis.

Key questions are posed and then answered based on information in the scientific literature which collectively lead the author to reject the AGW hypothesis.

APPLICATION OF INTEGRATED PROXIMAL SENSING TECHNOLOGIES TO RECOGNIZE SPATIAL VARIABILITY OF SOILS AND CROP PERFORMANCE

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To properly account for existing soil heterogeneity, it is important to assess and interpret measures of mechanical, physical, chemical, biological and other phenomena related to the various processes occurring within the root zone. Traditionally, this has been accomplished through soil sampling (extracting a fixed amount of soil from a predefined depth) for off-site laboratory evaluation. Although there are ongoing improvements of relevant equipment and methodologies, the process remains cost- and labor-intensive. To overcome the low spatial resolution typical of the type of sampling that is economically feasible, both remote and proximal sensing technologies have been employed. Remote sensing relies on acquiring imagery-type data using optical and radiometric sensors installed on an aerial platform or a satellite, whereas proximal sensing systems are placed near the surface or in contact with the soil being tested. When proximal soil sensors are used while travelling across the landscape (on-the-go), the resulting georeferenced data can be used to create high-density maps of measurements, similar to the way harvest data is used to create yield maps. Many design concepts are available, but most on-the-go soil sensors involve one of the following measurement methods: 1) electrical and electromagnetic sensors that measure electrical resistivity/conductivity or capacitance affected by the composition of the soil tested; 2) optical and radiometric sensors that use electromagnetic waves to detect the level of energy absorbed/reflected by soil particles; 3) mechanical sensors that measure forces resulting from a tool engaged with the soil; 4) acoustic sensors that quantify the sound produced by a tool interacting with the soil; 5) pneumatic sensors that assess the resistance to the air injected into the soil; or 6) electrochemical sensors that use ion-selective membranes producing a voltage output in response to the activity of selected ions (e.g., hydrogen, potassium, nitrate, etc.). When looking at the family of remote and proximal soil sensing systems, it is important to remember that crops themselves are the most effective "sensors" indicating the quality of a local environment. Remote sensing imagery taken during vegetation stages, proximal sensing of the crop canopy reflectance, and, ultimately, yield maps reveal the spatial distribution of the overall crop performance that in many instances can be explained by soil heterogeneity. Current precision agriculture research is focused on integrating various sources of soil- and crop-based sensing technologies to discover and understand the spatial variability of soil attributes limiting yield potential. The ultimate goal is variable rate application of agricultural inputs based on local, economically justified needs, leading to reductions in unnecessary environmental pressure.

EXPLORING THE USE OF REMOTE SENSING TOOLS FOR ESTIMATING NITROGEN FERTILISER REQUIREMENTS IN PERENNIAL RYEGRASS SEED CROPS

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Perennial ryegrass seed production is typically responsive to the application of nitrogen fertiliser. Typically, nitrogen application responses average 36% greater seed yield than the untreated controls and in the linear phase of response, gains of between 3 and 5 kg seed/ha/kg N applied are common. However, as nitrogen application rates increase the response changes from linear to a plateau or curvilinear. Economically N contributes approximately 15% of input costs therefore, when N rates are applied within the linear response phase the economic results are positive however, when excessive N rates are applied, economic losses (and potentially environmental losses) can occur. Therefore an accurate estimate of plant N requirements is required for economic and environmental sustainability. Measurement of canopy reflectance with remote sensors has the potential to use the plant as an indicator of N requirements.

The "Greenseeker" is an active type remote sensor that measures canopy reflectance in the red (~650nm) and near infrared (770nm) wave bands. From these measurements a vegetative index can be calculated. The normalized difference vegetation index (NDVI) as calculated by ; $NDVI = \frac{NIR - Red}{NIR + Red}$ has been used for many years to estimate ground cover, vegetation greenness and more recently has been used in maize and wheat to estimate crop N requirements.

For two seasons crop NDVI has been collected as a measurement of crop nitrogen status and dry matter production. Following the application of nitrogen, changes in NDVI were found to reflect the amount of applied N, up to a saturation point. In ryegrass seed crops N is traditionally applied in two or three applications. It is envisaged that NDVI may be used to better assess N requirements at applications two or three to those areas of the paddock which may or may not respond to further N applications. For this to be practical an NDVI map may be required before each N application i.e. to work out what has changed and what has not. The possibility of using the "Greenseeker" to estimate nitrogen nutrition index was also investigated as a tool for altering the amount of total N applied to a paddock. Initial results are positive but the data requires further analysis.

Challenges for the future of this technology include; differences between cultivars, linkages to other precision agriculture tools and an understanding of what is actually limiting crop production e.g. soil type or another nutrient.

THE EFFECT OF STORAGE CONDITIONS ON THE ACCURACY OF DEEP MINERAL NITROGEN CONTENT OF SOIL

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Predicting nitrogen (N) fertiliser application rates based on the prior analysis of fresh soil for deep mineral N (the sum of NO_3-N and NH_4-N) is a widely accepted practice. Target N rates ensure optimum crop production and environmentally safe practice so it is important to ensure the deep mineral N (DMN) test accurately reflects the mineral N content of the soil at sampling. NO_3-N and NH_4-N exist in soil in dynamic form making sample pre-treatment necessary to prevent changes to the concentration of these two ions. This study determined the baseline NO_3-N and NH_4-N content of three different soils extracted immediately after sampling with 4 pre-treatment times of 12, 24, 48 and 96 hours and 4 pre-treatment temperatures of freezing (-8°C), 4, 10 and 20°C.

A further study was also undertaken to determine the changes in DMN for frozen samples allowed to thaw at ambient temperature for 0, 1, 2, 4, and 6 hours. In the first study, the three soils had low, medium and high N levels, with samples being moist for the low and high N soils, but dry for the medium N soil. For the frozen medium and high N samples, there was a small but significant ($p<0.05$) drop in DMN between the initial sample and the 12-hour sample (mainly due to a drop in NO_3-N), but little change with further storage up to 96 hours. For the moist samples (low and high N soils), there were large and significant ($p<0.001$) increases in NO_3-N and DMN both with increasing storage temperature and storage time, and significant ($p<0.001$) decreases in NH_4-N. For the drier samples (medium N soil), these trends followed similar patterns, but were much reduced in magnitude.

