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Climate Change

Mitigation and Adaptation Strategies for the Land-Based Primary Sector

Tutor Information

MAF

DairyNZ

Version 2

Contents

Introduction

This resource has been designed to provide information to support Level 4 and 5 sustainable management vocational training for the land based sector. Material included addresses the issues land managers face in dealing with the impacts of a changing climate.

There are four topics:

- Climate change projections
- Key nutrient, soil and animal processes
- Efficient resource use
- Adapting to the impacts of climate change

The information included for each of these topics can be used by you, the Tutor, when incorporating climate change messages into your teaching.

Key messages

In response to climate change, land managers will be required to:

- Implement strategies to deal with increased weather variability
- Reduce greenhouse gas (GHG) emissions.

So that this can be carried out in an efficient and appropriate manner, land managers must be well informed and their response strategies should be aligned with:

- Improved efficiency
- Good agricultural practice
- Good Business

Each topic includes key sections. Each section is introduced with the key information to be addressed and suggested activities to support your teaching.

Topic 1

Introduction to Climate Change

The key sections in this topic are:

- What is climate change and what are the projections?
- New Zealand GHG emissions
- Projected impact on pests and plants.

What is climate change and what are the projections?

This section covers:

- Climate variability
- The role of GHGs
- Predictions for future climate change.

It provides background on the reasons for concern about GHG emissions and the need to address agricultural gases.

Tutor notes

Suggested activities:

- Look at the variability in temperature and GHGs in the past and compare the rate of change in temperature in recent times.
- Explain the role of GHGs in the atmosphere.
- Identify the various sources of GHG including volcanic activity, solar radiation and human activity.
- Identify the range in projections for future changes to the climate.
- Identify the projected 'likely' change in climate for New Zealand and your region.

What is climate change?

Climate change is a significant and persistent change in climate or its variability. Climate has changed over millennia, and will undoubtedly continue to change in the future due to natural processes.

The scientific theory that humans could change the global climate had it's beginnings in the 19th century. Unlike many scientific theories that are tested under control conditions in the laboratory, this theory is being played out beyond our control in the Earth's biosphere.

New Zealand's climate, like the global climate, has warmed over the past century, and the trend is expected to continue for at least the next century.

Some facts

- Global variations in temperature are strongly linked to variations in the amount of GHGs in the atmosphere, particularly carbon dioxide (CO_2).
- GHGs trap the sun's heat and despite only accounting for 0.04% of our earth's atmosphere, they represent the difference between Earth being an almost lifeless planet of -19°C and the comparatively comfortable one we live in today of around +14°C.
- Levels of GHGs in the atmosphere have increased as a result of human activities and will continue to increase in the absence of measures to reduce emissions.
- The global climate has always been changing but the rate of change in temperature and sea levels, witnessed since the mid-20th century, cannot be accounted for by natural causes such as solar activity and volcanic eruptions. For example, global average temperature has risen by 0.74°C in the hundred years from 1906–2005 which is an unprecedented rate of increase.

Climate change and the agricultural sector

Climate change poses operational and productivity risks to agribusinesses through adverse weather conditions such as droughts or floods, or even from invasion of new weed species into pasture. In some cases annual production may increase and new crops may be viable. These factors affect either the total feed production or seasonal patterns of feed availability. Anticipating the impact of climate change is not an additional farming skill but simply an extension of good farming practice.

Feed budgeting is a fundamental skill in livestock farming. Farm profitability may suffer when the budgeted feed (anticipated pasture or crop growth) fails to meet expectations. It is likely climate change will add to the variability of feed supply as larger swings in pasture growth are likely. This puts greater emphasis on monitoring and planning practices.

Planning for a risk starts with identifying the risk (such as drought) and determining the likelihood of that risk occurring. The National Climate Change Centre at the National Institute of Water and Atmospheric Research (NIWA) provides information and projections about climate change. Projections are based on estimates of global GHG and aerosol emissions for the next century which are uncertain as they depend on human and economic factors. Specific climate change risks have been projected by region in New Zealand. These projections are updated as new information comes to hand.

