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The Climate Change Challenge for Managed Grasslands in New Zealand

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The climate change challenge for managed grasslands in New Zealand

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Key points:
1) New Zealand grassland systems were created by humans through land use changes of national proportions. This has brought many economic and social benefits, but at an increasing cost to the environment and people-biodiversity loss, loss of ecosystems integrity, flood damage, soil loss and greenhouse emissions associated with livestock and pasture management.
2) Grassland systems will be affected by changing climate and climate variability. Farming systems will need to be adapted creating systems that are more resilient and able to withstand increased climate variability and extreme events.
3) New Zealand is introducing an emissions trading system to price carbon that seeks to drive behaviour change to reduce emissions and sequester carbon.
4) Complementary research is seeking to develop on-farm solutions that can mitigate greenhouse gases through, rumen processes; genomics for rumen CH_4 production; forage and plant inhibitors for diet manipulation; animal factors; and nitrification inhibitors.
5) The ability to respond to the climate challenge for managed grasslands lies with the people that have to implement these changes-the farmers.

Key words: grassland systems, climate change, land use change, emissions trading system, research programme

Introduction

The climate change challenge for managed grassland systems is twofold. a) to produce food in an increasingly efficient and environmentally sustainable way that minimises greenhouse gas emissions and/or enhances carbon sinks; b) to adapt to an increasingly variable and changing climate with more extreme events. New Zealand has been grappling with these parallel issues through research, new technology implementation with some successes. This paper will outline where New Zealand grassland systems have come from; why New Zealand agriculture greenhouse gas profile is unique for a developed country; what responses have been made and are planned; and how farmers are the key ingredient for making a paradigm shift towards a more sustainable way of managing our land uses and agriculture systems.

Grassland systems impacts and benefits

Where we have come from Managed grassland systems globally have been created by humans, following land use change of global proportions-from forests, wetlands, native grasslands and alpine herb fields. New Zealand is no exception. In only 1000 years, 56% of New Zealand's landscape and ecosystems have been transformed from forests and natural grasslands to the managed grasslands and planted forests of today. Over the last 200 years most of the accessible productive land has been cleared and modified for agriculture, horticulture and human settlements, with resulting loss of habitat and the introduction of pest plants and animals (Ministry for the Environment, 2007a). While 44% of New Zealand land area is still in native vegetation, it is mostly in hill and alpine areas; lowland and wetland habitats are under-represented. However, New Zealand has 32% of its land area both public and private, legally protected for conservation purposes, (Ministry for the Environment, 2007a).

The impacts The land uses have changed over time between planted forests, extensive grazing of sheep to intensive beef and dairy farming and reversion of land and its re-afforestation. These changes have been influenced by settlement patterns, government policies, world markets for the livestock products and climatic conditions. Some of these ongoing changes have resulted in declines in land and soil integrity, increased hill country erosion and flooding, water quality degradation and increased greenhouse gas emissions (GHG) emissions from livestock (methane), soils and excreta (nitrous oxide).

Recent research on carbon (C) sources and sinks from erosion and sedimentation in New Zealand (Baisden et al., 2008), show that New Zealand rivers currently deliver approximately 3+/-1 Tg C y^{-1} to the oceans. Of this, 65% is derived from the most mountainous 9% of NZ land area and 20% is derived from the 2% area of soft rocks with human-induced land cover. The C loss it represents in the terrestrial environment may be negated by C accretion on old erosion scars and it may be considered a C sink as it sits on the ocean shelf. Overall the data suggests New Zealand terrestrial ecosystems are close to net C balance (Tate, et al., 2008), gaining on the hill country and losing C under intensive flat land farming systems. Large uncertainties remain, including C losses/gains from land use change from forests, land use and management effects on soil C and future impacts of bio-fuel and bio-char use.

Greenhouse gases These land use changes have resulted in a steady rise in pastoral agriculture non-CO_2 greenhouse gas emissions-methane and nitrous oxide, at a rate of approximately 1% per annum since 1990 (Ministry for the Environment, 2007b). While New Zealand emissions are only 0.2% of estimated world emissions (Ministry of Agriculture and Forestry, 2006), this represents 4.9 Mt $CO_{2^{-e}}$ growth in emissions since 1990 and is projected to rise by a further 2.3Mt by 2010. New

Zealand's greenhouse gas profile is quite unique amongst developed nations. Half of New Zealand's greenhouse gas emissions comprise non-CO_2 emissions -methane from ruminant animals (one third of total GHG emissions) and nitrous oxide (one sixth of total GHG emissions) from microbial breakdown of animal faecal matter and nitrogen from urine, and inorganic nitrogen fertiliser.