It is hypothesised that for samples with a higher moisture content and greater water activity (A_w), conversion was able to proceed at a much faster rate than in the drier samples. In the second study, there was a significant increase in DMN with increasing thawing time, mainly due to increasing NH_4-N. As in the first study, these increases were much smaller for the drier samples than the moist samples. The results indicate that immediate chilling and subsequent freezing is a relatively reliable pre-treatment for soil samples submitted for DMN determination.

ALL PADDOCK TESTING – A NEW PARADIGM FOR NUTRIENT MANAGEMENT ON FARMS

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A new soil testing service is available, where every paddock on the farm is individually tested. This greater intensity of soil testing (typically ten-fold over current practices) allows fertility maps of the property to be generated. This more comprehensive understanding of the variation of soil fertility enables the farmers to extract more value from their fertiliser spend, by allowing them to apply the fertiliser more strategically. As well as enabling more effective fertiliser programming, the service also provides information of environmental relevance.

This approach represents a significant increase in work over what is currently common practice, and the key issue is finding the way to keep the costs down. There are four components that needed to be worked through: sampling, testing, presentation of the results, and interpretation with fertiliser recommendations. Each of these is discussed in turn.

All paddock testing (APT) does not replace the current soil test monitoring approach, where transects representative of the Land Management Units (LMU's, typically 4-6) are sampled and analysed every 1-2 years. Rather, it is complementary service, showing whether or not the current LMU's are appropriately delineated, and the uniformity of each of these areas. The APT approach therefore need only be undertaken every 5 – 10 years.

PRECISION AGRICULTURE TECHNIQUES TO REDUCE DAIRY FOOTPRINTS

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If water and carbon footprints are to be considered in terms of resource use efficiency per unit of production then precision agriculture offers considerable potential to improve the performance of New Zealand dairy farms. Precision dairying takes account of the spatial and temporal variations in feed production and nutrient levels with monitoring and control of individual animals, this offers considerable efficiency gains.

A number of examples are given.

The CDax pasture meter offers a reliable method of measuring pasture mass, farmers using this systems have reported an increase in feed utilisation. A Pastoral 21 project involving, AgResearch, Massey University, Landcare Research and DairyNZ has examined methods of sensing pasture nutrient levels.

The nitrogen content of the diet determines cow urinary nitrogen excretion, which rises rapidly as diet nitrogen becomes excess to cow requirements. Precision application of nitrogen fertiliser using spatial pasture nitrogen maps could improve both the timing and rate of application of nitrogenous fertilisers while maintaining pasture production.

The use of water has been under considerable focus in recent years and methods of improving water utilisation for irrigation are feasible through adoption of irrigation scheduling and techniques such as variable rate irrigation, (VRI). The potential of VRI is both in increasing water use efficiency and reducing nutrient leaching.

Characterising soils and tailoring irrigation design and nutrient plans to suit each zone of the farm could also benefit yield, nutrient and energy efficiencies. This has been demonstrated through case study and techniques of rapidly mapping and zoning soil are available. If the nutritional characteristics of consumed pasture can be measured then a more balanced approach to nutrient budgeting that takes spatial variation into account can be developed.

Individual animal management tools exist, linking these and informing stock movement and grazing/effluent management from the status of the wider system (irrigation, rainfall, drainage, leaching, fertiliser use, pasture production, pasture quality) could deliver value to farming businesses. The key to moving to the next step appears to be system integration using existing tools.

ACTIVITY PATTERNS AND NUTRIENT REDISTRIBUTION IN AN INTENSIVELY MANAGED DAIRY HERD

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Most animals have distinctive activity patterns. Factors such as topography, pasture mass, available shelter can all affect nutrients distribution through the effect of these on the behaviour of individual animals or groups. Sensor technologies are used at farm level and are employed in the study of animal behaviour.

This study used sensor technologies to investigate the patterns of behaviour and excreta distribution in dairy cows under commercial conditions. Seventeen cross-bred dairy cows in late lactation, in a herd of 180, were fitted with global positioning system (GPS) collars, IceTag3D® activity sensors and urine sensors for seven consecutive days. The herd was milked twice a day and rotationally grazed, without supplements. Animals were at pasture from 06:00 h to 14:00 h (AM grazing) and from 15:00 h to 05:00 h (PM grazing). Cows were rotated through 12 paddocks of ~1.1 ha. Urination events followed a non-random distribution pattern. Urination activity was associated with grazing and lying behaviour. Cows spent more time grazing and less time lying down during the AM than PM grazing period. As the frequency of grazing decreased, the frequency of lying increased within AM and PM grazing periods. Activity patterns were consistent within and between grazing periods.

Understanding activity patterns and subsequent excreta distribution may have application in farm management strategies aimed at managing loss of nutrients and pasture utilisation.

AN ECONOMIC ANALYSIS OF THE TOPDRESSING INDUSTRY

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Over recent months, there have been some well publicised reports which raise doubts about the financial viability of the topdressing industry within New Zealand. There seems little evidence of a systematic analysis of the business model and suitability of the charging structures in place.

This paper considers three aspects of topdressing costs in order to estimate the actual costs of spreading fertiliser and lime. The questions posed are; what are the actual costs of operating the two main models of aircraft flown in New Zealand? What size of aircraft fleet is required to fulfil the spreading requirements? What are the on-farm infrastructure costs that also need to be considered in order to calculate the true costs of servicing the application of fertiliser to our hill country sector?

Topdressing services mainly the sheep and beef sectors which contribute 22.5% of New Zealand's agricultural output. Farm income in this sector is nearly $4 billion. Application of fertiliser is important to sector productivity and the possible collapse of the topdressing industry would have far reaching consequences for these farming sectors and New Zealand's export earnings.

The model finds that there is no financial return on capital invested in the industry. Therefore, the best returns are found by applying fertiliser from old aircraft with aged support vehicles all with little capital value. This is clearly unsustainable as even old aircraft require large injections of capital periodically to maintain airworthiness.

As fertiliser prices have increased, application rates have fallen which increases application cost per tonne applied. The agreed fixed price charging model is traditionally based on an application charge per tonne. It is likely that farmers perceive increased application charges per tonne as a price increase, whereas it is only compensating the applicator for the additional time of sowing at a lower rate.

FACTORS AFFECTING FERTILISER APPLICATION UNIFORMITY

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In aerial topdressing and ground spreading there are a number of sources of error that contribute to the unevenness of spreading, these errors are identified and quantified in relation to their contribution to the actual level of error observed in the field.

