Understanding the Carbon Footprint in Farming Systems

NEW ZEALAND NUFFIELD FARMING SCHOLARSHIP TRUST

A Report to the

New Zealand Nuffield

Farming Scholarship Trust

Craige Mackenzie

2008

Contact Details

Craige Mackenzie
Greenvale, 337 Reynolds Road
R D 6 Ashburton
New Zealand 7776

P +64 3302 8753
M +64 2179 6092
E cmackenzie@farmside.co.nz

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Understanding Carbon Footprints within Farming Systems

"*Understanding and managing the carbon footprint on farm will become critical in maximising the potential of New Zealand's agricultural sector, both economically and environmentally."*

Craige Mackenzie – Nuffield Scholar 2008
FAR Climate Change Workshop, Ashburton June 2008

Executive Summary

Climate Change has become one of the crucial issues of the early 21st Century. Pressures are increasing on agribusinesses to reduce carbon emissions. This drive for change is coming from an international level, not just nationally. The Intergovernmental Panel on Climate Change (IPCC), established in 1988 by the United Nations, has played a huge part in turning our attention to the concerns surrounding climate change. More recently in May 2008, the European Union adopted a report calling for carbon foot-printing labels on all goods and services. Recently UK supermarkets have adopted programmes which offer incentives to their growers if they join and achieve good scores in whole farm carbon footprint assessment.

New Zealand has a unique emissions profile with the agriculture sector the largest source of emissions, very unlike that of other developed countries. They make up almost half of our total emissions and have been rising at close to 1% per year since 1990. No matter what happens with the Kyoto Protocol or our national Emissions Trading Scheme (ETS), New Zealand needs to prepare for a world where cost will be associated with greenhouse gases (GHGs). The current global credit crunch may have an impact on the timeframe but it is likely only to delay the inevitable – GHGs will be a cost to New Zealand's agriculture.

The aim of this study was to analyse some of the different factors that could have a substantial impact on a New Zealand farmer's ability to undertake GHG mitigation strategies on-farm.

To gain an understanding of on-farm carbon footprints I narrowed my focus to include

- **Carbon management models** and their influence on N_2O and CO_2 levels
- **Biochar** and what role it might play in New Zealand
- **Irrigation efficiency** and what changes we can make
- **Precision agriculture** – its role in minimising our carbon footprint

Conclusions

Carbon Models

- Access to an accurate Carbon Calculation Model, providing farmers with knowledge of how their emissions relate to their current farming practices will be of a huge benefit in helping them understand what changes they might be able to make to reduce GHGs. Overseas research would suggest carbon sequestration is obtainable; this should be measured and included in carbon calculators. All carbon calculation methods appear to have inherent inaccuracies; thus it is important that farmers are rewarded for the best practice and not on exact outcome - modelled or measured.

- Under current legislation it is proposed that farms be assessed on their emissions with all the accounting done on inputs, with assessment done on the potential amount of carbon that can be stored through good farming practices. For any management purpose, regulatory or otherwise, CH_4 emissions need to be related to stock levels. An individual stock unit produces CH_4 no matter what their production level. CO_2 and N_2O emissions however should be related to production levels. The purpose of an Emissions Trading Scheme is to encourage effective utilisation therefore it would appear that any tax would need to be on a proportional basis, e.g. kg urea in/tonnes product out.

- In any carbon management system, be it regulatory (ETS/Carbon Tax, Regional Authority/Government) or advisory (on-farm calculator), farmers need to be recognised for best practice. One size does not fit all. It is important to have the right drivers for efficient production and environmental management. If through an ETS or Carbon tax, farmers are to be taxed on their inputs, they should also be credited for the amount of product they produce to encourage better management of carbon on farm. If there is no incentive provided for efficiency gains, I believe that the uptake of future beneficial technologies could be impaired. New Zealand is a world leader in agricultural production because of its efficient farming systems. As a country we can’t afford for this to change.

- To date in New Zealand there has been limited assessment of GHGs using eddy covariance towers and other sophisticated methods. If we are to advance in our understanding of GHGs we need to be utilising this technology across all agricultural sectors in all their related systems (irrigated/non irrigated, no-till cultivation/conventional cultivation, high input/low input) and across a spectrum of climatic and soil conditions in order to obtain an accurate assessment of our emissions. This continued validation needs to be in collaboration with international research organisations as well as leading New Zealand farmers to ensure the best systems are identified. It is pleasing to note that this collaborative approach is being promoted by Government through their Climate Change National Greenhouse Gas Inventory Research Grants but I believe this could be extended further.

Irrigation

- Issues of water demand and supply differ little in New Zealand from the rest of the world. Irrigation plays a very important role in helping to maximise carbon sequestration and minimising GHG emissions through increased yields. With substandard application it can also play an extremely negative role causing leaching of nitrogen in the soil, resulting in polluted waterways.

- A changing climate will mean greater extremes in climatic events, e.g. longer droughts, bigger storms. Irrigation is about filling the holes between the rainfall events. As climate change has an increasing effect on New Zealand then irrigation will become more crucial, and possibly more widespread, as we try to manage those gaps in rainfall. This is where water storage becomes vital. There are many wise heads in New Zealand currently looking at our storage and delivery needs regarding irrigation water. I don't think I need to enter the debate – suffice to say that storage provides reliability, and reliability is essential.

- Irrigation delivery systems need to be as efficient as possible, ensuring that value of water as a multi-use resource is recognised. Examples of good practice include the Opuha Dam Ltd in South Canterbury with enhanced waterways, power generation and recreational facilities, and the recent installation of the Ashburton Lyndhurst Piped Irrigation Scheme in Mid Canterbury. The latter has piped and pressurised irrigation water to 3600 ha (previously delivered in open ditches) to give a 27% saving in water. This water saving has been utilised on previously un-irrigated land. Benefits to the wider community are the elimination of energy requirements and increasing carbon sequestration. These and similar initiatives need to be replicated elsewhere.

- Excellence in irrigation design is extremely important due to the potentially huge saving to be made in both energy and water use. Irrigation NZ Inc, with support from the MAF Sustainable Farming Fund (MAF SFF), has recently released an Irrigation Code of Practice and Irrigation Design Standards. This Code is an excellent document in that it provides a framework as to industry-acceptable design levels, although it is purely advisory. With such large on-farm investments being made by farmers in irrigation systems it would appear beneficial to have a method for measuring a system's suitability for purpose. This should help to ensure that the most efficient systems are being installed, as well as helping the farmer with the decision making process prior to purchase.

- Being an efficient irrigator is not just about buying the biggest and best machine and calling it done. It's about matching land to the most suitable machine. While as farmers we may not be able to control the storage or delivery options of our irrigation water, we can take full responsibility for which system we use to apply the water on farm and how efficiently we apply it. Effective on-farm management is about ensuring that the irrigation machine is operating to its optimum level. Irrigator auditing, still in its infancy in New Zealand, is the only way to achieve this. Auditing can result in significant energy and water savings with the potential of increased watering ability – this needs to be actively promoted. Farmers also need to be more involved in the monitoring of pasture and crops, matching their water requirements to the water available.

Biochar

- Biochar may have a huge potential for aiding carbon sequestration. The attention given to it by Government is warranted. Further research of its potential benefits to New Zealand is essential. Issues of production, transportation and quality will need to be addressed.

Precision Agriculture

- Precision Agriculture (PA) plays an essential part in the reduction of GHGs. PA has progressed from Global Positioning (GPS) and pretty maps to the broader stance of using the **right** input, in the **right** amount, in the **right** place, at the **right** time and in the **right** way. The acceptance of all 5 R's will ensure that New Zealand farmers are maximising PA to its fullest potential, enabling them to operate in the most efficient, environmentally sustainable manner possible. The greater understanding of the farm environment that comes through the use of this advanced technology will enable the farmer to make decisions based on specific facts rather than assumed cause and effects. The efficiencies gained by using GPS and other PA technology could be a very quick way to make some significant progress in the reduction of agriculture's GHG emissions. PA technology is being used to a much higher degree in many other countries than here in New Zealand. It is time for us to play catch up.

Education & Technology Uptake

- Greater emphasis needs to be placed on the ways to enhance technology uptake. We have a lot of good science out there waiting to be utilised at farm level but there is a long time lag before new technology or methods are accepted on farm. The challenge to government, research groups and industry leaders is to find ways to help change farmers perceptions. The argument that many farmers have for not utilising new technology is the perception that the cost-saving benefit of using such technology is outweighed by its difficulty of use, lack of trust in the results and a lack of time to learn the skills required to best utilise the technology. An improved uptake of new technology will be achieved by ensuring that farmers have access to easily understandable information, enabling them to better accept the benefits of integrating the technology into their farming systems.

- All the tools and technologies in the world are useless without the knowledge to use them effectively. Education of users is essential. While we have some well-trained support personnel in both the Precision Agriculture and Irrigation sectors, there is a considerable lack of numbers and depth of expertise in servicing what has become an integral part of New Zealand farming. There has been an exponential growth in these fields over recent times, more particularly in irrigation, and it would appear that too often there has been a push for sales without the educational support to back it up.

- We need agricultural courses at our universities to include a greater focus on irrigation and PA as they are areas that will provide many of the answers to our GHG issues. It will be the current generation with the responsibility of taking agriculture forward in the coming decades. We need innovative and passionate young people to extend the horizons in the use and understanding of both water and PA.

- With the huge increase in irrigation in recent years there are many farmers who would benefit from further education in irrigation efficiency and crop monitoring. Empowering farmers with the knowledge of how many mm of water is required/kg of the product they grow, be it grain, milk, meat or fruit, will assist them in making decisions on where they should use their water based on the most sustainable practices and best economic return. Some NZ farmers are leading the way in aspects of irrigation efficiency but the uptake of best practice could be improved greatly across the sector.

General

- In comparison to farmers in many overseas countries, New Zealand farmers are very conscious of their role as custodians of the land, monitoring their inputs and managing their businesses in an environmentally acceptable manner. As many New Zealand farms are intergenerational businesses those operating the farms have a vested interest in the long term sustainability of their properties and the resources required to operate them.

- Internationally, there is currently no silver bullet to solve agriculture's GHG issues. New Zealand's desire to have significant mitigation measures in place by 2013 is extremely ambitious. Much work is being done both here and internationally on ways to reduce GHGs but the time frame may not be achievable. New Zealand needs to ensure there is a collaborative approach to all research being undertaken. We need to find out what mitigation is possible and what can be realistically achieved.

Recommendations

- **Government and Research organisations** to ensure a collaborative approach to all research being undertaken.

- **Government and Industry** to actively promote increased educational support personnel in the fields of Irrigation and Precision Agriculture (PA).

- **Universities** to include a greater focus on Irrigation and PA in Agricultural courses.

- **Government and Research organisations** to actively promote the formation of an independent organisation to provide pre-sale irrigation assessment and on-farm irrigation auditing.

- **Government, Research organisations and Industry leaders** to place greater emphasis on communicating the benefits of new technology, ensuring that farmers have access to easily understandable information.

- **Farmers** to take greater responsibility for their gaps in skill level.

While away on my study tour I had the privilege of visiting the WWI battlefields of the Somme and the Ypres Salient. At Ypres I stood in the trenches of Sanctuary Wood Farm and remembered the huge sacrifice that previous generations made. I'm sure each soldier often questioned the importance of their involvement, but still they fought believing it would provide a better future for their families. Managing Climate Change is to be the war of our generation. The steps we all take, individually and as nations, will all play a significant part in the outcome we achieve. The implications of failure look pretty significant.