Further reading

For the latest on this go to the NIWA website:
www.niwa.co.nz/our-science/climate

The Ministry of Agriculture and Forestry have published a series of climate change projections by region titled 'Climate Change: A Guide for Land Managers'. These are available at:
www.maf.govt.nz/climatechange/reports or by
0800 CLIMATE or through
Ministry of Agriculture and Forestry
PO Box 2526 Wellington 6140
Freephone: 0800 008 333

These regional summaries are also available from the 'Climate Change Information for Tutors' USB stick — contact Ruth McLennan:
ruthm@agito.ac.nz and **www.ruralsource.co.nz**

General projections

A ‘middle-of-the-road’ prediction for the impact on New Zealand agriculture has been established, and this represents the most likely outcomes as the Earth’s climate changes. This suggests that temperatures are likely to rise by 1°C by mid century and more than 2°C by 2090. Projections for temperatures in 2090 range from a 0.76°C rise where carbon emissions are rapidly reduced through to a 3.56°C rise where carbon emissions increase at the current rate.

Possible impacts of climate change on the pastoral sector

New Zealand is likely to become more:

- Sub-tropical in the north
- Wetter and windier in the west
- Drier in the east
- A milder climate in southern regions of the country.

Climate change may also bring opportunities. For example, a milder more temperate climate in southern regions may extend the growth season and total pasture supply.

Likelihood of these projections occurring

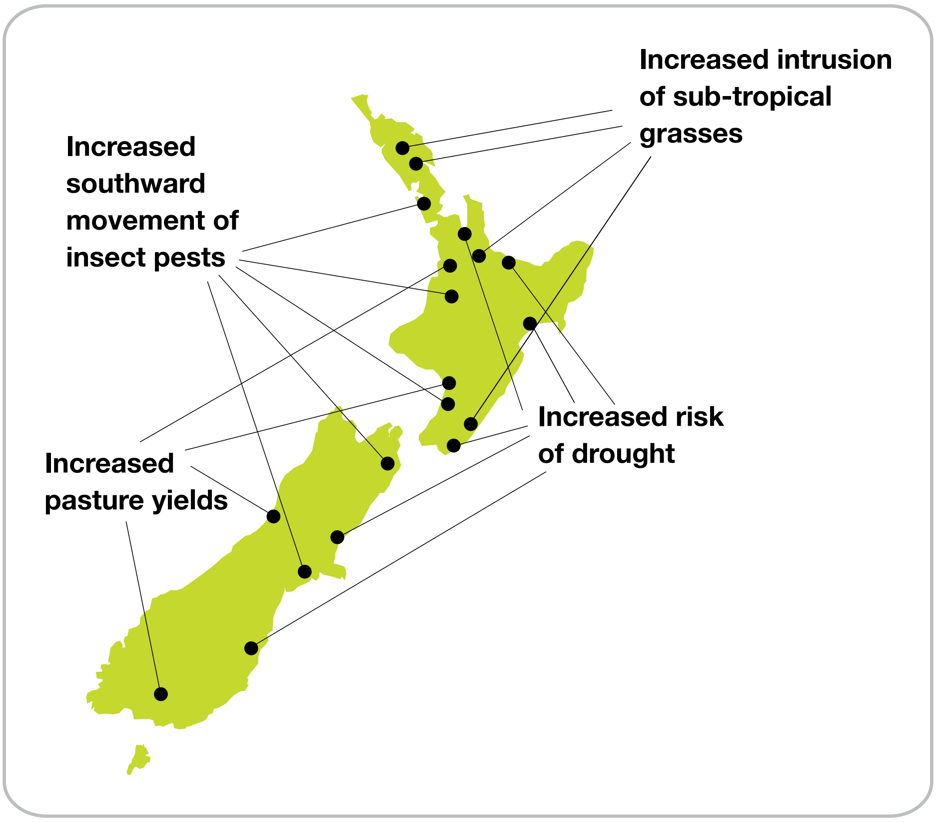
At a national and global level, these mid-range projections are suggested to be the most likely outcomes as the Earth’s climate changes. They assume ongoing global economic growth and associated GHG emissions with the introduction of new, more efficient technologies and declining global population from mid-century.