Although agronomists, researchers and farmers assume that spread is uniform this is impossible. The testing regimes used throughout the world, including New Zealand's Spreadmark code, assume a level error when calculating appropriate bout widths for operating machinery. This error level is represented as a coefficient of variation, CV, (standard deviation over the mean) and for Spreadmark the standards are set at 15% for nitrogenous products; and 25% for non-nitrogenous products. Further errors are evident when validating an in-field CV on-farm. Measured CV have been calculated at 37% for ground spreading with a likely range of between 20 and 60% in dairy farming. Field CV's for aircraft have been measured at between 70 and 90%.

Positioning the vehicle is a significant source of error and adhering to the exact bout width is difficult. The use of GPS guidance assistance has helped improve performance and this has been measured in a number of studies.

With aircraft one of the most influential factors are changes in speed, the speed of an aircraft varies considerably during discharge of its load, this can be related to terrain and loading. Control of spread is difficult if the product is not free-flowing. Free-flowing products have predictable flow from a given orifice, which can be controlled to deliver the correct application rate. If the product has cohesive strength and is not free flowing then its behaviour is less predictable, flow often slows or stops completely. This is the biggest factor determining the performance of aircraft systems.

Simple operational considerations effect ground-spread vehicles, for example starting and stopping in the correct position in small paddocks can be significant. The effect of slope is difficult to mitigate.

The effect of particle size distribution in respect of the proportion of small particles <0.5mm, which either tend to drift or do not spread, is considered, in both situations.

ANALYSIS OF MATERIAL FLOW FROM TOPDRESSING AIRCRAFT

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In order to improve the predictability of material flow from an aircraft the flow characteristic of these materials needs to be better understood. If a higher level of spreading accuracy is to be achieved then discharge from the aircraft must be controlled precisely. This works well for products such as urea which are free-flowing. Other products such as agricultural lime can be problematic. These products have cohesive strength and this means that their flow behaviour is much less predictable. This creates two problem, poor control of application rate (inaccurate spreading) and possible danger to the pilot and aircraft because the product bridges in the aircraft hopper.

The Civil Aviation authority have a regulation that requires an aircraft to jettison 80% of its load in 5 seconds. A range of agricultural limes were tested and none were found to be capable of achieving this requirement. This is a serious safety issue for the industry.

The agricultural products spread have been subject to testing in order to estimate their likely flow behaviour. The Walker Carr shear cell was found to be the most appropriate analysis tool to characterise these products.

In order to achieve free flow conditions with these products they require modification. The simplest modification that proved effective was the removal of fine particles. This had the effect of reducing the particle size distribution which is important in reducing the packing density and cohesive strength. This was also achieved by only having particles within a narrow particle size range, by removing the fine particles the cohesive strength was reduced and the materials were free flowing.

Although this can be done there is clearly a cost involved, the industry is already struggling with reduced demand and any increase in cost is likely to be unwelcome even though it could help to save pilots' lives and improve the quality of spread achieved.

IN-FIELD METHODS OF COLLECTING CROP REFLECTANCE DATA

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A number of new tools are being introduced to commercial agriculture for in-situ measurement of growing crops. In their main commercial applications the reflectance data gained from these tools is used to assess the need for nitrogen fertiliser. Used in conjunction with decision support systems they allow agronomists to make better decisions that allow efficient use of nitrogen and yield maximisation.

Within this work three sensors have been used to collect in-field crop reflectance data. Comparative maps have been developed on some sites to look at the consistency of these individual sensors. For field measurement the sensors have been mounted either on the sprayer tractor or the spray booms. Four Crop Circle Sensors have been used over either a 24m or 32m bout width, two Crop Spec sensors mounted on the spray tractor cab were used and up to eight Greenseeker sensors mounted over a 24m boom.

The sensors are slightly different in design, they have a different measurement footprint and the wave lengths they operate at are also slightly different. They all have at least one sensor channel in the visible (VIS) band and one in the near infrared. This allows a normalised difference vegetation index (NDVI) or simple ratio (SR) to be calculated.

The sensors were found to give broadly consistent results when whole fields were mapped. Farmers buying decisions are likely to be based on the level of support offered to users, pricing, ease with which the information from the sensors can be used and supported. Within the scope of this work only the sensors themselves were tested.

pH MAPPING USING THE VERIS pH DETECTOR

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Soil acidity, measured by pH, varies spatially within paddocks therefore customising lime inputs can help maximise farm profitability by optimising inputs and reducing the likelihood of lime over or under application. Standard laboratory based methods for measuring soil pH are expensive ($50 + GST per soil sample, Ravensdown) and therefore restrictive to intensive sampling. A sensor based pH detector would cut chemical costs and provide a rapid method of taking multiple geo-referenced samples in the field.

The Veris Mobile Sensor Platform uses an antinomy based pH detector sensor that is operated from an ATV, the unit consists of pH probe, pH detector, data logger and GPS unit. The unit is hand operated and has an easy push mechanism that inserts the pH probe 75mm into soil. This triggers the unit to record and log a geo-referenced pH reading. Cleaning of the pH probe is done automatically when the probe is lifted out of the soil ready for the next sample to be taken.

The purpose of this initial experiment was to determine if the system would work in dairy pasture and establish the in-field variability of pH on two New Zealand Dairy farms. VRA lime map was produced using the portable Veris Mobile Sensor Platform on Massey No.1 Dairy Farm and Niaruo Farms, Fraser Road, Hawera (NZ Topo Map Stratford 260 – Q20 238917). Variability of soil pH was determined by obtaining pH readings, with their respective GPS coordinates, every 20m on transect lines which are 20m apart. The pH points were added as a layer on Geographic Information System (GIS) program where Interpolation function was used to create a VRA lime map

The main results show that soil acidity detected from the Veris Mobile Sensor Platform varies within paddocks and the interpolated surface shows pH variation. The concept of VRA can increase the efficiency of lime inputs by targeting soil pH variation within paddocks. Ground conditions did create difficulties for the pH detector and some modification is required for reliable operation.

WHEN MORE REALLY IS MORE….!