GREENHOUSE GASES OVERVIEW

"Carbon is the C in Conservation"

Don Reicosky, ARS- USDA, Morris Minnesota

To gain an overview of the whole Greenhouse Gas/Climate Change/Carbon Emissions story my first visit was to the National Centre for Atmospheric Research (NCAR) in Boulder, Colorado. NCAR is the centre of climate recording in the US and also the official US Government Climate Change modelling facility where climate models from throughout the world are tested and validated. Here, scientists studying the changing nature of the global climate say they have completed one crucial task - proving beyond a doubt that global warming resulting in climate change is real. Their task now is to gain a greater understanding of the effects that global warming will have on the world and what/how mitigation measures can be used to manage or reduce these effects.

Climate is weather, averaged over time - usually a minimum of 30 years. Regional climate means the average weather trends in an area. Global climate, an average of regional climate trends, describes the Earth's climate as a whole. NCAR's Climate and Global Dynamics Division of the Earth and Sun Systems Laboratory conducts broad-ranging research on all aspects of climate. With data from the climate modelling they have undertaken, scientists predict that climate will be more extreme in the future. The greater the land mass, the greater the extreme events. Therefore the Northern Hemisphere is likely to be more affected because of its greater land mass. Results from this modelling are also showing a sharper rise in temperature than in the past.[1]

These days, when global climate is mentioned, conversations usually go straight to climate change. Global climate change, whether it involves higher or lower temperatures, more precipitation or more droughts, is mainly the result of planetary warming. Since 1900, the Earth has warmed about 1°F (0.7°C). Regionally the effects of this warming vary. For instance, scientists contributing to the 2007 International Panel on Climate Change predict changing precipitation patterns and retreating glaciers in Latin America, higher crop productivity in high-latitude regions, and sea level rise along coastal regions.[2]

My visit to NCAR was followed by a meeting with Dr Keith Paustian of Colorado State University, who is co-ordinating lead author of the IPCC Good Practice Guidelines for Land Use, Land Use Change and Forestry, National Inventory Guidelines and also involved in the development of the COMET VR carbon management model.

Greenhouse gas estimates are based on international guidance established by the IPCC and follow an internationally agreed reporting format, reporting annually to the United Nations Framework Convention on Climate Change. The greenhouse gases estimated in the inventory include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs).[3]

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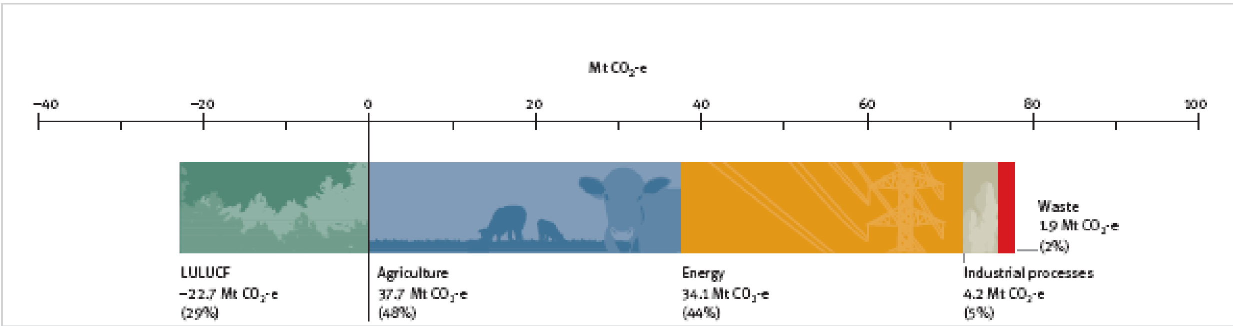
[1] *National Centre for Atmospheric Research http://www.ncar.ucar.edu/research/climate*
[2] *Intergovernmental Panel on Climate Change http://www.ipcc.ch/ipccreports/ar4-wg2.htm*
[3] *New Zealand's Greenhouse Gas Inventory 1990 – 2006 – An Overview. Ministry for the Environment http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-overview-apr08/html/page1.html*

To compare the warming effect or global warming potential (GWP) of different gases, all emissions are converted to carbon dioxide equivalents (CO_2-e). The standard measurement unit is 1 for carbon, and carbon is the least effective of the GHGs in trapping the earth's heat. Over a one hundred year time span methane's GWP = 21, and nitrous oxide's GWP = 310. Each GHG also has a life span, or time it remains stable in the atmosphere. The figures for carbon look somewhat benign in terms of its GWP, but things start to change when looking at carbon with regards to terms of life span. Scientists estimate that CO_2 remains stable in the atmosphere for anywhere between 50 and 200 years. CH_4 on the other hand, remains stable for only around 12 years, whereas the life span of N_2O reaches the 120 year mark.[4]

Globally, of all human activities, energy generation (25.9%) is the main GHG emitter, followed by industrial processes (19.4%) and forestry (17.4%) then agriculture (13.5%) and transport (13.1%).[3]

The agriculture sector is the largest source of emissions in New Zealand, contributing 48% (37.7 Mt CO_2-e) of total emissions in 2006. In other developed countries, agricultural emissions typically are around 12% of their national emissions with the UK agriculture at just 7%; their big contributor is transport at 27%.[3]

New Zealand's total greenhouse gas emissions by sector: 2006



New Zealand's Greenhouse Gas Inventory 1990 – 2006 – An Overview[5].

In New Zealand, agricultural emissions have increased by 16% (5.2 Mt CO_2-e) from the 1990 level of 32.5 Mt CO_2-e. By comparison Canada has seen an increase in agricultural emissions of 25%, while globally agricultural emissions have reduced 1.4% over this time. Despite the continued rise in absolute emissions, emissions intensity, the amount of GHG produced per unit of food produced, has been dropping and the emissions intensity of New Zealand agricultural goods compares favourably with that of other developed nations[6].New Zealand's agricultural sector produces enough food for approx 35 million people annually. Because of this New Zealand's greenhouse gas emissions, from ruminant stock in particular, are disproportionate to its relatively low population. In 2006 the agriculture sector contributed

[4] *United Nations Framework Convention on Climate Change http://unfccc.int/ghg_data/items/3825.php*

[5] *New Zealand's Greenhouse Gas Inventory 1990 – 2006 – An Overview. Ministry for the Environment http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-overview-apr08/html/figure-5.htm*

[6] *Greenhouse Gas Emissions from New Zealand Agriculture; Issues, Perspectives and Industry Response- M Leslie, M Aspin and H Clark*

96% (12.8 Mt CO_2-e) of New Zealand's total nitrous oxide (N_2O) emissions and 90% (24.9 Mt CO_2-e) of total methane (CH_4) emissions.[3]

According to scientists at NCAR, CO_2 that has been absorbed by the ocean over the past 100 years is set to be released as the oceans' temperatures rise. With the amount of CO_2 that is expected to be released, what we have today in the way of changing climate is what we should expect for the next 50 years. But what we do from today onwards will impact on what happens in 51–52 years time. Standing still is not an option. It's time to start looking at carbon.

CARBON MANAGEMENT MODELS

"Understanding the carbon balance of a business is a vital first step towards thinking about management decisions that may have some mitigating effect on climate change by reducing GHG emissions."

Country Land and Business Association, UK

Agricultural soils are often a source but can also be a sink of carbon dioxide. Regional and larger scale estimates of GHG emissions are usually obtained using simple spreadsheet calculations which are associated with high uncertainty. Carbon management models can be a very precise way of working out what is happening on farm and what steps can be taken by agribusinesses to increase carbon conservation measures.

The Models

Many countries are currently working on or have produced soil carbon models and carbon calculators to help manage agricultural GHG emissions. In discussion with researchers at Arhus University, Denmark, it was stated that the best models were those that had a C/H_2O/N relationship and included mitigation.[7] The following are some of the overseas models I saw.

COMET-VR Calculator [8]

The Voluntary Reporting of Greenhouse Gases-Carbon Management Evaluation Tool (COMET-VR) calculator is an on-line carbon accounting, decision support tool for agricultural producers, land managers, soil scientists and other agricultural interests. It is one of the most widely used models at the United States Department of Agriculture (USDA).

COMET-VR provides an access to a database interface containing land use data from the Carbon Sequestration Rural Appraisal (CSRA) using the CENTURY soil carbon model to provide estimated soil carbon differences resulting from changes in land management. Century is a generalised ecosystem model which simulates carbon (e.g. biomass), nitrogen and other nutrient dynamics. The model simulates management impacts on soil carbon, as well as the effects of land use changes between cropland, grassland and forest, and it calculates in real time the annual carbon flux.

Farmers using no-till, conservation tillage, improved grazing management or other conservation practices provide storage for carbon, thereby benefiting their farms and the environment. COMET-VR allows them to document their carbon changes and evaluate the impact of their management activities on soil carbon.

Once farmers have run COMET-VR and obtained a soil carbon sequestration value, they can register those values as carbon credits under the Voluntary Emission Reduction Registration Programme. Through this programme, carbon credits may become a traded commodity.

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[7] *Nick Hutchings, Co-Chair , Dept of Agroecology, Aarhus University, Foulum, Denmark*
[8] *National Resources Conservation Service (NRCS) USDA*

GRACEnet Model [9]

Greenhouse gas Reduction through Agricultural Carbon Enhancement network (GRACEnet) is a new research program initiated by the Agricultural Research Service (ARS) of the USDA. It is being used by 60-plus ARS scientists to look at carbon sequestration and GHG emissions across 30 sites in the States to measure the net emissions from agriculture. GRACEnet's geographical extent, use of common procedures, and cooperation with other North American carbon cycle research programmes should ensure that it has very good information to promote scientifically based carbon conservation technologies.

On a marketing front, information from a GRACEnet article was used to develop a carbon credit programme for the North Dakota Farmers Union (NDFU) in collaboration with the Chicago Climate Exchange.

DAYCENT Model [10]

DAYCENT model is being assessed by the USDA for delivering full energy audits and carbon accounting. The DAYCENT ecosystem model (a daily version of the CENTURY carbon model) and an emission factor (EF) methodology used by the IPCC were used to estimate direct and indirect N_2O emissions for major cropping systems in the USA. The EF methodology is currently used for the USA GHG inventory but it is thought that process based models, such as DAYCENT may yield more reliable results because they account for factors such as soil class, daily weather, historical vegetation cover and land management practices such as crop type, fertilizer additions and cultivation events that are ignored by EF.

Rothamsted Soil Carbon (RothC) Model [11]

This is a well established soil carbon cycle model developed at Rothamsted Research, UK which has been widely applied in different environments. Researchers in China, Japan, Australia, Switzerland and Denmark, to name a few, have all utilised the RothC model for research calculations. Due to its robust design the model is being used as the background programme for a variety of other carbon calculators.

CALM Calculator [12]

CALM is the first free business-based calculator in the UK. It shows the balance between annual emissions and carbon sequestration of the key greenhouse gases associated with the activities of individual land-based businesses. It follows the widely used IPCC methodology with the accounting guidelines approved by Government for business to understand, quantify and manage GHG emissions. The project has been endorsed by the UK Government's Department of the Environment, Food and Rural Affairs**.**

Cplan is another online whole farm calculator available in the UK. (www.cplan.org.uk).

Accurate data are essential in making a reliable carbon assessment tool. Internationally a lot of work is being done to monitor and measure localised emissions. New Zealand needs to follow suit rather than use internationally recognised defaults. We are in the process of developing carbon models and calculators with local data.