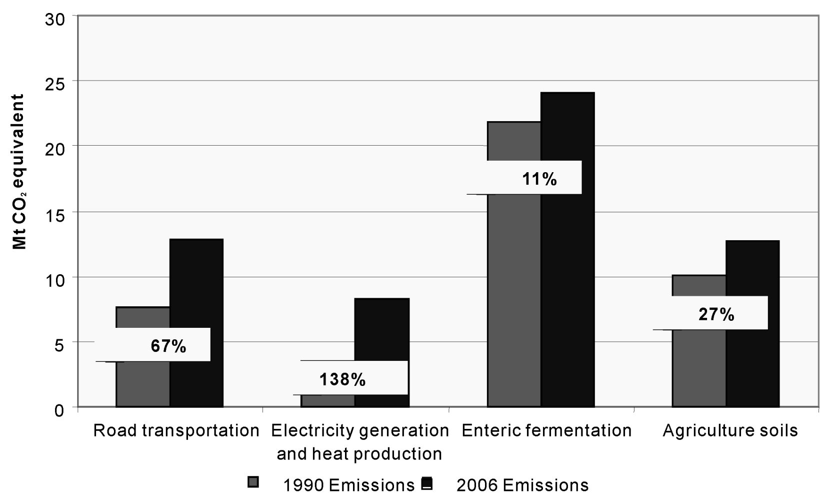

Figure 1 *Growth in New Zealand GHG emissions Source: Ministry for the Environment*, 2008

These increases in emissions have been driven by increases in meat and milk production from each animal (more forage through each animal means more methane and nitrous oxide), and an increase in nitrogen fertiliser use, driven off rapid growth in world demand for food products and the resulting high commodity prices. (Ministry for the Environment, 2007b).

However, while the total amount of GHGs emitted from pastoral agriculture has increased since 1990 (dairy has risen 70%, sheep has declined by 18%, (Ministry for the Environment, 2007b; Ministry of Agriculture and Forestry, 2006)), the amount emitted per unit of product has declined by 17.7% and 17.5% respectively, due to changes in the numbers of animals and animal productivity, (Leslie, et al., 2008). Productivity increases are due to new technologies, better feeding and disease management, improved genetics and better pasture and animal management.

The benefits In 2004, pastoral land use for sheep beef and dairy farming was the largest human land use at around 37% of the total land area of New Zealand. Our economy and social systems have gained from the production from the new grasslands. New Zealand's prosperity has been built from its agricultural heritage. Agricultural exports account for 52% of New Zealand's total exports by value and over the last 15 years have increased their productivity at more than double the rate of the rest of the economy (Sherwin, 2007). Internationally, New Zealand's agricultural trade is significant-66% of the world lamb trade and 40% of the world's traded milk products come from New Zealand farms (Leslie et al, 2008).

It has been estimated that 17% of NZ's GDP derives from the top 15 centimetres of our soil (Ministry for the Environment, 2007a). Our national psyche has been shaped by this economic contribution to the economy. However, that is changing rapidly as increasingly corporate ownership structures, rather than family owned farms, are emerging. The ratio of land price to output price has been rising in New Zealand (sheep and beef currently 14:1; and dairy at 10:1, Robobank, 2008) and the family farm and succession to it, is now beyond most individual's ability to pay.

In addition, people's expectations are changing, as we have seen in New Zealand with the growth in eco-tourism. The value of ecosystem services to the New Zealand economy per annum, was estimated at NZ$46 billion in 1999 (Patterson and Cole, 1999). The New Zealand export earnings from tourism are NZ$8.3 billion and rank second to agriculture which is NZ$16.1 billion. Tourism depends largely on the conservation of our natural ecosystems (Ministry for the Environment, 2007a).

Climate Change

The IPCC (2007), has reported that there is now observational evidence from all continents and most oceans that many natural systems are being affected by regional climate changes, particularly temperature changes. Furthermore, global assessment of data since 1970 has shown that it is likely that anthropogenic warming has had a discernable influence on many physical and biological processes.