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Ravensdown Fertiliser Coop, Pukekohe

Fertiliser applications historically have being relatively 'uniform' in rate and type such that soil fertility could be expected to be uniform across the farm. In reality this is never the situation for many reasons including soil type, topography, animal behaviour, paddock history, fertiliser spreading patterns. With, current costs of fertiliser relative to farm returns, pasture performance in relation to soil fertility should be maximised as the most economic use of fertiliser dollars. This can be achieved by quantifying the variability of soil fertility across the whole farm, by soil testing all or many more paddocks than usual, so that differential rates of fertiliser/lime can be applied. This will allow either increased productivity in low fertility areas where appropriate and financial savings where less or no fertiliser may be required. Farmers have become more interested in intensive soil testing given the high cost of fertiliser recently. In the dairy industry, there has been good progress in applying different types and rates of nutrients to dedicated farm effluent blocks. In the sheep and beef sector some small inroads have been made in applying different nutrients to differing slopes and topographies. The results of whole farm soil testing from 15 case studies are shown and the resulting variable rate fertiliser regimes are presented for two farms.

FUEL USE REDUCTIONS THROUGH THE USE OF PRECISION AGRICULTURE: REDUCING THE FOOTPRINT OF FARMING

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Within the LandWISE Advanced Farming Systems project, several focus farmers are implementing controlled traffic farming techniques. The aim is to separate crops (gardens) and traffic (roads).

Interestingly, both broad acre maize and intensive fresh vegetable farmers are experiencing similar fuel savings of over 50% by adopting controlled traffic farming. Reasons for fuel saving include avoiding soil compaction and associated remedial tillage costs, as well as having lower rolling resistance on formed traffic lanes.

On the maize case study farm, the technique adopted is standard controlled traffic farming. All operations are based on 12 row bouts (9m), except spraying which is 36 rows (three bout widths). The wheel track is set around the harvester's three metres. So traffic areas represent only about 11% of the field area. With traffic and compaction greatly reduced, no-till maize is viable. Where compaction is experienced (mainly in headland areas) strip tillage is used as required.

On the fresh vegetable case study farms, growers are developing permanent bed systems. While the beds may still be cultivated between crop cycles, the wheel tracks are being maintained. Thus the heavy draft, energy intensive aspects are avoided.

A very simple spreadsheet has been prepared to assist farmers to estimate fuel use under alternative cropping regimes. The tool has been tested by case study farmers and found to reflect the magnitude of fuel consumption variation they have experienced.

At present the tool allows only the schedule of operations to be varied, so savings reflect avoided operations or use of lower energy demand operations. Further development would allow recognition of reduced draft and reduced rolling resistance once controlled traffic is established.

This work is funded by LandWISE, the Sustainable Farming Fund, FAR and industry sponsors.

LandWISE distribute information in protocols, articles and via the web, we also host regular field events and an annual conference for farmers and others in May each year. Visit the website www.landwise.org.nz for information on successful precision agriculture, membership or upcoming events around NZ.

QUANTIFYING SOIL CARBON SEQUESTRATION IN KIWIFRUIT ORCHARDS: DEVELOPMENT OF A SAMPLING STRATEGY

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In offshore markets there is growing concern that many existing land management practices for food production are releasing additional carbon into the atmosphere thereby contributing to greenhouse gas emissions. If it can be demonstrated that in New Zealand the production of perennial fruit crops such as kiwifruit can enhance or maintain carbon storage then this may allow greater differentiation of our products in environmentally concerned markets such as Europe.

Currently, there is no standard methodology to verify any claims of carbon storage in kiwifruit orchards. One of the objectives of a current SFF project is to develop a robust sampling protocol to quantify soil carbon stocks (SCS) in kiwifruit orchards.

Our hypothesis was that the depth distribution of SCS will be different in ‘young’ and ‘old’ kiwifruit orchards and that the vine row and grass alleyway have to be separately sampled. We identified two blocks that are representative for many kiwifruit orchards in the BOP on a property in Te Puke. The soil is a typic orthic allophanic soil with a loamy texture. One of the blocks was established 10 years ago (‘young’) and the other 25 years (‘old’) ago. The blocks are besides each other and have the same soil type and climate, and receive the same management. We sampled the SCS of each block from the soil surface to 1 m depth in six depth increments.

These were our key results:

(1) The ‘young’ kiwifruit block stores about 139 t C/ha and the ‘old’ one about 145 t C/ha to 1 m depth.

(2) With a maximum sampling depth of 0.5 m there was no significant difference between the SCS in row and alley.

(3) We found a CV of 5-15% and, therefore 4-10 cores are needed to have at least 80% confidence in the estimated SCS.

(4) We recommend separating each core from the top to the bottom into the depths 0-0.1, 0.1-0.3, and 0.3-0.5 m for a general inventory.

(5) We could detect a weak spatial pattern of the SCS only for the ‘old’ kiwifruit Block.

EFFECT OF CONSERVATION TREES ON THE CHEMICAL, BIOLOGICAL AND PHYSICAL PROPERTIES OF TWO HILL COUNTRY SOILS IN HAWKES BAY

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The value of trees for the stabilisation of soils in hill country pastoral land is well recognised. However, there is considerable uncertainty around how trees affect pastoral soil quality, and the difference to soil quality that may be contributed by different tree species. Willow (*Salix* spp) is an introduced deciduous tree commonly planted on unstable slopes to minimise erosion and therefore maintain pasture production. Kanuka (*Kunzea ericoides*) is an endemic evergreen species that is seldom planted on pastoral land, but often exists in remnant patches or as reversion growth on steep, less productive areas of pastoral blocks promoting slope stabilisation. In addition to soil stability, trees may improve soil quality through the influence of canopy and roots. This study compared soil chemical, physical and biological properties at various distances from conservation trees on a hill country farm in the Hawkes Bay region.

Sampling was conducted along two transects across a pastoral slope of similar gradient containing conservation trees. One transect included two Willow trees with the other including two Kanuka trees. Soil samples were taken along each of the transects at depths 0-10 cm and 10-20cm at various distances from the trees between 0.5m and 10m for the Willow transect and 0.5 and 12m for the Kanuka transect.

The soil properties assessed were bulk density, soil water content, dehydrogenase activity, total carbon and nitrogen content, C:N ratio, hot water extractable carbon and nitrogen content, and mineral nitrogen content. In addition, the degree of hydrophobicity was measured using the molarity of ethanol droplet test (MED) and the water droplet penetration times (WDPT) test. A field method for testing the occurrence of preferential flow triggered by a hydrophobic top soil was also trialled.

Preliminary analysis of the results indicate that dehydrogenase activity, labile carbon content and water repellency decreased with increasing distance from both Willow and Kanuka trees. Total carbon and nitrogen content, labile nitrogen content, and mineral nitrogen content decreased with increasing distance from Kanuka trees but do not change significantly with distance from Willow trees. C:N ratio was not significantly affected by distance from either tree species.