At a farm level some changes will be gradual, such as a change in the balance and composition of pasture species. Others will be difficult to predict, such as the occurrence of droughts, or impossible to predict, such as floods. Despite this, each can be planned for and potentially avoided or adapted to by modifying management practices.

Threats and opportunities

These projections present a combination of threats and opportunities to the New Zealand agricultural sector. The map below summaries some potential threats and opportunities.

Once a potential threat and its impact have been identified and the likelihood of it's occurrence has been assessed, we can look at specific strategies to manage the risk. This is considered further in Topic 4.



Further reading

The following pages contain general information on how climate change might effect New Zealand and in particular, Hawkes Bay — this Factsheet is available from:

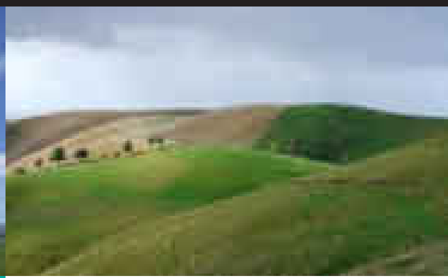
Hawkes Bay Regional Council
Phone: 06 835 9200
www.hbrc.govt.nz

For other regions see 'Climate Change: A Guide for Land Managers: Regional Summaries'. Published by Ministry of Agriculture and Forestry. These are available at: **www.maf.govt.nz/environment-natural-resources/climate-change/resources-and-tools/** or by calling 0800 CLIMATE, or through
the Ministry of Agriculture and Forestry:
PO Box 2526, Wellington 6140
Freephone: 0800 008 333

'Costs and Benefits of Climate Change and Adaptation to Climate Change in New Zealand Agriculture: What do we know so far? Contract report by EcoClimate Consortium: Integrated Research on the Economics of Climate Change Impacts Adaptation and Mitigation'. By A. Stroombergen, A. Stojanovik, D. Wratt, B. Mullan, A. Tait, R. Woods, T. Baisden, D. Giltrap, K. Lock, J. Hendy and S. Kerr. Prepared for the Ministry of Agriculture and Forestry 112 pages.

www.maf.govt.nz/environment-natural-resources/climate-change/research-and-funded-projectsclimatechange/slm/ag-production/page.htm

Factsheet 1: Climate Change


These fact sheets contain information shared through discussions with 20 Hawke's Bay farmers during the 2008/09 season.

March 2010

What is climate change?

- Climate change is a significant and persistent change in climate or its variability. Climate has changed over millennia, and will undoubtedly continue to change in future, due to natural processes.
- The scientific theory that humans could change global climate had its beginnings in the 19th century.
- Unlike many scientific theories that are tested under control conditions in the laboratory, the theory that human activity is resulting in climate change is being played out beyond our control in the earth's biosphere.
- The evidence is mounting that human activity is changing the global climate.
- New Zealand climate, like the global climate, has warmed over the past century, and this trend is expected to continue for at least the next century.
- The only final proof of climate change will be after significant changes have occurred.

Key facts about climate change

(for more information see http://www.mfe.govt.nz/issues/climate/about/key-facts.html)

1. Global variations in temperature are strongly linked to variations in the amount of greenhouse gases in the atmosphere, principally carbon dioxide.
2. The earth is getting warmer and other changes in climate are occurring.
3. There is increasing evidence of effects on natural systems.
4. Levels of greenhouse gases in the atmosphere have increased as a result of human activities and will continue to increase in the absence of measures to reduce emissions.
5. Natural factors, such as volcanic activity and changes in solar radiation by themselves, cannot account for the changes in climate that are now happening.
6. The effects of climate change will continue beyond the 21st century.