Grasslands and the livestock footprint
Where do grasslands fit into the picture? Globally, livestock activities contribute 18% of total anthropogenic GHG emissions (including deforestation for grazing land), which is more than the contribution from transport (FAO, 2006). Livestock is the single largest anthropogenic user of land globally FAO, (2006).

Table 1 *Livestock contribution to greenhouse gas emissions.*

CO_2-e	18%	Pasture degradation and land use change
CO_2	9%	Not considering respiration
CH_4	37%	
N_2O	65%	Incl. feed crops

Source: Adapted from FAO, 2006

Climate change effects Climate change effects from the impact of GHG emissions, are threefold-changes in average climate conditions; changes in the incidence and severity of extreme weather events; and changes in climate variability. The IPCC (2007) suggests that the most significant impacts of climate change by the end of this century for New Zealand are likely to be an increase of up to fourfold in flood risk in most regions; a two to fourfold increase in drought risk, especially in eastern regions; and changing biosecurity risks. The climate changes are projected to affect a large proportion of New Zealand's prime agricultural land for cropping, dairy, sheep farming, viticulture, and market gardening. The IPCC (2007) has also concluded that production from agriculture by 2030 in New Zealand is likely to decline over parts of eastern New Zealand, with initial benefits to agriculture in western and southern areas and close to major rivers, due to a longer growing season, less frost and increased rainfall. However, they consider that there is substantial adaptive capacity, due to a well developed economy and science and technical capability, but considerable constraints to implementation and major challenges from changes in extreme events

Projected impacts on agriculture A recent risk assessment (EcoClimate, 2008), suggests that for the coming century while there may be little change from the present in total pasture production over New Zealand, there were strong regional variations projected and national production in the driest years may become worse than at present. These will have significance for local agriculture management. These findings are for climate scenarios with a significant increase in west-east rainfall difference across New Zealand.

Likely impacts on agriculture, in addition to the effects of rainfall events, could include; changes in pasture growth and hence capacity to intensify agriculture in some regions, with opportunities for new pasture species and management systems in others; changes in pasture composition, with invasion of weeds, pests and diseases increasing biosecurity risks and costs; changes in water availability, reducing expansion of irrigation for more intensive grazing regimes; reductions in water availability; changes in cold hardening in some crops; significant social and economic impacts on rural communities.

These projections are well outside what New Zealand has already experienced, so any resulting costs are likely to be even greater than what has already been experienced. For comparison, the following figures give an indication of the economic costs of events we already experience that result from mainly natural causes. The February 2004 floods affecting a wide area of central New Zealand had losses estimated at NZ $107 million to hill-country sheep and beef farms, and NZ $24 million to cropping. Six thousand people were evacuated, some farms lost 30% of grazing land and 20,000 hectares of land was affected by landslips (Ministry of Agriculture and Forestry, 2004a; 2004b). The effect of the 2007 drought on sheep and beef farming on the East Coast region of New Zealand was a NZ $326 million fall in total Value-Added or a 15% decline in the sector contribution to the regions GDP (Ministry of Agriculture and Forestry, 2007)

New Zealand has to date managed the effects of climate events through increased water harvesting, movement of animal feed from areas not affected, the development of drought resistant pasture species and social support through government disaster recovery packages. However, such adaptive management will need to be matched by cuts in GHG emissions by the international community, to reduce the extent and effects of climate change, to avoid the extreme projections at the higher end of the scale.

These projected effects could require significant changes in farm management practices. For example, average dry conditions over a wider area will constrain the ability to import feed. In addition, if changes in climate occur gradually over time, adaptive responses can be made, but if unexpected climate extremes occur more frequently, which the IPCC (2007) projects, then animals and plants may not be able to fully adapt. This presents opportunities for land use changes and costs, if land management practices alone, cannot adapt as a consequences of more frequent extreme events.

The response

The potential consequences necessitate a change in the paradigm governing grasslands management, from one driven primarily by commodity prices, to one that is risk based and takes the full cost of the farming activity into account including environmental externalities. Such an approach will drive mitigation of emissions and adaptation to the effects.