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[9] *Agricultural Research Service (ARS) USDA*
[8] *Global Scale DAYCENT Model Analysis of Greenhouse Gas Mitigation Strategies for Cropped Soils. ARS, USDA.*
[11] *Rothamsted Research, Harpenden, UK http://www.rothamsted.bbsrc.ac.uk/aen/carbon/rothc.htm*
[12] *Country Land and Business Association, UK http://www.cla.org.uk/Policy_Work/CALM_Calculator/*

Land Use and Carbon Analysis System (LUCAS) [13]

At a national level the Ministry for the Environment uses LUCAS to estimate New Zealand's soil carbon stocks and likely stock changes with changes in land-use (particularly afforestation with *Pinus radiata*). It is a statistical model based on IPCC default methodology. It uses actual soil carbon data from New Zealand soils, together with national spatial datasets of soil type, climate, land-use and topography.

Carbon Calculator for New Zealand Agriculture and Horticulture [14]

This is the first monitoring tool of its kind made specifically for New Zealand farmers and was launched in May 2008. It is a free web-based calculator, designed by Lincoln University's Agribusiness and Economics Research Unit (AERU) and engineering consultancy AgriLINK.

The calculator determines emissions from livestock, farm energy use and the use of fertiliser and feed, to arrive at totals for CH_4, N_2O and CO_2 emissions. These are then converted and expressed as total CO_2-e. The calculation requires farmers to enter basic data such as farm size, livestock numbers, fertiliser application, fuel usage and their contractors' activities.

Under a Dairy or Stock system scenario all inputs and the production either in milk solids or carcass weight is included at a farm level, but under Arable and Horticultural systems the model fails to include any of the production. It would seem important to include all this data to gauge efficiencies accurately. I am sure the Arable or Horticultural farmer is not just cultivating, fertilising and spraying for recreational purposes and the farmer would like to see it related to production levels. It would also be great if the model was to include carbon sequestration. Overseas research would indicate that carbon sequestration is achievable.[15] In the recent research by the USDA, results show that corn can sequester enough carbon in the four months that it grows to be carbon neutral, possibly because of the speed at which it grows and the amount of biomass it produces.[16]

Trials

Any model is only as good as the information that goes in. Ongoing research at a local level is essential for ensuring accurate outcomes. If the information that is put into these models is not accurate then they will not represent reality. Dr Tim Parkin[17] advised that some of the data that went into the early stages of our ETS with regard to N_2O were 300% overstated and has had to be reviewed to give accuracy. These figures came in as IPCC defaults, which shows that even the best scientists can't get it right all the time. Yet agriculture in New Zealand is not in any position to afford such inaccuracies.

Tillage

Some models have been set up using the assumption that no-till cultivation practices will have the least amount of emissions; however recent studies are now showing this to be incorrect over longer time spans. The Millennium trial run by Crop & Food Research and the Foundation for Arable Research at Lincoln, New Zealand, shows no difference between any

[13] *Ministry for the Environment, NZ http://www.mfe.govt.nz/issues/climate/lucas/index.html*
[14] *www.lincoln.ac.nz/carboncalculator*
[15] *Keith Paustian, Soil & Crop Science, Colorado State University*
[16] *Doug Karlan, Research Leader, National Soil Tilth Laboratory, Ames, Iowa*
[17] *Tim Parkin, National Soil Tilth Laboratory, Ames Iowa*

of the tillage practices trialled over a seven year period. This is similar information to that coming out of the USDA in the past year. Continuous cropping systems were able to store 20% more carbon in the soil compared to systems where there was a fallow period in the rotation.[18] Research is showing that the best practice is to use the most suitable tillage system for the crops being grown.

No-till cultivation practices have large N_2O losses when the soil is wet due to de-nitrification. Under no-till, half of the nitrogen is in the deep root zone so it is important to manage this to retain it in the profile. Nitrogen inhibitors may have a role in this situation. Slow release nitrogen is being tested but is not currently being used in any of the models.

Aarhus University are also running tillage trials looking at GHG emissions. These trials include looking at the corresponding yield and protein levels in grain. In other trials they have been studying different crops and their corresponding soil carbon storage potential. Trials have shown that perennial crops have an increased storage potential than other crops tested and that those with a deeper root system e.g. miscanthus and switchgrass, do so more efficiently.[19] These trials suggest that New Zealand's perennial ryegrass pastures might offer good carbon storage potential.

Fertiliser Application

To help minimise the amount of nitrogen that is applied it is necessary to grow a range of crops in a rotation where practical. If nitrogen-fixing crops are grown in the rotation then there is less reliance on synthetic fertiliser. Between 1% and 2% of the total world's energy is used to produce nitrogen-based fertilisers and associated products, and the IPCC default figure of 1% is used to account for N_2O from these products. Is this an accurate measure for N_2O losses within New Zealand agricultural systems? The amount of uptake of nitrogen by plants will differ according to management practices of individual farmers, i.e. application timing and rates, irrigation use etc., and the production level of the crop/pasture, since a higher yielding crop will utilise more N than a poor crop.

In Iowa, Minnesota and Nebraska traditional practices also dictate that nitrogen is applied to the fields in the autumn once the preceding crops have been harvested and fields are in a fallow state. This is due to the cropping rotation in the Corn Belt region where they either grow corn on corn or corn/soya rotations which means there are several months without any ground cover. The nitrogen is applied in an anhydrous form in autumn, the main reasons being the availability of staff immediately following harvest and the discounts given by fertiliser companies at that time of the year, primarily to assist their cashflow, but with what appears to be a disregard for sustainable land management practices. The practice of applying nitrogen when the fields are fallow increases N_2O emissions, because each time there is a rainfall event there is a flux of N_2O emissions and without any cover it is very difficult to control. When there is a lot of winter rain and snow followed by frost and then in the spring more rain and thawing ground, the negative consequences of applying autumn nitrogen are huge.

Organic and conventional farming systems had the same nitrate emissions regardless of the system but there were huge fluxes when organic fields were ploughed or deep tillage was done. Soil cracking is also proving to be a huge issue in regard to nitrate leaching and

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[18] *Neil Hansen Associate Professor , Soil and Crop Sciences, Colorado State University, Fort Collins CO*
[19] *Mette Laegdsmand, Crop Production, Aarhus University, Foulum Denmark*

potential N_2O emissions so the efficient use of irrigation can be beneficial to minimising this. Studies as Rothamsted Research, UK also show that soil cracking increases the potential of nitrate leaching.[20]

Nebraska and parts of Iowa have similar issues to Colorado regarding water quality with nitrogen levels as high as 26 ppm (parts per million) being found in the waterways. This nitrogen level is so elevated that it is taken into account as free nitrogen when nitrogen budgets are done under irrigation. Water is being applied at a rate of 25 mm/ha/pass of the pivot and in the calculation it is assumed that there are 15 kg N/ha/pass. This nitrogen is predominantly a leachate and run-off from cropping land.[21]

With the tributaries of the Mississippi River badly polluted with nitrates from both urban and rural sources, steps will have to be taken in the near future to mitigate this, especially as the Gulf of Mexico is now also becoming extensively polluted.

The USDA has some very good data and is doing ongoing trials to show what needs to be changed to achieve a significant reduction in agricultural nitrate pollution, but getting farmers to take up these changes is, and will continue to be a real challenge. Researchers need to demonstrate to the farmers how they can save money and increase yield to be able to make headway in this area. Trials in Michigan and Minnesota are showing that if a ryegrass cover crop is grown after the corn then N_2O emissions are significantly reduced. Once it is time to plant the following corn crop, glyphosate is applied and the field is either strip-tilled or no-tilled, ensuring most of the nitrogen is retained in the grass, reducing N_2O emissions and minimising the nitrate leaching. Currently, USA farmers are eligible for Federal Government payment of US$35 per acre to grow a cover crop to help reduce both, but farmers believe that there is a yield loss to the following corn crop through this practice so have not taken it up to any degree.[22]

Testing Systems

Eddy covariance and closed box testing systems used in the measurement of N_2O and CO_2 are being utilised by Michigan State University at the Kellogg Biological Station, Gull Lake, Michigan and also the USDA in Minnesota. The IPCC is planning to use data obtained from these testing systems in their inventory and accounting system for agriculture.

Photo above: chamber system

Eddy covariance towers and closed box systems are quite an accurate way for the testing of GHGs. Aarhus University are doing similar testing with a chamber system. Other systems used to test for emissions include lasers which can pick up a range of gases. These are currently used for checking for leaks in gas pipe lines.

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[20] *Keith Goulding, Head of Soil Science, Rothamsted Research, Rothamsted UK*
[21] *Derrel Martin, Professor of Biological Systems Engineering, University of Nebraska, Lincoln, Nebraska*
[22] *Jerry Hatfield, director, National Soil Tilth Laboratory, Ames, Iowa*

Photo to left: Closed box system

To the left is a closed box system, which takes four samples for analysis every four hours. Trials at Michigan State show in a wheat crop N_2O levels increased in relation to applied N, once N levels exceeded 110 kg/ha. Under the first testing regime with the closed box, de-pressurising the box to retrieve the N_2O for measuring caused N_2O to be sucked out of the soil resulting in overstated readings. To date trials with the closed boxes has failed to incorporate the testing of soil N levels. Therefore, their finding that 110kg/ha was the maximum level may not be correct due to the possible presence of high residual N in the soil. The variation in crop yield also influences the amount of N_2O released.

Photo to left: Eddy covariance tower

N_2O levels vary in a crop canopy between night and day, which indicates that the crop is actually recycling some of the nitrogen. In a corn crop in July there will be 1000ppm at night when respiration is low and only 280ppm during the day. Since this is the case it is important to test what emissions are actually coming out of the top of the canopy and this can be done with Eddy Covariance towers to test actual fluxes at different times of the day and under different climatic conditions. It would appear that after rain there is an increased flux of N_2O released from the soil but this is significantly dependent on the crop, ground cover and soil wetness as more N_2O is released from a saturated soil. Measurements in a crop are not always accurate due to the difficulties in obtaining readings. Some of the measurements may be taken from between the rows due to the inability to cover a row and record the data. In this instance the emission figures are calculated.

Conclusion

Adaptation

Through the Ministry of Agriculture and Fisheries (MAF), the New Zealand Government is funding research to validate some of the available models, inventory methodology and emissions. However, to date in New Zealand there has been limited assessment of GHGs using eddy covariance towers and other sophisticated methods. If we are to advance in our understanding of GHGs we need to be utilising this technology across all agricultural sectors in all their related systems (irrigated/non-irrigated, no-till cultivation/conventional cultivation, high input/low input) and across a spectrum of climatic and soil conditions to be able to create an accurate assessment of our emissions. This continued validation needs to be in collaboration with New Zealand's leading farmers to ensure the best systems are identified. We need to find out what abatement is possible and what can be realistically achieved.

There are many different models and it would seem that we should not necessarily try to reinvent the wheel by creating our own but instead work with international researchers and scientists to help validate work they have already done by trialling it in different environments here in New Zealand. It would seem logical that agriculture researchers around the world should be working together to create the most accurate assessment tools which could in turn help to eliminate potential trade barriers. It is pleasing to note that this collaborative approach is being promoted by Government through their Climate Change National Greenhouse Gas Inventory Research Grants [23] but I believe this could be extended further.