GROWING BIOMASS FOR SUSTAINABLE BIOFUELS IN A CLOSED-LOOP NITROGEN SUPPLY CROPPING SYSTEM FOR USE ON MARGINAL LAND

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Abstract: This paper describes a novel energy crop production system that reduces greenhouse gas (GHG) emissions both by fossil fuel substitution and by virtue of its closed loop nitrogen (CLN) supply feature. The system will be used on marginal lands (defined as part of the research), where these energy crops will not compete with intensively grown food crops. New non-woody plant types with high nitrogen (N)-use efficiency in combination with legumes are being trialled for their potential to produce biomass in sustainable rotations not requiring external N inputs. N needs of crops on these marginal lands will instead be met with the residual N from processing biomass to biofuel.

A key element of the CLN system is the conversion of biomass into biogas using anaerobic digestion (AD). This is the only conversion technology that captures the energy in the biomass but conserves the mineral nutrients. Having a gas rather than liquid fuel is not a great inconvenience considering it is superior in all other respects. Biomethane can be liquified if desired. In addition to fuel substitution, this system will replace some manufactured N fertiliser via return of enough biogas digestate to supply the energy crops with supplemental N if needed, while leaving a surplus to provide to food crops. This unique feature to recycle nutrients back to food crop land makes biomass cropping sustainable. It also makes it possible to use high N-requiring crops such as maize and sorghum, the highest DM producers among annual crops. Since biogas digestate is safe for food crops this also enables those manures and industrial/urban wastes deemed unsanitary for direct use on food crops to be processed first in the digester.

Uptake of this new sustainable energy crop production system will increase the value of marginal land and sustain rural and Maori communities with a secure, affordable source of fuel.This will have increased future importance as the area of marginal land is predicted to increase following climate change.This integrated system with evident rural benefits (once proven) will have applicability in many countries.

SOIL-BASED EVALUATION OF LABILE ORGANIC CARBON AND ITS ROLE IN NET SOIL MINERALISATION RATES WITHIN KIWIFRUIT ORCHARDS

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The N-mineralisation process is driven by factors influencing microbial activity in soil; these factors are soil temperature, moisture and soil carbon.

Seasonal fluctuations of labile organic carbon from two conventionally managed blocks were compared from a Te Puke Research Orchard. Soils were sampled monthly over 12 months from two blocks; irrigated Hort16A vines and non-irrigated Hayward vines. The monthly samples were evaluated for mineral N and soil microbial activity, measured using dehydrogenase assay, in addition for labile carbon.

Also samples of intact soil cores from Te Puke were used for the seasonal evaluations and the rate of N-mineralisation, given variable temperatures and moisture. Lastly, soil evaluations of contrasting management strategies (conventional verses organic) but soils of the same series and similar textures were compared.

Mineral-N levels were higher at 150-300 mm and 300-450mm soil depths within the non-irrigated Hayward in comparsion to the irrigated Hort16A. These differences may be influenced by vine activity at sampling time, as the Hort16A vines were further advanced in regard to canopy development, thus likely better uptake of the mineral-N available. Gravimetric water content was similar between both, so increased leaching of the irrigated block is not a likely explanation for the difference in mineral-N. There was no significant difference in labile carbon between both. Microbial activity was reduced with profile depth and there appears to be a reduction in time also. This drop in microbial activity may be linked to drop in soil moisture content as the season progresses, especially within the top 0-150mm soil layer. A strong statistical relationship was observed between soil dehydrogenase activity and soil labile C concentrations within any given time over the three sampling depths.

Within Kaharoa ash soils, organically managed orchard blocks demonstrate higher labile carbon and higher overall microbial activity than that observed from conventionally managed systems.

BIOFUMIGANTS
− ADDING VALUE TO COVER CROPPING?

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Leaving soils fallow between vegetable crops can result in a significant loss of soil condition, particularly during winter when the risk of erosion is greatest. Identifying cover crop options that fit well within existing rotations is therefore very important to growers, as is their profitability. Annual grasses and cereals are often favoured because they are cheap, quick to establish, easy to manage and winter hardy. However, many other cover crops such as biofumigant mustards can offer additional soil conditioning benefits, including improvement in soil quality and control of soilborne diseases, pests and weeds. The objective of this trial was to quantify the short-term benefits of three different cover crops, annual grass (‘Moata’) and two Caliente mustard blends (ISCI 99, Nemat), on soil quality. This on-farm study was conducted during the winter of 2009 on a clay loam soil at a site in Horowhenua. The three cover crops were compared in a fully replicated experiment against the grower’s standard fallow approach. Cover crops received no fertiliser or chemical inputs during the winter and were incorporated according to best practice in September 2009. All cover crops produced comparatively small amounts of above-ground biomass (2.8–3.5 t DM/ha), reflecting the late sowing date; 5−8 t DM/ha is not uncommon for Caliente mustards. Below-ground root biomass was highest under `Moata’, 2–3 times higher than under either of the mustards. A basic total N balance (crop N + soil mineral N to 60 cm) at incorporation confirmed large differences in the amount of N that was in each system (73 kg N/ha in the fallow control compared to 131−157 kg N/ha in the cover crop plots). N lost below 60 cm is of little value due to shallow rooting depths of many vegetables. The cost of the lost soil N alone under fallow conditions was about $100, while the cost of the cover crop seed was between $100 and $200. Aggregate stability improved under cover crops compared to the fallow control, but there were no large differences between the cover crop options. It is important to note that improvements in soil condition can be quickly undone by poorly timed or excessive cultivation in the following crop. In the short term, cover crops offer measurable benefits compared to leaving soil fallow during winter. The residual soil biofumigant benefits for the subsequent vegetable crop are currently being assessed.

THE EXTRACTION OF MINERAL-N IN SOIL – REDUCTION OF THE CONCENTRATION OF KCl AS EXTRACTANT

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Mineral forms of nitrogen (Min-N) are currently measured in soil by utilising a 2 M KCl solution to extract NH_4^+ and NO_3^- from the soil. Min-N is the sum of NO_3^- and NH_4^+. It is generally regarded that NO_3^- can be easily extracted from soil using water; where as for NH_4^+ this is not the case. Potassium chloride (2 M) is used as the extraction solution, as papers in the 1960s found that 2 M KCl extracted maximum amounts of NH_4^+. Potassium chloride (2 M) was further advocated as it worked best with their method of choice; steam distillation.