New Zealand has recently embarked on a challenging response to climate change-a market mechanism and related policies (an emissions trading scheme (ETS) and a Sustainable Land Management and Climate Change Plan of Action). As a Party to the Kyoto Protocol, New Zealand is committed to reducing its emissions to 1990 levels, on average over the period 2008-2012, or taking responsibility for any excess emissions by purchasing or generating Kyoto-compliant units. New Zealand is taking a constructive role in the negotiations for international commitments beyond 2012.

Emissions trading system and Plan of Action Legislation is before the New Zealand Parliament to introduce an ETS for all sectors and all greenhouse gases. This will put a price on carbon in the economy and thus take account of the environmental effects of our emissions. There is a staged introduction proposed and a transition for the agriculture sector to enable mitigation technologies and adaptive management to be implemented. Agriculture will enter the ETS in January 2013.

The ETS will first affect liquid fossil fuels in January 2009; stationary energy and industrial process emissions in 2010 and agriculture non-CO_2 emissions in 2013, with a currently proposed transition period to 2025 before there is full exposure of all agriculture sector emissions to the carbon price, through a free allocation pool equal to 90% of 2005 emissions, when it is brought in to the ETS. This is likely to be phased out progressively by 2025. The delay in entry of the agriculture sector to the ETS, is in part due to the fact that mitigation solutions for reduction of agriculture emissions are poorly developed compared with other sectors (Ministry for the Environment, 2007c) and to enable cost effective mitigation measures to be developed through investment in research. New Zealand has a Kyoto commitment and an unusually high proportion of its GHG emissions come from agriculture, so it is proposed that agriculture is included in the ETS following the first commitment period of the Protocol. The design for this is underway now.

Research The Pastoral Greenhouse Gas Consortium (PGGRC) is the cornerstone investment by New Zealand in mitigating agricultural GHG emissions. This public private research partnership between the livestock and fertiliser industries and the New Zealand government funds 1:1, to understand the animal/soil/atmosphere/water processes, find solutions, develop products, commercialise them and transfer these technologies to the farm after on-farm testing and demonstration. Between 2002-2007, the consortium invested NZ $15million in the following research areas; rumen processes; genomics for CH_4; forage and plant inhibitors for diet manipulation; animal factors; nitrification inhibitors.

The government has recently increased its investment in finding solutions to mitigate agriculture GHG emissions, and on impacts and adaptation to climate change-NZ $50 million for research and development and NZ $25 million for technology transfer. This also includes an intensive government-funded programme, to better understand, measure and verify GHG emissions from livestock agriculture, and to ensure that any new solutions can be verified for international recognition in our National GHG Inventory, by the UNFCCC, otherwise, New Zealand will not be able to get the credit for the GHG reductions. New Zealand has also established an international research network to better understand GHG emissions from livestock and develop cost-effective and practical means to reduce emissions-the Livestock Emissions and Abatement Research Network (LEARN) *www.lives tock emissions.net*

Early signs of progress from the research are good, especially for nitrous oxide emissions. These were extensively reported at the Greenhouse Gas and Animal Agriculture 2007 Conference, (Special Edition: Australian Journal of Experimental Agriculture, 2008). For example, nitrification inhibitors can reduce nitrous oxide emissions by up to 21% on an annual basis. However, achieving these reductions relies on farmers using the new products. Nutrient management models like OVERSEER™ have been developed and can estimate nitrous oxide emissions on the farm. Reductions in greenhouse gases from agriculture will only occur when the tools and techniques are designed to be used by the farmers as an integral part of their ongoing farm management practices. People matter.

Historical evidence of behaviour change People respond to price signals and have the capacity to make quite radical changes when conditions change. New Zealand experienced this in 1984 when the government removed agriculture subsidies. At the time, subsidies were approximately 33% of farm income. By 2003, this had fallen to less than 2% (mostly spent on agricultural research). The anticipated shift of people off the land did not occur- farmers adapted along with the significant changes to the institutional arrangement governing agriculture (Smith & Montgomery, 2003). The subsidy removal was tantamount to a price change and saw significant farmer behaviour change.