Access

Access to suitable Carbon Calculation Model providing farmers with knowledge of how their emissions relate to their current farming practices will be of a huge benefit in helping them understand what changes they might be able to make to reduce GHGs. Any calculator needs to include the ability to compare different management techniques. If farmers can be provided with the tools to show them how they can better manage their environmental impact while maximising their economic return, then this will aid in the quick uptake of other advanced technology.

Accuracy

Models should include carbon sequestration as well as with recording all the emissions output. At present farms will be assessed on the emissions with all the accounting done on inputs and there is no assessment done on the potential amount of carbon that can be stored through good farming practices. For any management purpose, regulatory or otherwise, CH_4 emissions need to be related to stock levels. An individual stock unit produces CH_4 no matter what their production level. CO_2 and N_2O emissions however should be related to production levels.

If farmers are to be encouraged to better manage their carbon account they should receive direct benefit. It would seem unfair, if one farmer was to apply 300kg of urea to light soils prior to a heavy rain event, causing nitrogen to leach through the soil and another farmer was to apply the same amount of nitrogen but through best practice applied it at the optimum time to ensure that all the nitrogen went to the plant rather than leaching, then for both farmers to be taxed the same amount. If there is no incentive provided for efficiency gains, I believe that the uptake of future beneficial technologies could be reduced.

All methods appear to have inherent inaccuracies. Therefore it is important that in any future ETS farmers are rewarded for the best practice and not on exact outcome - modelled or measured. New Zealand is a world leader in agricultural production because of its efficient farming systems. As a country we can’t afford for this to change.

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[23] *Ministry of Agriculture and Fisheries http://www.maf.govt.nz/climatechange/slm/gg-grants.htm*

BIOCHAR

"Black gold agriculture may revolutionize farming, curb global warming."

The American Chemical Society – April 2008

Overview

Two biochar professorships are being established at Massey University; one focuses on biochar and its behaviour in New Zealand soils, and the other on the processing of biomass feedstock into biochar, known as pyrolysis. It is another important step on the path towards New Zealand becoming a low-carbon nation.[24] The establishment of these professorships underlines the importance that our Government is placing on biochar as a possible solution to New Zealand's agricultural GHG emissions.

New Zealand's first biochar production system was launched in September 2008 by Carbonscape at its Marlborough plant. Initial production is expected to go to a research project at Lincoln University where soil scientists and agronomists will assess its effect in soil.[25] Farmers' interest in biochar is for both for GHG mitigation in soil carbon storage, but also as a possible feedstock for animal methane reduction.[26]

Internationally both the United States and Australia, along with New Zealand, have included biochar initiatives as part of their government climate change policy.

On my Nuffield study tour I had the opportunity to meet with Debbie Reed, Executive Director of the International Biochar Initiative (IBI), while in Washington DC. The IBI was formed in 2006 with the aim of promoting the research, development, demonstration and deployment (RDD&D) and commercialisation of technology of biochar production. Reed stated that the IBI were very interested in forming a collaboration with the New Zealand Government to advance biochar. I also met with David Laird, soil scientist with the National Soil Tilth Laboratory in Ames, Iowa and Don Reicosky, soil scientist with the ARS in Morris, Minnesota, who gave me a great insight into the rapidly developing field of Biochar.

Background

Biochar is a fine-grained charcoal high in organic carbon and largely resistant to decomposition. It is produced from pyrolysis of plant and waste feedstocks. As a soil amendment, biochar creates a recalcitrant soil carbon pool that is carbon-negative, serving as a net withdrawal of atmospheric carbon dioxide stored in highly recalcitrant soil carbon stocks. The enhanced nutrient retention capacity of biochar-amended soil not only reduces the total fertiliser requirements but also the climate and environmental impact of croplands. Char-amended soils have shown 50-80% reductions in nitrous oxide emissions and reduced runoff of phosphorus into surface waters and leaching of nitrogen into groundwater. As a soil amendment, biochar significantly increases the efficiency of and reduces the need for

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[24] *Former Agriculture and Forestry Minister Jim Anderton*
[25] *http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10534943*
[26] *The New Zealand Biochar Network, MAF SFF*

traditional chemical fertilisers, while greatly enhancing crop yields. Renewable oils and gases co-produced in the pyrolysis process can be used as fuel or fuel feedstocks.[27]

Trials

Trials with biochar are currently being undertaken by the National Soil Tilth Laboratory (NSTL) in Ames, Iowa, and are being run in conjunction with the USDA in Morris, Minnesota.

Quality

The quality of the biochar varies according to the material used and the benefits vary accordingly. Biochar can be made from raw materials such as pine trees or pine waste, chicken manure, turkey manure, corn Stover and any other plant material. Trials run by the USDA in Iowa show turkey manure char was having little effect on soil pH only moving it from 8.2 to 8.3 even though the pH of the char was 10.6, whereas the same weight of other high carbon content such as pine char, the pH moved it from 8.2 to 9.7. High pressure in the pyrolysis system limits the amount of carbon in the product.[28]

Application

In Iowa, biochar is being applied at rates from 11.8 t/ha to 20.2 t/ha for trials in year one[29] to be able to determine what might be the appropriate application rates and to find the best method for applying and incorporating the product, which is a very light and fluffy material. Currently it is being applied with a modified manure spreader.

N_2O Levels

Initial trials in Iowa have shown that soils with biochar as a soil amendment have a 10% decrease in nitrate leaching. A possible reason for reduced leaching is that it may slow down microbial activity within the soil, making the nitrogen less available in the short term. Major reductions in N_2O were recorded when biochar was added but it is early days and further trials need to be done at different sites. Biochar may also help with water quality in areas where water shed is an issue such as beside lakes and streams.[29]

CO_2 Levels and Carbon Storage

Initially biochar can increase the CO_2 released at the soil surface due to increased mineralisation. Again, in Iowa studies have shown that after one year 90% of the carbon was still in the soil as a very stable form of carbon. Continuous corn in a rotation showed a slight increase in carbon in the soil, soya was flat and alfalfa had a large positive effect on soil carbon. [29]

Burning of Crop Residues

Burning of crop residue can assist in maintaining soil pH. This is dependent on there being a large quantity of crop residue and it being burnt at a high temperature, effectively creating a form of biochar. Burning of crop residue is a beneficial management technique used on New Zealand's arable farms. Biochar needs to be made at temperatures between 200°C and 400°C depending on the raw material and at high pressure. It is possible to lose sulphur in the pyrolysis process but if it is kept under 400°C it should retain most of the carbon. Most

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[27] *The International Biochar Initiative. www.biochar-international.org.*
[28] *Don Reicosky, ARS- USDA, Morris Minnesota*
[29] *David Laird, National Soil Tilth Laboratory, Ames, Iowa*

crops have 20% of biomass under the soil surface hence some carbon storage regardless of what is done with the above ground residue.[29]

Liming

Agricultural liming has a huge footprint due to the carbon that is removed from the ground as lime and then spread onto the farmland. As this breaks down carbon is released into the atmosphere over a period of time. Fresh biochar retains calcium and magnesium and has a liming ability of about 25% of that of agricultural lime, but is much more stable.[29] Application of lime plays a very important role in New Zealand agriculture, ensuring that soil pH is at optimum levels for plant growth. It is possible that the use of agricultural lime will attract a tax in the future. Biochar may prove to be a very good alternative.

Conclusion

Integration

There are some possible drawbacks to the wide-scale adoption of biochar. It is a very light, bulky product and it is likely that fairly large tonnages would need to be applied to the soil to be of benefit. Finding ways to effectively and economically integrate biochar in the soil profile will be the first challenge.

Transportation

The second challenge revolves around the points of production and transportation. Biochar requires a large amount of biomass to produce a small amount of char. Having to source the biomass from too far a distance from the manufacturing plant could result in quite a high carbon footprint negating some of the potential benefits of biochar use. The transportation of biochar from plant to farmland may be equally problematic. A possible solution to this may be the installation of smaller, localised manufacturing plants or the creation of mobile plants that can be relocated to different areas when suitable biomass is available.

Research

Biochar as a modern day application is still in its infancy. Much research is still to be done before we really have a good understanding of how beneficial it may be. Further trials are underway overseas, the results of which are being released from this past season. Research-wise in New Zealand, work at both Massey and Lincoln is taking place. We need to get biochar in the ground for the coming growing season, with trial sites linked to lysimeters and eddy covariance towers run in conjunction with weather stations and irrigation trials, to assess its benefits here.

Biochar may not be the silver bullet that New Zealand is looking for but it looks likely to be an important tool for use in the war against climate change. The early signs are promising. I believe biochar definitely deserves the attention currently being given to it nationally.

IRRIGATION EFFICIENCY

"Irrigation efficiency is a key issue in the achievement of sustainable irrigated agriculture because maximising efficiency will significantly contribute to minimising the environmental impacts of water abstraction and drainage"

Ministry of Agriculture and Fisheries (MAF)

Overview

One of the major issues facing agriculture globally is the amount of water farmers will have access to in the future for production. Managing a limited resource through use of efficient delivery systems and irrigator design along with up-skilling farmers to better manage what water they have will result in a more competitive agricultural sector as well as providing significant benefits in reducing GHG emissions.

In looking at irrigation efficiency I visited the High Plains of the United States, location of the Ogallala aquifer. The entire Ogallala system underlies about 450,000 square kilometres of the eight states of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming. It is an unconfined aquifer with most of its annual recharge of 25 millimetres coming from rainwater and snowmelt. Because of the Ogallala, the High Plains is the leading irrigation area in the Western Hemisphere. Overall 5.5 million hectares are irrigated in the Ogallala region.[30]

The Ogallala aquifer is dropping approximately 600 mm a year in most areas with no significant recharge. The amount the aquifer is dropping is coincidently the same as the average annual application for irrigation throughout the region. One has to ask if this is a sustainable practice and what are the long term effects?

Water resource management in Colorado

Traditional management of the Colorado irrigation resource appears to revolve around keeping the soil profile as full as possible. With Colorado irrigation water there is a requirement that all the allocation is taken regardless of need. There are different levels of water rights with allocation used firstly by the senior consent holder (generally the most historic, of which some consents are up to 200 years old) and flowing through a minimum of three consented properties from its source to its final destination. This is achieved by applying an excessive amount of water and having it either drain through the profile or run off at the end of the fields. The excess water will then return to the original water source for subsequent water users. Once this water has returned to its source it is generally high in nitrates which have potential to pollute these water sources. As water levels drop the water users with the more recent water rights are restricted first.[31]

The combination of climate variability, drought, groundwater depletion and increasing urban competition for water has created water shortages for irrigated agriculture in Colorado and is driving the need to increase water use efficiency. A state-wide water supply survey predicts that 428,000 irrigated farm acres will be converted to dryland cropping or pasture within the next 15 years, mostly due to transfer of water from agricultural uses to meet the water needs

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[30] *http://en.wikipedia.org/wiki/Ogallala_Aquifer*

[31] *Neil Hansen, Associate Professor , Soil and Crop Sciences, Colorado State University, Fort Collins CO*

associated with population growth, with estimates that by 2020 there will be a 60% increase in population along the front ranges of the Rockies.[32] This will mean a huge increase in demand for the available water with choices having to be made between urban and agricultural use. If water is lost to agriculture and has to be used for other reasons such as urban growth, then the land in question will become a net emitter of carbon compared to its previous irrigated state. Who will pay the bill? Is the farmer responsible for this cost or is it the responsibility of the urban developers or dwellers? A shift from irrigated to dryland cropping would significantly impact the economic viability of agricultural producers and have far-reaching indirect effects on businesses and communities that support irrigated agriculture.