Automated colorimetric techniques are now used in the lab more than steam distillation. With these automated instruments, 2 M KCl can give rise to problems, including directly interfering with the indophenol determination of NH_4^+. Varying concentrations of KCl, (DI water, 0.01, 0.1, 0.2, 1 and 2 M KCl) found that concentrations above 0.1 M KCl extracted maximum amounts of Min-N.

An experiment was conducted where 100 dried soils and 100 field-moist soils were analysed for min-N in duplicate at 0.1 and 2 M KCl. The dried soils ranged from 0.5-63, 0.2-116.2 and 3.1-179.2 mg kg^{-1} for NH_4^+, NO_3^-, and Min-N respectively. The average difference (± 1 SD) attributable to changing the method for the dried samples was -1.0 ± 1.2, -0.1 ± 0.0 and -1.0 ± 0.2 mg kg^{-1} for NH_4^+, NO_3^-, and Min-N respectively. The field-moist samples ranged from 0.8-13.6, 0.3-116.4 and 1.6-118.6 mg kg^{-1} for NH_4^+, NO_3^-, and Min-N respectively. The average differences (± 1 SD) were 0.0 ± 0.4, -0.2 ± 0.7 and -0.3 ± 0.8 mg kg^{-1} for NH_4^+, NO_3^-, and Min-N respectively. The negative biases suggest that 0.1 M KCl extracted slightly more on average than 2 M KCl.

THE DETERMINATION OF SOIL pH
– REDUCING EXTRACTION TIME FROM 16 H TO 1 H

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Currently the measurement of soil pH for advisory purposes involves the addition of water to the soil sample and left to stand overnight (16-20 h). This method is slightly modified but is based on the method by the Soil Bureau of New Zealand and refers to studies conducted in the 1960's using a two-electrode system to measure soil pH. The reason for leaving it overnight was for the soil particles to settle. This enabled a stable reading to be obtained as the electrode response drifted if there was not a clear supernatant. However, technology has improved, and electrode drift with short settling times is no longer an issue.

A study of 500 soils, including sedimentary, ash, pumice and peat were measured in duplicate at different standing times for soil pH. It was found that no significant difference was found between 1 and 4 h, but a small difference found between 1 and 20, and 4 and 20 h standing times. The difference was highly variable but not soil type dependent. The average difference between 1 and 20 h (± 1 SD) was found to be -0.04 ± 0.12 pH. A second experiment was conducted which found the change was largely microbiologically induced, due to leaving the slurry to stand for long periods of time under anaerobic conditions.

We conclude that the 20 h soil pH is an inferior method to the 1 and 4 h tests, as most of the difference was due to microbiological activity. For the vast majority of soils, the results are the same as for the 20 h equilibration. The literature also suggests that New Zealand is one of the only countries that perform an overnight standing period.

THE DIAGNOSIS AND CORRECTION OF POTASSIUM DEFICIENCY IN NEW ZEALAND PASTORAL SOILS: A REVIEW

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Field-trial data from a database comprising records of 804 potassium (K) fertiliser trials were used to define the production functions relating exchangeable soil K (Quick Test K (QTK) 0-75 mm) to the relative response to fertiliser K applications, for the major soil groups in New Zealand. For all soil groups for which there was sufficient data, the production functions were generally flat in the range QTK 5 to 10, and thus the estimated relative pasture production at QTK 5 and QTK 10 were similar. The critical QTK levels to achieve 97% maximum production were relatively well defined for the Sedimentary soils (Brown and Pallic soils) and the Brown soils being 6 (5-8) and the Pumice soils 7 (5-10). The data for the Allophanic soils was unstable and the best estimate was 6 (5-10). For the remaining soils groups, for which there was much less data: Podzols & Raw soils, Organic, Recent and Gley soils, the relationships were essentially flat over the range QTK 2 to 10. The probability of pasture responses to applied K increased as soil QTK decreased from 10. For the Sedimentary and Volcanic soils (including both Allophanic and Pumice) the probability was about 70%-80% at soil QTK < 2. The comparable probabilities were 50-60%, for the Recent and Gley soils, and 30-43% for the Podzols and Raw soils. A feature of the response functions was that some trials were not responsive to fertiliser K despite having low soil QTK. In most cases this could not be attributed to soil K reserves as measured by the soil TBK test (sodium tetra-phenol-boron extractable which measures exchangeable K plus plant available but non-exchangeable K). Other possible reasons for this feature in the data are discussed including, uptake of K from below the soil sampling depth and the temporal effects of clover responses to applied K.

WATER FOOTPRINTING: MAPPING FROM DIRECT WATER USE TO INDIRECT WATER USE IN NEW ZEALAND

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In 2002, Professor Arjen Hoekstra introduced the concept of water footprinting to assess and compare the direct as well as indirect water used to support human activity in different regions of the world. The water footprint has three main components, the green water footprint (use of rainfed soil stored water), the blue water footprint (use of water harvested from surface and groundwater storages), and the grey water footprint (the amount of water required to dilute polluted water to an acceptable standard). It is generally expressed in the terms of volume of freshwater use per year, and could be calculated of a product, individual, business, community, region or a nation.

Traditional water use statistics in New Zealand report on the volume of water allocations and withdrawals for different activities, but not on the actual water use related to the goods and services consumed by the inhabitants of the nation. Water footprinting can provide statistics indicative of the actual water use, its sources, and water self-sufficiency or dependency, opportunities and risks for New Zealand. Degrading water resource quality is of a great concern in New Zealand. The green and blue water footprints indicate “water dependency”, and the grey water footprint indicates the “water care” aspect of water use. A better understanding of the water footprints of different products, businesses, communities and regions within New Zealand would be very useful to identify the hotspots of water use, to optimize production and economic benefits from limited freshwater resources, to ensure equitable and efficient water allocation, to set quantitative water use targets to protect environmental flows and water quality, to explore alternate and future water use scenarios, and to inform freshwater policy formulation and virtual water trade with other countries.

Water footprinting could also highlight the comparative advantage of New Zealand, blessed with plenty of freshwater resources. This is particularly important in the context that future primary production investments could be attracted towards the areas or regions with lower and sustainable water footprints of primary production systems. Today’s investment in reducing water footprints would pay off by attracting primary production industry investments in the future.