The change on the ground saw a shift from sheep and beef (the number of commercial sheep and beef farmers fell from 22,000 in 1984/85 to 15,000 in 2005/06 (Davison, 2006)), initially to forestry and more recently to dairying and the emergence of a vibrant viticulture industry and a major increase in horticulture. The significant changes were a change in farm size, their distribution , the number of animals (dairy) farmed and the ownership structures . At one level this was a success story-at another , there were significant social impacts to individuals along the agriculture value chain and for whole communities , which lost their infrastructure e .g . schools , postal services . In addition , as world commodity prices have become more favourable for our dairy products , the expansion and intensification of dairying has now brought additional environmental impacts in its wake , greenhouse gas emissions being one of them .

The people It is the farmers who ultimately need to respond to the challenge of climate change and the ETS pricing mechanism . This will be through developing more resilient farm management systems , with adaptive management that can withstand climate variability and extreme events . Land use management in New Zealand has been shown to respond to these challenges in the past . A survey of North Island hill country farmers (Smith , et al ., 2007) , showed that over the period 1995-99 , 50% of farmers had implemented some land use or land management strategy designed to meet changing environmental expectations .

Greenhouse gases can be seen as representing inefficiencies in farm production systems and thus they affect farm profitability , directly through production losses , or indirectly through market pressures for environmental integrity . Examples of industry responses include ; a significant reduction in the dairy sector carbon emissions from reduced energy use in the production of dairy products ; cropping farmers adjusting their management practices through low tillage systems , reduced energy inputs and efficiency practices through purchase of more energy efficient capital equipment for the farm ; the use of standoff pads for cows during wet winter months , when nitrous oxide emissions are likely to be greatest from the soil ; tree planting to reduce the effects of rainfall events in erosion-prone areas ; changing crop types and planting dates to anticipate changes in season length (Sinner , 2008) . The response at the farm-level will be a mixture of mitigation of GHG emissions and adaptive management of farm practices to a number of environmental pressures .

Such initiatives have promoted further development of tools such as OVERSEER^{TM} , a model to manage nutrients on the farm which is now being developed to monitor GHG emissions . Landcare Research has developed knowledge about the terrestrial carbon cycle which has enabled piloting of a voluntary carbon trading system for New Zealand landowners to sell carbon credits from regenerating indigenous forests in a pre-Kyoto market . So far , 18 ,000 tonnes CO_2^{-e} has been traded through the Emissions-Biodiversity Exchange (EBEX21) project . This facility has encouraged some farmers to shift to carbon farming on land that is better suited to regenerating indigenous forest for ecotourism enterprises , while also gaining an income from the carbon credits and plant-based health products . This is adaptive management at work , experience which will inform the climate change response .

A highly consultative process with the agriculture industry is underway at various levels to develop ways of developing farming systems that are resilient and can adapt . The government has set up a Climate Change Leadership Group to oversee the introduction of the ETS and related policies , comprising members from across the sectors and technical experts . There is an Agriculture Sector Peak Group and a Technical Advisory Group of technical and scientific experts in agricultural science and research , to design agriculture entry to the ETS . There is a Research and Innovation and a Technology Transfer Advisory Group designing ways of enhancing and transferring science knowledge and technologies to farmers so they can be adopted as best practice as they are developed . The ETS and the Sustainable Land Management and Climate Change Plan of Action , will facilitate the behavioural changes needed to fulfil the UNFCCC and Kyoto obligations of New Zealand . However , there are no illusions as to its challenging nature . It has never been done before ; nor has there been a greater challenge than climate change .

Furthermore , adapting to climate change policy (a carbon price which costs environmental externalities of production) , will be as important as adapting to climate change itself . The refocusing of some agriculture enterprises towards the provision of ecosystem services , while utilising other land for high value agricultural production , is one example of land use change triggered by environmental pricing . Recent work (Ministry of Agriculture and Forestry , 2008) , indicates that the use of nitrification inhibitors as the ETS is introduced would allow most dairy farmers to improve or maintain their profitability depending on the market price for carbon and milk prices . Land use change is another response . There is approximately 3 .2 million hectares of medium and low quality grazing land that could be converted to energy production forests for woody biomass-an area that could supply New Zealand's total projected heat and transport fuels demand (Hall , & Gifford , 2007) . These changes and recent deforestation of planted forestry land which is better suited to dairying , is just the beginning of a massive readjustment of land uses that will come as the full price of carbon is felt by the agriculture sector in New Zealand . The hope is that such changes will transition New Zealand to a more sustainable future for people and the environment .

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