There is talk in New Zealand of putting a value on water to drive efficiency. At present the annual lease cost of irrigation water in Colorado is $400-$500 per acre foot. The sale price of the same water is between $10,000 and $15,000. To date this has not resulted in any discernable drive to create more efficient irrigation systems. Rather it has created a temptation to sell the water to municipalities for short term gain and at that point the water is lost to agriculture.[23]

Trials

Carbon Sequestration

Research at Colorado State University has shown that crops are successfully sequestering large amounts of carbon. Irrigated crops will sequester approximately 16 t/ha of carbon and store about 6 t/ha. A dry land crop will sequester approximately 15 t/ha but will only store about 2 t/ha.[33] So from an environmental point of view it is important that we use the water wisely and irrigate as much land as efficiently as possible to be able to maximise carbon sequestration.

Water Use Efficiency

Studies at Colorado State University have also shown that conservation tillage is giving an approximate 25% increase in the water use efficiency (WUE) of crops.

Limited Irrigation Systems

According to Dr Neil Hansen,[34] water conservation options other than complete land fallowing are desirable because of the potential economic and environmental concerns associated with conversion to dryland. One approach to reducing use of irrigation water is adoption of limited irrigation cropping systems. With limited irrigation, less water is applied than is required to meet the full evapotranspiration demand of the crop. Crops managed with limited irrigation experience water stress and have reduced yields compared to full irrigation, but management is employed to maximise the application efficiency of the limited irrigation water applied. These systems are a hybrid of full irrigation and dryland cropping systems and are currently of great interest to Colorado farmers. Successful limited irrigation systems are based on the concepts of: 1) managing crop water stress, 2) timing irrigation to correspond to critical growth stages for specific crops, 3) maximising water use efficiency by

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[32] *Colorado Water Conservation Board, 2004*

[33] *Keith Paustian, Soil & Crop Science and Natural Resource Ecology, Colorado State University, Fort Collins CO*

[34] *Neil Hansen, Associate Professor , Soil and Crop Sciences, Colorado State University, Fort Collins CO*

improving precipitation capture and irrigation efficiency, and 4) matching crop rotations with local patterns of precipitation and evaporative demand. Research in the Great Plains illustrates that limited irrigation cropping systems are significantly more profitable alternatives than dryland.[35] In addition to reducing water use, well managed limited irrigation systems can reduce the risk of deep water percolation and the associated leaching of soluble nutrients such as nitrate.[36]

At Colorado State University, Hansen is undertaking trials to demonstrate the difference between full irrigation and limited irrigation and at what stage in the crop development this has the biggest affect. Currently the most economic crop is alfalfa (lucerne).[33] This could prove to be particularly useful information for researchers and irrigated farms in NZ.

In one area of eastern Colorado a five year volume allocation has been introduced to help manage water use, and as a result the farmers involved have reduced the average application from 600 mm to 330 mm per year without any loss in production. This has been achieved by using the limited irrigation system advocated by Hansen.[37]

On-Farm Efficiencies

In much of Colorado inefficient irrigation techniques are used. Historical water rights are providing little incentive to install new and efficient systems that would better protect a limited water resource. Some of the reasons for the maintaining of these systems hinge around ensuring conservation values in significant but marginal flow waterways. Eastern Colorado has mainly centre pivots in operation, which are efficient for applying the water to the crops, especially given the sandy soil types there. But little soil moisture monitoring or budgeting is being done. Instead water is applied once the corn is planted and then is left running for the rest of the season, on the understanding that they will be unable to catch up if the soils get too dry. It is not uncommon to see pivots stuck, due to over-watering of the soils, as farmers attempt to keep up to date with irrigation. However the assessed water need is only an assumption as there is a lack of monitoring to back up the decision. Currently most farmers have an annual water right of 2 acre feet (1482 mm/ha) and are applying all of it. Water holding capacities (WHC) of soils here are very low and also have very low organic matter levels. These sandy soils have a WHC of 25 mm to 30 cm depth and about 10% of this available to the plant. With an annual rainfall of 300 mm there is a heavy reliance on irrigation water.[20]

Efficiency of irrigation is measured in production related to the amount of water used. In Eastern Nebraska and Iowa on average farmers are achieving 3900 lb of corn/acre (4378kg/ha), and 2460 lb of wheat/acre (2761kg/ha) for every acre foot (741mm/ha) of water applied. In metric terms this equates to 5.9 kg/ha of corn for every mm irrigation applied and 3.72 kg/ha of wheat for every mm applied.[38]

Interestingly, wheat production on some irrigated Canterbury farms is as high as 60 kg/mm of water applied.

[35] *Schneekloth, 1991 and 1995*
[36] *Neil Hansen, Associate Professor , Soil and Crop Sciences, Colorado State University*
[37] *Derrel Martin, Professor of Biological Systems Engineering, University of Nebraska, Lincoln*
[38] *Derrel Martin, Professor of Biological Systems Engineering, University of Nebraska, Lincoln*

Here in New Zealand research has shown that good design and management can be an effective way of managing energy costs and reducing related emissions. Many irrigators are operating more than 10% below the efficiency readily available with that irrigator. A 10% increase in efficiency by modifying an irrigator can equate to a 25% reduction in water use.[39] Good design can cut energy use by 18% and good management, such as matching application to soil moisture levels and scheduling, can cut energy use by a further 25%[40]

Conclusions

Issues with water demand differ little in New Zealand to the rest of the world. Irrigation plays a very important role in helping to maximise carbon sequestration and minimising GHG emissions through increased yields. With substandard application, it can also play a very negative role causing leaching of nitrogen in the soil, resulting in polluted waterways. Concerns regarding water quality and availability are reported in the media most weeks. Many researchers, scientists and farmers are looking at ways to better manage what is often regarded as New Zealand's premier natural resource.

Storage and Delivery

A changing climate will mean greater extremes in climatic events, e.g. longer droughts, bigger storms. Irrigation is about filling the holes in the rainfall events. As climate change has an increasing effect on New Zealand then irrigation will become more crucial, and possibly more widespread, as we try to manage those gaps in rainfall. This is where water storage becomes vital. There are many wise heads in New Zealand currently looking at our storage and delivery needs regarding irrigation water. I don't think I need to enter the debate – suffice to say that storage provides reliability and reliability is essential.

Delivery systems need to be as efficient as possible, ensuring that water's value as a multi-use resource is recognised. Good examples of this include Opuha Dam Ltd in South Canterbury with enhanced waterways, power generation and recreational facilities, and the recent installation of Ashburton Lyndhurst Piped Irrigation Scheme in Mid Canterbury to deliver pressurised irrigation water to 3600ha which had previously been delivered in open ditches. The Ashburton scheme has allowed a 27% saving in water. This water saving has been utilised on previously un-irrigated land. Benefits to the wider community are the elimination of energy requirements and increasing carbon sequestration.

Irrigation Design and Efficiency

Excellence in design is extremely important due to the potentially huge saving to be made in both energy and water use. Irrigation NZ Inc, with support from the Sustainable Farming Fund (SFF), has recently released an Irrigation Code of Practice and Irrigation Design Standards.[41] This is an excellent document in that it provides a framework for industry acceptable design levels, although it is purely advisory. With such large on-farm investments being made by farmers in irrigation systems it would appear beneficial to have an independent organisation to assess a system's suitability for purpose. This should help to ensure that the most efficient systems are being installed as well as helping the farmer with the decision making process prior to purchase.

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[39] *Foundation for Arable Research newsletter Issue No 53 March 2008*

[40] *Dan Bloomer, PageBloomer Associates, NZ*

[41] *Irrigation NZ Inc - http://www.irrigationnz.co.nz/media/CoP.pdf*

On-Farm Management

Being an efficient irrigator is not just about buying the biggest and best machine and calling it done. It's about matching land to the most suitable machine. While as farmers we may not be able to control the storage or delivery options of our irrigation water, we can take full responsibility for which system we use to apply the water on farm and how efficiently we apply it. Effective on-farm management is about ensuring that the irrigation machine is operating to its optimum level. Irrigator auditing, still in its infancy in New Zealand, is the only way to achieve this. Auditing can result in significant energy and water savings with the potential of increased watering ability - this needs to be actively promoted. Farmers also need to be more involved in the monitoring of pasture and crops, matching their water requirements to the water available.

Education

With the huge increase in irrigation in recent years there are many farmers who would benefit from further education in irrigation efficiency and crop monitoring. Empowering farmers with the knowledge of how many mm/kg of the product they grow, be it grain, milk, meat or fruit, will assist them in making decisions on where they should use the water based on the most sustainable practices and best economic return. Some NZ farmers are leading the way in aspects of irrigation efficiency but the uptake of best practice could be improved greatly across the sector.

While we have some well trained support personnel in the irrigation sector there is a significant lack of numbers and depth of experience in servicing what has become an integral part of New Zealand farming. There has been an exponential growth in this field over recent times and it would appear that too often there has been a push for sales without the educational service to back it up.

We need better courses at our universities that focus on irrigation. It will be the coming generation which has the responsibility to take agriculture forward in the coming decades. We need innovative and passionate young people to extend the horizons in the use and understanding of water.

PRECISION AGRICULTURE

"The right input, in the right amount, in the right place, at the right time and in the right way"

Prof Rajiv Khosla, Colorado State University
Organiser of the 2008 International Conference on Precision Agriculture

Overview

In New Zealand many farmers have seen Precision Agriculture (PA) as pretty maps and auto-guidance systems in tractors but it is so much more. The use of Global Positioning Systems (GPS) originally developed in the USA as a navigation and timing system for military applications, is the source of PA; however it has moved on to include many other technologies.

PA is based on the 5 R's, these being applying the **right** input, in the **right** amount, at the **right** time, in the **right** place and in the **right** manner. Put simply this means that whatever area of agriculture a person is involved in there is always some form of precision agriculture for their business. For some this may be dealing with livestock but with others this may be a cropping system. Some of these factors may easily be incorporated into a farming enterprise, but without all 5 R's taken into account PA is not being maximised to its fullest.

PA has been described as the art and science of utilising advanced technologies such as Global Positioning Systems, Geographic Information Systems, remote-sensing and information systems to enhance the efficiency, productivity and profitability of agriculture production systems in an environmentally friendly manner.[42] It covers areas as diverse as the more "traditional" spatial variability in soils and nutrient mapping and the "newer" applications such as remote sensing for nitrogen management to the emerging PA methods such as precision conservation, bio-fuels in PA and traceability.

It has been developed primarily in arable industries; but PA can relate to any agricultural production system. These may involve animal industries, fisheries and forestry and in many cases PA techniques are being put into practice without being identified as such, for example in the tailoring of feed requirements to individual dairy cows depending on production levels, the stage of their lactation, or other measured variables.

Advanced Technologies

The benefits of PA are being recognised by more farmers around the world as they see the many new applications that can be easily utilised on farm, enabling the farmer to grow a more economic crop by best utilising inputs to increase their efficiency. The resulting impact on the environment is beneficial while still maintaining high production levels to feed an ever growing population. The following are some of the advanced technologies I saw

Identifying Management Zones[43]

This is now being undertaken in parts of the US, using satellite imagery which recognises different soil types, crop colour-relating to N and evapotranspiration, topography etc, then

[42] *Precision Agriculture Programme, Colorado State University, http://www.precisionag.colostate.edu*
[43] *Rajiv Khosla, Precision Agriculture, Colorado State University Fort Collins Colorado, USA*

identifying the range of crop yields within the same field. Once this has been done it is then possible to set up the system to allow the farmer to utilise variable rate technology

After different management zones have been identified it is then possible to be able to take remedial action. This remedial action may be, for example applying cow manure from a neighbouring dairy farm to the areas that are unable to hold onto the nutrients due to low organic matter. This would reduce N application in some areas of the field because of already high N content.