REDUCING THE PRODUCTION FOOTPRINTS OF HORTICULTURAL PRODUCTS - [1] WATER FOOTPRINT

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The Economist (18 September, 2008) asserted that "… the world is facing not so much a food crisis as a water crisis'. Farming uses 70% of the world's water consumption and there is a pressing need to make it go further, by developing knowledge and tools to monitor water-use efficiency. ***The Economist*** concluded that "… farming tends to offer the best potential for thrift". The concept of virtual water and water footprinting seeks to achieve such thrift

Virtual water is the volume of water used to make a product, and is the sum of the water use in the various steps of the production chain. Virtual water consists of three components: the green water which is rainwater stored in soil and transpired by the plant, the blue water which is the water drawn from surface and groundwater reservoirs and irrigated onto soil to maintain transpiration, and the grey water which is the leachate that becomes polluted by nutrients and pesticides during production.

We have evaluated the virtual water content of the older-style, *Splendour* apples grown on large trees, and compared this to apples from smaller high-density plantings of *Braeburn* trees on dwarfing root stock. We found the virtual water contents to be 10.0 and 6.5 L/apple for apples from the larger and smaller trees. Thus, the apples from the newer cultivar, when grown under modern orchard practices, have a smaller water footprint. Furthermore, we arrive at much lower figures for the virtual content of apples than that listed by FAO of 70 L/apple for Californian conditions. This lower value is because of the lower evaporative conditions here in New Zealand, but primarily because of the higher yields per tree that our skilled growers can achieve.

The world's water can be best utilised if products that have high virtual water contents are sourced from countries that have available water resources, by countries whose water resources under greater stress. It is of global value for water conservation that apples be sourced from New Zealand, for not only can we produce them with a smaller water footprint, we do so without placing stress on our own water resources.

Along with carbon footprinting, there is a drive for primary production systems to move towards practices that minimise the wasteful use of natural resources, such as water. Reducing the virtual water content of our food products will increase the eco-efficiency of our food production systems, and through eco-verification of the water footprint we can enable the premium pricing of our products to the world's increasingly discerning retailers and consumers.

DEVELOPMENT OF A WHOLE ARABLE FARM IRRIGATION SCHEDULING SOFTWARE PACKAGE

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Ensuring crops are fully watered helps maximise yield and quality. Applying more water than required to maximise production means excess water is pumped, increasing energy and labour costs. There is also increased risk that nutrients will leach as water moves through the soil profile. Also, if regulations restricting the quantity of water available to growers become reality it will become more important to optimise the use of irrigation. With the increasing pressure on farmers to use water efficiently, decision support tools that assist growers' irrigation management are needed.

There are two main methods for scheduling irrigation: soil moisture meters and the soil water budget. Soil moisture meters are expensive if they are placed in all paddocks and may not account for variability across a paddock and do not assist forecasting timing of the next irrigation. This paper reports on the development of an irrigation scheduling software tool. The software can schedule irrigation for multi-paddocks, accept imported weather data, has the ability to input actual soil moisture measurements and gives the date of the next scheduled irrigation. The tool also calculates the potential economic loss from not irrigating a particular crop to help prioritise irrigation when there is insufficient water.

THE IRRIGATION CALCULATOR FOR TREE AND VINE CROPS

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Irrigation supports the biological basis of our productive economy and currently comprises about 75% of the nation's consumptive water use. Hence it is vital that irrigation is used wisely and on the basis of need. Our freshwater resource is precious and finite. Tools to monitor, audit and predicting crop water use are needed to help create the maximum economic benefit from our finite water resources. In addition, international sustainability standards for water use are being developed and our farmers will increasingly need to show that their use of water is sustainable.

Plant and Food Research and HortPlus are collaborating in a Sustainable Farming Fund project to develop *CropIR_Log*, an irrigation calculator for tree and vine crops. The 'Irrigation Calculator' is a software tool to help growers schedule irrigation to their tree and vine crops based on local values of evapotranspiration and rainfall that are accessed via a web-based interface. This software combines HortPlus tools to access real-time climate, plus a 10-day forecast, with Plant and Food's crop modelling to provide on-line irrigation recommendations for orchardists and viticulturalists.

The calculator has a graphical interface to show the seasonal patterns of soil moisture, rainfall and irrigation, plus deep drainage beyond the depth of the root-zone. Targeted soil-moisture deficits across the growing season can be entered into the calculator in order to mimic a preferred irrigation strategy. Different crops on the same property can also have a tailored water management strategy that minimizes unproductive water use. With this new tool growers can devise their irrigation in a way that can be benchmarked throughout the growing season.

The Crop_IR-Log tool utilizes local soil properties as well as calibrated crop-factors for apples, kiwifruit, summerfruit and wine grapes. These crop factors are being derived from sap flow measurements in the tree and vine stems over the course of the growing season. In this paper, results from *CropIR_Log* are compared with data from experiments where the soil water balance has been measured using arrays of time-domain reflectometry (TDR) probes and drainage flux meters. These comparisons, and some fine-tuning, are very important to provide growers with high quality recommendations.

REDUCING THE PRODUCTION FOOTPRINTS OF HORTICULTURAL PRODUCTS – [2] CARBON FOOTPRINT

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"Carbon footprinting" (CFP), estimates the total volume of GHGs emitted in carbon dioxide equivalents across the entire life-cycle of a product. For example, a CFP analysis of apples determines the total volume of GHGs emitted by one kg of apples grown and packaged in New Zealand, transported to the United Kingdom, and sold and consumed there.

In some markets, consumers and retailers demand sustainability credentials for the products they buy, and the CFP serves as an eco-verification. The continuous reduction of the CFP is important for sustaining premium prices for New Zealand's 'clean green' export products. Changes in practices along the supply chain of a product that reduce the CFP may also save energy, reduce inputs or increase productivity, helping industry find areas where they can save costs and at the same time promote their stewardship for the environment.

We have designed reduction options for the CFP of various horticultural export products: a tray of kiwifruit, a kg of apples, a bottle of wine and several berryfruit products. For devising reduction options we recommend proceeding in four steps. (1) Identify the CFP hot-spots from the results of an LCA analysis. (2) Identify the processes (e.g. fuel use in orchards) causing the hot-spot. (3) Assess the feasibility of the reduction option(s) considering such factors as verification ability and costs. (4) Securing support from the industry - for example, to package wine in Tetra Pak containers instead of glass bottles is a feasible reduction option but the NZ wine industry did not support it for marketing reasons.