Variable Rate Technology (VRT)
VRT should possibly be used to put higher inputs onto the best areas and the optimum on the lower producing areas so as to have a minimal impact on the environment. Further research is still needed to find out what these levels are. Yield maps are a useful tool but need to be used in conjunction with other technology such as soil testing and identifying management zones.

Greenseeker®[44] (and other similar systems that measure crop reflectance e.g. Crop Circle) is a tool that has been developed to measure reflectance of the crop. This information can be used to estimate how much nitrogen is in the crop and how it should be applied either as a variable rate application or to individual fields. Weedseeker®[35] is another tool that has been developed to be able to spray a crop using two spray lines on the one boom, turning on and off individual nozzles once a specific weed is sensed. Both of these technologies are in use in Australia and the USA.

Lasers[45]
Lasers are being developed to be able to measure the architecture of the canopy, measuring both height and density to calculate the amount of nitrogen that will be required by the crop. Once this technique is quantified then it will be possible to use on the front of a tractor and to send the information through a computer to the fertiliser spreader on the back of the tractor, and be able to apply accordingly.

Go Sensor[46]
Another piece of equipment being developed is an on-the-go sensor which has a tine that is pulled through the soil to measure pH, phosphate, nitrogen, moisture content, and carbon. This is still in the development stage in Denmark and the UK but is very accurate in trials to date. It has the possibility to either change an application "on the go" or map a field and then apply later the specific requirements by way of GPS application. The VIS-NIR is a similar tool developed in the USA.

Above Photo: Go Sensor Tine

[44] *Richard Chynoweth, Foundation for Arable Research, NZ*
[42] *Anton Thomsen, Precision Agriculture, Arhus University, Foulum Denmark*
[43] *Anton Thomsen, Precision Agriculture, Arhus University, Foulum Denmark, and Abdul Mouazen, Agricultural & Environmental Engineering and Natural Resources Dept, Cranfield University, UK*

Weedcast[47]
Part of PA is ensuring the cost effective use of all products available and one of the new technologies to aid this is the model Weedcast. It is being developed to forecast what weeds will emerge and when. This is done by using daylight and length, rainfall, irrigation maximum air temperature and location. A 10 day weather forecast can be included in the model to help predict what the likely issues will be. Information provided by the model will allow decisions to be made around obtaining the most appropriate control. At present there are over 20 weed species in the model. With this it will be possible be able to help manage resistance of weeds to chemicals. The benefit of this can be seen with weeds such as giant ragweed and water hemp, both of which are resistant to Roundup and ALS herbicides. This is a major concern when almost 75% of corn and 95% of soya bean being grown are now Roundup ready crops.

AmaizeN, Sirius Wheat Calculator and the Potato Calculator [48]
These are great examples of Decision Support Systems (DSS) developed here in New Zealand. One corn grower in Northern Iowa is using technology similar to the Sirius Wheat Calculator to grow his crop and has lifted yields from 225 Bushels/acre (15 t/ha) to over 300 Bushels (20 t/ha) with the same inputs, a significant increase in corn yield and also a sustainable practise.[49]

Conclusions

The application of Precision Agriculture is forging ahead in many areas around the world, but in many respects New Zealand appears to be lagging behind. In the past farmers here have probably looked upon the advanced technology as a toy or luxury item with applications only of benefit when farming large paddocks, but this must change. It is time for us to catch up with the rest of the world.

Efficiency Gains
Precision Agriculture (PA) plays an essential part in the reducing of GHGs. PA has progressed from GPS and pretty maps to the broader stance of using the **right** input, in the **right** amount, in the **right** place, at the **right** time and in the **right** way. The acceptance of all 5 R's will ensure that New Zealand farmers are maximising PA to its fullest potential, enabling them to operate in the most efficient, environmentally sustainable manner possible. The greater understanding of the farm environment that comes through the use of this advanced technology will enable the farmer to make decisions based on specific facts rather than assumed cause and effects. The efficiencies gained by using GPS and other PA technology could be a very quick way to make some significant progress in the reduction of agriculture's GHG emissions.

Technology Uptake
Greater emphasis needs to be placed on the ways to enhance technology uptake. We have a lot of great science out there waiting to be utilised at farm level. The challenge to Government, research groups and industry leaders is to find ways to help change farmers' perceptions. A lack of PA technology uptake in the UK has resulted in a recent study which found the argument that many farmers have for not utilising new technology; results showing their perception is that it is complicated to use, they have a lack of trust in the results and

[47] *Frank Forcella, ARS – USDA, Morris Minnesota*
[48] *Crop & Food Research, NZ and Foundation for Arable Research, NZ*
[49] *Jerry Hatfield, Laboratory Director, National Soil Tilth Laboratory, Ames Iowa*

lack the time to learn the skills required to use the technology. An improved uptake of new technology will be achieved by ensuring that farmers have access to easily understandable information showing the benefits of integrating these into farming systems.

Education

The ever increasing technology is only one part of precision agriculture. Without a conscious management effort and a proficient skill level for the technology the farmer is dealing with, all the tools and technology will be rendered useless. Suppliers of PA tools and technologies need to ensure that they are offering training as part of the sales package. However education also needs to be more focused at tertiary level, which should flow on to greater access for the farmer to more research-based rather than sales-based personnel. As with irrigation, we have a few well trained support personnel in the PA sector but there is a lack of numbers and depth of experience to provide the service required by the agricultural sector.

PART 2

GLOBAL FOCUS OVERVIEW

My personal study was broken up when I spent six weeks travelling on the Global Focus Tour (GFT) with ten other Nuffield Scholars from New Zealand, Australia and Canada. We visited many places, from a small Chinese farm of 7.5 Mu (half a hectare) using traditional farming methods of oxen and plough and hand harvesting rice and peanuts to sitting on Capitol Hill, Washington DC, with both Republican and Democrat senators, discussing the recently passed US Farm Bill; from a traditional French dairy farm milking 120 cows to the state of the art Hilmar cheese factory in Dalhart, Texas; from Sir Anthony O'Reilly's innovative beef stud in County Cork, Ireland to UK farms, whose main focus appeared to be on maximising the various government incentives/subsidies available to them. We met many farmers and industry personnel with a huge passion for agriculture. We gained an insight why others do things the way they do and, all the while, had our perceptions challenged. The sights we saw and the situations we found ourselves in all contributed to excellent, robust discussion, which lead to greater learning and understanding of global agriculture and New Zealand's place in it. These six intensive weeks spent on the GFT were a highlight of my year as a Nuffield Scholar.

The following is a snapshot of agriculture in 2008 throughout the world.

Beef Production

- **USA**

Cattle feedlots are under significant pressure mainly due to high feed stock prices which have risen on the back of the high oil prices coupled with lower beef returns. Most feedlots across the US were at levels of below 50% capacity and dropping with some empty. The exception to this was the large corporate operations which had a greater degree of control of the supply and distribution chains providing greater flexibility. It was quoted that on the whole most feedlots were losing approximately $200 per head and this looked set to continue with a lower forecasted beef price. The largest feedlot I saw contained 130,000 head of cattle.

Pork Production

- **USA & Europe**

Pork operations around the world are in a similar state of disarray and most in the USA are losing US$20 per head as a result of both high grain prices and lower pork prices. Many large scale operations are going out of business across North America and Europe. It could well be a time to invest in these industries as there may be a looming shortage of these protein sources.

- **China**

China produces 50% of the world's pork, almost all of which is grown in 1-2 pig units. It also consumes approximately 50% of the world's pork. They are particularly vulnerable to potential disease outbreaks due to their reliance on pork as a source of protein.

Dairy Production

- **USA**

There is a rapidly expanding dairy industry in some regions of the USA. In areas where the only option is to supply DFA dairy co-operative plants expansion is currently limited and prices were at the highest point they had been for some time, however the farmers were struggling to make a lot of profit.

DFA has been rationalising its business. It has closed several plants in the last couple of years that have been losing significant amounts of money. Reportedly, one plant in California was losing US$20 million per annum and the wholly owned subsidiary company American Cheese accumulated losses of US$40 million over the past five years. It was closed in January 2008. In the past two years DFA has exited 14 joint ventures and closed the two above plants.

DFA has a partnership with Fonterra in a company know as Dari Concepts producing high quality cheese and dairy powders, cheese concentrates, functional dairy replacement dairy systems and hard Italian cheeses. DFA was very happy with the relationship as it was getting a 15% return on capital which is the best of any of its joint ventures. DFA has been a supplier of fresh milk to the US market and has not had access to the world market. It was looking for an opportunity to access these, hence an alliance with Fonterra.

In Colorado farms that I visited were getting an average price of US18c/lb for liquid milk with the cost of production was approximately US16-17c/lb, so not a lot of profit in the system. Costs had risen by 5-6c/lb but that depended on the actual feed stock source. Some of the farms are close to ethanol plants or breweries where they have access to cheaper feed stocks. All feed is brought in to the open-lot type operations. Almost all farms are on a covered free stall system or in large pens holding up to 1000 head in a pen. One of the operations visited was milking 10,000 head of Holstein cows and were operating an 80 aside parallel milking shed, milking three times a day. All the calves were fed pasteurised milk to help avoid any infections at a young age.

By comparison in Texas there is a rapidly expanding dairy industry where a new cheese plant has been built serviced by 21 new dairy farms for the expected growth in the domestic cheese market. This plant is set to expand a further 300% over the next few years. One dairy farm will be built this year that will have 30,000 cows milked, and will also supply the Hilmar cheese plant.

- **China**

Dairy farming has come under the spotlight in China negatively in the past six months but this could still provided an opportunity for growth. There is a 15% increase in consumption per year at present, but the continued growth relies on their economy remaining strong and a desire to consume milk products which has come under pressure in the last few months. A milk promotion is being run using the media to show the benefits of pasteurised milk. The Guangshou Fengxing Dairy Company we visited is supplying 10-15 t of milk a day to schools to increase the standard of living. This is a national government initiative. Five years ago the milk production was at a level of 5kg /person/year and is now at 25 kg/person/year.

The Guangzhou Fengxing Dairy Company is the biggest in Southern China. They have control of the supply chain, which is probably their strength. They started buying in Australian and US cows in 2001 to increase production and milk quality and now have three farms with 5000 cows in total. These cows are producing 6500 litres milk/cow/year. Their biggest challenge is heat stress and growing high quality feed. Alfalfa hay is imported from the US to help in the diet. Feed is 60% of the cost of production. Local herbs are used for stock health issues at times. Cellmatic cell counts range from 300,000-400,000 maximum.

The milk price is at 4 Yuan/litre (NZ$0.57c) and the retail price is 14 Yuan/litre (NZ$2/l). The average wage for the workers is 100 Yuan/day (NZ$7/day) and the operation that was milking 1600 cows had a staff of 70 workers. Managers were on a wage of 15000 Yuan/ month (NZ$214/month).

They own and operate their own dairy factory to retain total control of the milk. They also have 25 stores where they market some of their products directly to the public. The plan is to put together another 24 units of 10,000 cows as the market grows. It is projected this will be possible within three years.

This factory is running at 40% capacity so that as consumer demand rises they have the ability to set up more farms and ramp up production in the factory to meet this demand. Most of the production is pasteurised Ultra High Temperature (UHT) fresh milk but they are also producing milk powder and yoghurt.

Arable Production

- **China**

Wheat production in China is split into three main areas and they operate quite differently. In the NW a large area is run by the army and in the NE the area is run by the Government and rest is farmed independently. 70% of the wheat production is near the Yellow and Huai rivers. The Government is very keen to increase the productivity of wheat production, running courses to help small farmers up-skill. These courses average around 60-80 attendees. A crop protection channel is run on television by the Government to educate the farmers on the latest agricultural issues.

Currently China is producing 100 million tonnes of wheat, and will store 65% of this and put it into the world market when it sees fit, meaning it could effectively, along with India, control the world market. Yields of wheat have increased from 1 t/ha in 1949 to 4.5 t/ha in 2007. Levels of subsidy for growing wheat are quite high compared to other parts of the world, at US$177/ha.

In China 50% of the barley is imported and is twice the value of wheat.

Rice production is now grown predominantly in the southern half of the country where there is a ready supply of water, until recently some of the rice has been grown in the NW but availability of water has become a problem and this area is now growing more wheat rather than rice.

Farmers in China are growing two crops of rice a year, both being planted with oxen and traditional techniques but the first harvest is done with a small combine harvester to speed up the harvest so the second crop can be planted as quickly as possible, because the latter half of the season results in a much longer growing period due to cooler conditions. The second crop is cut by hand. Combines are usually owned by the Government.

There is a range of crops grown from rice, white melons, sugar cane, peanuts and a huge amount of fruit. Some very large new fresh produce handling and trading facilities have been set up to be able to handle the produce and effectively get it to the markets.

- **United Kingdom**

Wheat yields in the UK have been static since 1994 and oilseed rape since 1998. Many of New Zealand's wheat varieties are sourced from the UK, but climate change may mean that in the future they will be unsuitable for New Zealand.

Alternative Energy Sources

There has been for the last couple of years a large amount of debate surrounding food versus fuel. There are also growing concerns relating to the large amounts of water required to grow corn for ethanol.

- **USA**

One bushel of corn (25.4 kg) will produce 10.8 l of ethanol and the remaining grain will be used as 10% of the total diet in either dairy or beef cattle. The price of the Wet Distillers Grain (WDG) is 85% of corn and DDG is 90-95% of the corn price. Only 10% of the feed value of corn is removed during the ethanol production system and then the remainder of the product is used in the feed industry either for dairy or beef cattle.

There has been an increase of plantings of corn and most of this has come from areas of set-aside land that has been returned to production and not at the expense of wheat area. Corn for flour is still grown in similar areas as before. Currently 30% of the US corn crop supplies 5% of their fuel needs. It looks unlikely to supply a large amount of the US fuel requirements in the near future.

Most corn is grown in a corn on corn rotation or in a corn/soya rotation. Corn area grown will be dictated by the price historically tracking the price of oil. As of 24 Dec 2008 oil was US$28 a barrel, a huge contrast to the price of US$147 in July 2008 making it very likely that the corn price will soften dramatically over the next few months. Wheat is also a product that tracks these two and has followed the corn price astonishingly closely for the past few years.

Many ethanol plants are slowing down in production. Some that were planned will not be built and others where building had started may not be finished - a result of the combination of high corn prices and now the lowering of the oil price. At some stage the world will have to come up with an alternative sustainable fuel supply and ethanol may be a good starting point. The cars we drive today are not the cars Henry Ford invented so the fuel we use today may not be the fuel we use in the future.

Cellulosic fuel is being investigated at length by many organisations. I spent some time with the USDA in Oregon which has developed a thermo chemical gasification reactor plant using ryegrass straw to produce either light diesel or electricity that can be either used on farm or the excess energy put into the national grid.

Oregon has a desire to be 25% self sufficient by 2025 with renewable energy. Hydro is not considered to be an option by the Oregon or Washington State Governments but is by California. Interestingly, California has little water of its own with which to expand its hydro power options.

Biomass from renewable sources such as straw and wood will be the primary sources Oregon's renewable energy. At present levels there will be 17 million tonnes available for the production and this will be sufficient for 8% of the United States power or fuel. It is thought to be possible to produce 20% of the required fuel supplies by 2030 but it will require one billon tonnes of material.

There is a pilot plant operating in Laramie, Wyoming which operates at 600°C to convert ryegrass straw into light diesel or electricity. This is a Thermo chemical process and it is gasification reactors which will then convert syngas into electricity. This will best operate at a farm scale as the transportation of the raw material will be too expensive to make it viable. There is 8% ash left which contains carbon, silicone and potassium. At present the process is running at 38% efficiency but they expect it to reach 50% efficiency when the next plant in Washington is commissioned.

If this is to be a viable option then all alternative sources of material will need to be explored. Hybrid Hemp may be a good option as it has a high lignin to cellulose content. With this raw material it may be possible to take the resultant bio-oil and remove the water and generate hydrogen gas to be able to produce bio-fuel. When making bio-fuel, the drier the better for the raw material. 10% moisture in the bio matter will increase the efficiency of the operation.

- **United Kingdom**

In the UK biofuels are not likely to be produced from oilseed rape as the cost of producing it is too high and the plants are not economic. Instead it is more likely that second generation fuel production will be the way that they go. Miscanthus is currently being used for energy production in one of the coal plants with very good success and very few emissions. The biggest part of the footprint is the transport of the crop to the processing facility. Once a crop is established requires no nitrogen and can be harvested for up to 10 years. Crop yields are as high as 20t/ha. However there is strong competition for land with crops for food production. It has been thought that it could be grown on land that is not currently suitable for crop production but it would not be very productive on this land type either.

DEFRA has produced some figures to suggest that there may be 30,000 ha of Miscanthus grown by 2020 and 50,000 ha by 2050. If this is the case then it will occupy 10-15% of the arable land in the UK and will put pressure on food supply.

The NFU is pushing for renewable energy used on farm to be a carbon credit.

GHG Emissions

- **Ireland**

Irish farmers appear a little more focused on GHG emissions and their potential implications than most other places that I visited. No farmers in France commented on GHG as being an issue.

Understanding what the actual emissions are per cow is a very good starting point and in Ireland they now know that they are on average emitting 350kg of methane per kg of milk solids, or 200 l of methane/cow/day. Once you have an understanding of this then it is possible to look at ways to mitigate the emissions by way of changing the diet. By adding canola meal or other proteins it is possible to balance the rumen to neutralise the pH, which will slow the methanogens resulting in less methane production. One manufacturer of feed out wagons is working on the length of the feed in the ration and believes it is reducing the emissions from the cows. This is good but it will not work in all systems as not all farmers feed out with a silage wagon or have feed pads. However, this will not be of any benefit to the beef and sheep industries as in many parts of the world the animals are not contained. In a feedlot or dairy situation it may be possible to introduce some biochar into the diet and this may have a balancing effect on the rumen because of its pH status. There is a trial underway in the USA in a pig operation to see what the effect will be in these animals.

Irish farmers believe that, if a tax was introduced for cows then it would need to be on a per cow basis as this would encourage efficiency of production. If production can lift from 300 kg/Ms to 700 kg/Ms then it would be beneficial to the farmer but also more than halve the methane emission per Ms.

- **USA**

GHG emissions are not high on the agenda for the dairy industry at present in the USA, and they are mainly just focused on production. Some of the new operations are very large scale and are quite high cost systems which make them very vulnerable to the market and the struggling economies.

Subsidies/Support Payments

- **United Kingdom**

In Ireland and England it appeared that many of the farmers are very good at working out how to get every last dollar out of their government and working the systems that are available to them but were not actually focused on business and often could not tell us what the cost of production was in their business. Subsidies are having a negative effect on the productivity of their farms as they are not focused on cost-effective production. France had some similar issues to the UK in regard to inefficiencies in their businesses.

- **USA**

In Washington DC we had an opportunity to sit down with 6 US Senators, both Republican and Democrat, to discuss the farm bill amongst other things.

The farm bill and the support that it gives farmers is US$600 billion but is only 0.6% of the total US budget. Of the $600 billion 15% is for farm programmes and support payments. It was explained that there are some fundamental reasons why the US is unlikely to do away with support payments (Subsidies). There is a 2:1 ratio between $ support to the farmers and $ food support to the urban population. The reference to "urban" programs refers to the food safety, nutrition and feeding programs. These programs help everyone, rural and urban. The feeding programs refer to programs such as the food stamp program and the Women, Infants, and Children (WIC) program. People who have low income or may be out of work can receive assistance to purchase food. This helps them, but also helps the producers of the food commodities by consuming food produced. Because it is in the traditional "farm bill", food assistance, food nutrition, and food safety attract members of Congress who represent more urban districts as well as the rural members. Consequently it is very unlikely that the support will change in the near future unless there is a change in Government policy. The 2008 bill is just a continuation of the 2002 version and has been passed again.

Water

Virtual water is something that was brought up by a number of people on my study tour. Its application may have huge ramifications depending on when, why and how it is used.

"Virtual water is the amount of water that is embedded in food or other products needed for its production. For example, to produce one kilogram of wheat we need about 1,000 litres of water, i.e. the virtual water of this kilogram of wheat is 1,000 litres. For meat, we need about five to ten times more.

The per capita consumption of virtual water contained in our diets varies according to the type of diets, from 1m^3/day for a survival diet, to 2.6m^3/day for a vegetarian diet and over 5m^3 for a USA style meat based diet.

It is clear that moderating our diets especially in the developed world could make much water available for other purposes.

With the trade of food crops or any commodity, there is a virtual flow of water from producing and exporting countries to countries that consume and import those commodities. A water-scarce country can import products that require a lot of water for their production rather than producing them domestically. By doing so, it allows real water savings, relieving the pressure on their water resources or making water available for other purposes.

At the global level, virtual water trade has geo-political implications: it induces dependencies between countries. Therefore, it can be regarded either as a stimulant for co-operation and peace or a reason for potential conflict."[50]

Extract from the World Water Council

Currently wheat is calculated to use 1000l water per kg of seed produced. It may be that in NZ this amount of virtual water is less due to our different climatic and environmental conditions. However we need to know the exact figures related to production in New Zealand so that if/when Virtual Water becomes a trade barrier or advantage we are well prepared to deal with it.

Urban Sprawl

- **USA**

In Maryland, USA there are issues with urban sprawl and they have passed legislation to help stop the loss of agricultural land and to assist in controlling spiralling transportation problems by discouraging the excessive use of motor vehicles used in commuting to work in the cities. There have also been requirements to build communities rather than individual houses, as this practice was also impacting on day to day farming.

Also in Maryland, the State Government has put in place a system to protect agricultural land whereby a payment of US$6500/acre is available to the land owners if they put their land into the agricultural preservation programme which means that it cannot be developed into any urban land use in the future unless the money is repaid. This amount is the difference in the market price between the farm land and the potential housing land. It is primarily a tool to help ensure the retention of the farm land while giving the land owner the opportunity to realise to full value of the land.