The reduction options are either an optimization of existing processes, a modification/substitution of existing processes, or an increase in productivity.

Implementing reduction options along a supply chain is a highly multidisciplinary task. A critical step is estimating the cost-benefit ratio or payback time of reduction options, over industry sectors ranging from orchards to shipping. This is crucial information for industry buy-in. Unfortunately for many reduction options there is little published information, and a detailed calculation of the costs and benefits is beyond the scope of typical CFP projects. We suggest creating a database of common reduction options that contains both the typical GHG reduction potential and their associated costs and benefits or payback periods.

SMALL FOOTPRINTS AND THIN WALLETS – IMPLICATIONS FOR SHEEP AND BEEF FARMERS

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Sheep and beef farmers remain apprehensive about the impact and cost of climate change and green house gas emission policies and initiatives on their businesses.

To build sheep and beef farmer understanding of GHG emissions on-farm, focus groups have participated in farm systems modelling using existing tools (Farmax and OVERSEER) based on farms in the King Country and Wairoa. The current farm business has been modelled, together with several alternate scenarios with the potential to change the total or intensity of GHG emissions.

A high productivity King Country property with existing forest and bush blocks was modelled. Several scenarios, which included the use of nitrification inhibitors, changing sheep and cattle policies and use of summer fallow were modelled. These management options all had a small impact on total GHG production, ranging from a reduction of 463 tonnes CO_2-e to an increase of 302 tonnes of CO_2-e which equated to around 10% of the whole farm emissions. Each of these scenarios posed potential challenges including the very high cost of nitrification inhibitors and sensitivity of any stock policies to purchase and sale prices.

The Wairoa farm was a developed property with average animal and per hectare performance and significant (15%) forest and bush blocks. Nitrification inhibitors were predicted to reduce whole farm emissions by 6% but this was not economically feasible. Increasing sheep numbers and decreasing the beef cow herd increased GHG emissions by 252 tonnes but substantially reduced the intensity of emissions.

Both studies also considered historical (1990) with current level GHG emissions and confirmed that intensification of production systems and improvement in flock production efficiency have resulted in reduction of the level of livestock GHG emissions per hectare and per unit of production by between 10% and 18%.

Management policies can have a significant impact (about 10%) on GHG emissions while maintaining or enhancing profit. Some scenarios result in an increase in total emissions but a lower level of intensity of emissions.

THE ADVANCED FARMING SYSTEMS PROJECT: TECHNOLOGY FOR REDUCING THE FOOTPRINT OF FARMING

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LandWISE's Advanced Farming Systems project seeks to co-ordinate and disseminate learning about precision agriculture in the vegetable and arable cropping sectors. The project is focused around twelve farmers from Auckland to Canterbury. Each is integrating GPS and associated tools into their operations to improve their economics and take better care of land and water.

To accelerate and share learning, LandWISE is collaborating with FAR and linking with precision ag groups in New Zealand, Australia and Europe.

High accuracy GPS is now mainstream in cropping. Farmers are using the technology to guide and control machinery, collect spatial data, reduce inputs and improve yields. RTK GPS makes mechanical weeding within centimetres of the plant viable, with dramatic labour cost savings. Farmers are adopting implement correction for increased accuracy. GPS controlled booms shut off individual boom sections or nozzles, eliminating overlap, chemical waste, impaired crop growth and spraying sensitive areas.

Several focus farmers are implementing controlled traffic farming to separate crops and wheels. Avoiding soil damage and costs imposed by remedial tillage is giving fuel savings over 50% for fresh vegetable and maize growers. GPS guided earthmoving is levelling sand country to extend efficient irrigation systems and reduce soil moisture variability.

The farmers identified crop and soil sensors as opportunities for further gains. They are investigating these to define zones within paddocks to better use water, fertiliser and seed.

LandWISE is preparing protocols for successful precision agriculture. These allow for easier extension of precision agriculture and serve as an in-cab reminder of the steps for successful work with GPS and other precision agriculture tools.

This work is funded by LandWISE, the Sustainable Farming Fund, FAR and industry sponsors. LandWISE distribute information in protocols, articles and via the web, we also host regular field events and an annual conference for farmers and others in May each year. Visit the website www.landwise.org.nz for information on successful precision agriculture, membership or upcoming events around NZ.

USING MAIZE TO MANAGE DAIRY SHED EFFLUENT – MAXIMISING THE MARGIN AND MINIMIZING THE FOOTPRINT

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Intensive dairying generates significant volumes of nutrient-rich shed effluent (dairy shed effluent, DSE). This is often applied to pasture where it can increase the risk of environmental loss (leaching/runoff) where management is poor, applications are excessive or farming systems have intensified. Stock health problems (Mg deficiencies/milk fever/staggers) may result. Opportunities exist to mitigate such impacts through the strategic use of maize silage crops. These include: 1) growing maize silage to mine DSE nutrients from high fertility soils, and 2) using DSE as a nutrient source for crops grown on nutrient-depleted soils. In 2007 a 3-year project was initiated to explore these opportunities. Preliminary results were presented at the FLRC conference in 2008 with the latest results reported here.

Seven Waikato-based trials have now been conducted over two seasons to investigate the ability of maize to mine nutrients (N in particular) from high fertility soils. All paddocks had been in long-term pasture and had a history of regular DSE application or very high stocking rates (up to 7 cows/ha). All trials to date have shown that maize can be successfully grown without additional N fertiliser inputs in these situations. This is due to very high N mineralisation rates in these soils. Crop N removal in unfertilised plots ranged from 229 to 337 kg N/ha, which helps to reduce potential leaching risks during subsequent winters. Possible cost savings to farmers are high ($1350/ha, based on 2008–09 fertiliser prices). This excludes application costs. Two new trials are currently underway to investigate how long this benefit lasts after the first year of cropping. Data recently collected at these sites indicate that the soil is still generating enough N to meet crop demand compared to fully fertilised plots. Final silage harvests will be made in March to confirm these observations.

Two separate Waikato trials conducted last season investigated the potential of DSE as a nutrient source on nutrient-depleted soils.

Collectively, these trials are highlighting the potential to use maize crops to maximise the margin and minimise the footprints associated with intensive dairy farming. To support adoption, comprehensive best management practices for growing maize silage on dairy farms have recently been compiled in an industry publication that is available from project partners (Foundation for Arable Research, Dairy NZ and Environment Waikato).