- **China**

In China land use is being challenged by an expanding population and the available land for agriculture is diminishing. Currently 1200 million ha is available for agriculture and this is

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[50] *The World Water Council, www.worldwatercouncil.org*

seen to be the red line that China cannot afford to go below to enable it to be self sufficient but it would appear that the decline is unlikely to slow in the near future. Approximately 10 million people per year have been moving from the country to the cities to gain an education and a better way of life due to the significant job growth in the urban areas. Fewer people will run the farms in the future unless a downturn in their economy forces some family members to return to the villages. The one child policy is having an impact of the number of people on the farms as the population ages.

The Global Credit Crunch

- **USA**

In Oklahoma there were some issues that were starting to appear in the financial markets and also in the banking industry in regard to the farms. There has been a 75% drop in the farm land values in Oklahoma which was making the banks nervous, hence a tightening of lending criteria.

Farms had been able to borrow with very little equity up until the early part of the year because product prices were quite high and gave a good return along with farm payments providing good stability. This has changed with bankers we met advising that they had tightened their lending criteria and farms now needed to have at least 50% equity.

- **China**

The thought that China may be the saviour of the world's economy may well be misleading. Some factories were seeing a reduction in orders of up to 50% from western countries. This will have a very large impact on their economy and a lot of the growth will slow dramatically. However China is still predicting 9% growth for 2009.

Wages are not as high as in other parts of the world. At a manufacturing plant we visited they had just averted their first staff strike by raising their wages. The Western World is having an influence that would not have been predicted before.

We are currently in the midst of the largest financial meltdown that the world has ever seen. Globalisation has meant that no country is immune from its effects. Now would appear to be a very good time to focus on the sustainability of businesses. However every cloud has a silver lining and there will be some excellent opportunities out there for people with their eyes open who are in a position to take advantage of the markets.

ACKNOWLEDGEMENTS

My very sincere thanks must go to Stuart Wright and the New Zealand Nuffield Farming Scholarship Trust for selecting me as one of their 2008 scholars. It has been an honour to represent such an amazing organisation. Thanks also to the 2008 sponsors for without their support such an incredible opportunity would not be possible.

- Dairy NZ
- FMG
- Federated Farmers of New Zealand
- Foundation for Arable Research
- Landcorp
- Mackenzie Charitable Trust
- Meat and Wool New Zealand
- Mid Canterbury Farmers Charitable Trust
- Rabobank

Thanks to Jim Geltch and the Australian Nuffield Trust for hosting us at the Melbourne Contemporary Scholars Conference and also giving us the opportunity to be part of their Global Focus Tour. Through these events I had the pleasure to meet and spend time with an amazing group of people, the 49 2008 Nuffield Scholars from throughout the world. The robust discussions and sharing of differing ideas and opinions along with friendships made have been a highlight of my year. Thank you to all the 2008 scholars for this, in particular the New Zealand Scholars, Ali Undorf-Lay and James Parson.

Throughout my study tour I was assisted by a large number of researchers, scientists and farmers throughout the USA, UK, Europe, China and New Zealand. My sincere thanks must go to all who were so willing to share their knowledge and time, answering my huge number of questions. Special thanks amongst this group must go to Don Reicosky of the National Soil Tilth Laboratory in Morris, Minnesota; Raj Khosla and Neil Hansen of Colorado State University, USA; Roger Williams of the Royal Horticultural Society, UK; Jim Orson of The Arable Group, UK; and Nick Pyke, of the Foundation for Arable Research, NZ.

Thanks also to those who welcomed a roving Kiwi into their homes. It was a humbling experience to be shown such amazing hospitality.

Robert and Mary Nicholls	Jim and Twila Hendrix	Jack and Janelle Nicholls
Dyke and Terry Rogers	Bruce and Kathy Jauman	Don Reicosky
Greg Braun	Laura and Roger Williams	Ciaran and Bridget Hamill
Peter and Bernie Tighe	Jonathon Tighe	Mike and June Carver
Marty and Sophie McKendry	Rodney and Claire Down	Jim and Marilyn Orson
Ben Stanley and Victoria Fairley		

Heartfelt thanks to Trevor Croy for believing I might be worthy of a Nuffield Scholarship and encouraging me to apply. To all my family and friends, thanks for all the support and making sure the wheels kept turning while I was away. Thanks also to Nick Pyke and Rachel Greenwood (FAR) and Dan Park (Plant & Food Research) for all your help with this report. For someone who hasn't written much since the Sixth Form it was almost as big a learning curve as the Nuffield Tour. And my final thanks go to my children, Jemma and Scott, and wife, Roz, whose encouragement and support has been as always, limitless. It has been a great team effort.

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17 *Tim Parkin, Research Microbiologist, National Soil Tilth Laboratory, Ames Iowa, USA*
18 *Neil Hansen, Soil & Crop Sciences, Colorado State University, Fort Collins Colorado, USA*
19 *Mette Laegdsmand, Crop Production, Aarhus University, Foulum Denmark*
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PEOPLE AND PLACES VISITED

National Centre for Atmospheric Research, Boulder CO	Climate Change
Rick Smith, CEO Dairy Farmers of America	Dairy Business
John Johnson. Johnson Dairy, Greeley CO.	Dairy Farming
Casey &Janelle Deltaun, Greeley, CO.	Dairy Farming
Colorado State University, Fort Collins CO.	
William Wailes, Colorado State University, Fort Collins CO.	Dept of Animal Sciences
Rajiv Khosla, Colorado State University, Fort Collins CO.	Precision Agriculture
Keith Paustian, Colorado State University, Fort Collins CO.	Soil & Crop Sciences Natural Resource Ecology
Neil Hansen, Colorado State University, Fort Collins CO.	Soil & Crop Sciences
Jack Fenwick, Colorado State University, Fort Collins, CO	Soil & Crop Sciences
Oregon Dept of Agriculture, Salem OR.	
Stephanie Page, Oregon Dept of Agriculture, Salem OR.	Renewable Energy Specialist
Brent Searle, Oregon Dept of Agriculture, Salem OR.	Economist
Janet Fults, Oregon Dept of Agriculture, Salem OR.	Pesticide Registration
Jim Rue, Vice Chair, Oregon Global Warming Commission, Salem, OR	Climate Change
Oregon State University, Corvallis OR	
William Young, Oregon State University, Corvallis OR	Seed Production Specialist
John Hart, Oregon State University, Corvallis OR	Crop & Soil Science
Tom Chastain, Oregon State University, Corvallis OR	Agronomist
Mike Flower, Oregon State University, Corvallis OR	Cereal Extension
USDA, Corvallis OR	
Gary Banowetz, USDA, Corvallis OR	Forage Seed Production Bio Energy Production
George Mueller-Warrant, USDA, Corvallis OR.	Forage Seed Production
Jim & Twila Hendrix, Progressive Ag Management Inc. Wray CO	Beef/Corn/ Wheat/Beans Farm
Jerry D Olsen, Pfizer Senior Veterinary, Fort Collins CO	Animal Health
Reinke Manufacturing Company Inc, Deshler, NE	
Bob Frank, VP - Intl Sales	Irrigator Production
Ken Goodall, Sales & Marketing Support	Irrigation Production
Derrel Martin, University of Nebraska, Lincoln NE	Biological Systems Engineering
National Soil Tilth Laboratory, Ames IO	
Doug Karlan, National Soil Tilth Laboratory, Ames IO	Research Leader
Tim Parkin, National Soil Tilth Laboratory, Ames IO	Research Microbiologist
Jerry Hatfield, National Soil Tilth Laboratory, Ames IO	Laboratory Director
David Laird, National Soil Tilth Laboratory, Ames IO	Soil Chemistry/ Minerology,
Kelloggs Biological Service, Gull Lake, MI	
Steve Hamilton,	Emissions Testing
Rob Ashley	**Dairy Farming Research**
Jim Bronsyn	**Dairy Co-ordinator**
ARS- USDA, Morris MN	
Don Reicosky, ARS- USDA, Morris MN	**Research Soil Scientist** **Biochar**
Abdullah Jaradat, ARS – USDA, Morris MN	**Research Leader**
Frank Forcella, ARS – USDA, Morris MN	**Precision Agriculture** **Oil Seed Research**
Sharon Weyers, ARS – USDA, Morris MN	Research Soil Scientist
Sharon Papierink, ARS – USDA, Morris MN	Tillage Erosion
Russ Gesch, ARS – USDA, Morris MN	Plant Physiologist
Jane Johnson, ARS – USDA, Morris MN	Plant Biochemist/Research Soil Sc.
Joel Tallaksen, University of Minnesota, Morris MN	Biomass Gasification Project Co-ord
Debbie Reed, International Biochar Initiative. Washington DC	Biochar
Dyke & Terry Rogers, Dalhart TX	Dairy/ Cheese/ Beef Feedlot
Greg Braun, Blumenort Manitoba, Canada	Dairy Farming

John & Pat Stanley, Nr Coalvill, Leicestershire UK	Crop/Beef Breeding
Ben Stanley & Victoria Fairley, Leicestershire UK	Fresh Beef/Lamb Marketing
Rodney & Claire Down, Taunton, UK	Dairy Farming
Brian & Sarah Lindsay, Cirencester UK	Dairy Farming
Ciaran & Bridget Hamill, Lisburn Ireland	Beef Farming/
Charlie & Gail Kilpatric, Lisburn Ireland	Crop Farming/
Peter & Bernie Tighe Tuam, Ireland	Dairy Farming
Johnathon Tighe Waterford, Ireland	Dairy Farming
Gerard Keenan, Keenan Group, Borris, Ireland,	Animal Nutrition
Warwick HRI Wellesbourne - UK	
Jason Pole,	Climate Change
Graeme Teakle, Research Scientist	Crop Improvement
Andrew Thompson, Assoc Professor	Water Efficiencies
Kerry Burton, Research Team Leader	
NFU Stoneleigh – UK	
Ceris Jones	Climate Change Adviser
Jonathon Skerlock	
HGCA Pentonville Road, London - UK	
Kellie Payne	Environment & Climate Change
Richard Safford	Industrial Uses Project Manager
DEFRA London – UK	
Victoria Turner	Head- Agriculture & Environment
David Cooper	
Maize Growers Assn. Devon – UK	
Dave Moody	
Jonathon Morgan	
Rothamsted Research, Harpenden, UK	
Keith Goulding	Head - Soil Science
Richard Harrington	Entomologist
Bill Clark	Applied Crop Sciences
Steve Foster	Entomologist
Martin Parry Head – Plant Science Dept	Crop Genetics
Jonathon Storkey	Weed Modelling
Cranfield University – UK	
Jim Harris	Environmental Technology
Rob Simmons	Soil & Water Conservation
Abdul Mouazen	Agricultural & Environmental Eng.
	Natural Resources Dept
Arhus University, Foulum Denmark	
Nick Hutchings, Co-Chair, Dept of Agroecology	Climate Change
Mathias Andersen, Dept Agroecology & Environment	
Keith McCloy, Dept of Agroecology & Environment	Precision Agriculture
Anton Thomsen, Dept of Agroecology & Environment	Precision Agriculture
Mette Laegdsmard, Dept of Agroecology & Environment	Crop Production
The Arable Group (TAG) - UK	
Jim and Marilyn Orson, Director, Cambridge - UK	
Paul Miller, Silsoe TAG Bedford – UK	Spray Application Technology
Mike and June Carver, Carver Associates, Badminton – UK	Bio Energy Fuels
Roger and Laura Williams, Royal Horticultural Soc., formerly Home Grown Cereals Authority (HGCA)	
Martin Jenkins Cambridge - UK	Arable Farming
Ger Beemsterboer, CEO Bejo Seeds, Holland	Specialist Vegetable Seeds