7. The climate system is very complex and there are still uncertainties about future climate changes, especially the magnitude of global warming and sea level rise, and regional differences.

What scientists are doing

Scientists around the world are monitoring, measuring, modelling and analysing all manner of changes. These changes include:

- increases in atmospheric carbon dioxide and other greenhouse gases.
- increases in temperature and frequency of extremes such as heat waves.
- melting of snow and mountain glaciers.
- ice melt from Greenland and Antarctica.
- rising sea levels.
- increased intensity and duration of droughts.
- changes in rainfall patterns.
- effects on Arctic and Antarctic ecosystems.
- warming of lakes and rivers.
- earlier timing of spring events such as bird migration.
- longer growing seasons in some regions and shorter, more drought affected, growing seasons in others (such as the Sahelian region of Africa).

Responses to climate change

There are two main responses to climate change, mitigation and adaptation.

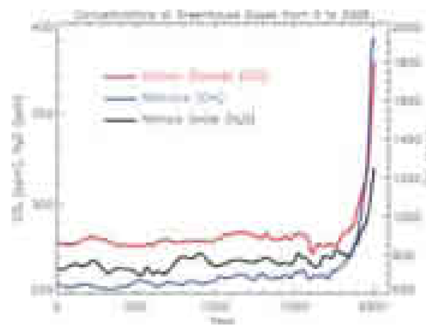
Mitigation relates to actions to reduce or offset emissions of greenhouse gases. Effective mitigation will require international cooperation and action. While some action is being taken, emissions of greenhouse gases are continuing at a level that will lead to significant climate change.

Adaptation involves actions to deal with the effects of climate change. The extent to which we need to adapt will depend on international actions to reduce emissions, and on the rate and extent of climate change that we experience.

Pragmatic farmers and growers tend to see mitigation and adaptation responses as ways of making their businesses more resilient and sustainable (see Fact Sheet 4 for a useful summary of this).

What do you believe?

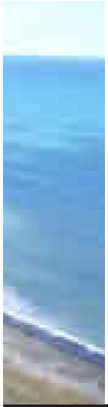
Regardless of what the science says, for many people 'seeing is believing.' Increasing numbers of farmers and growers are experiencing changes in weather patterns. They are reading and responding to the climate signals, as they are to economic, market and consumer signals.



Atmospheric concentrations of important long-lived greenhouse gases over the last 2,000 years. Increases since about 1750 are attributed to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion air molecules, respectively, in an atmospheric sample. *IPCC 2007* www.ipcc.ch

"There's plenty of information out there now saying that the potential through climate change is for more droughts, more wind, perhaps heavy rainfall events. That's enough to work to. A lot of people will say that's all rubbish and if they choose to go another way then good luck to them. Maybe they're right, but I'm taking information as well as what I see going on in the world and making my decisions."

"Climate change means to me the change in how our rainfall is spread across the year and in the way that it occurs now. That's as a farm view, and as a world view climate change means 'Mans greed'."



Hawke’s Bay climate change

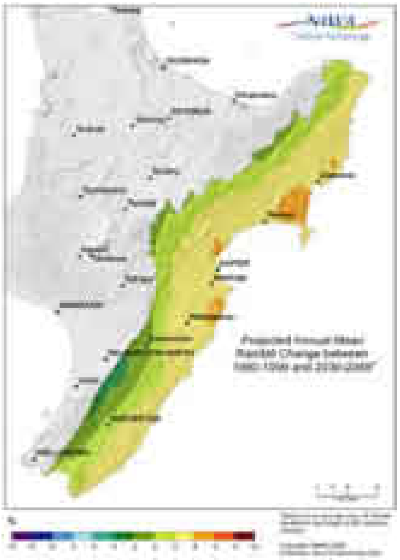
Hawke’s Bay could warm by about 1°C by mid-century and more than 2°C by late this century. Scenarios suggest that temperature increases will be highest in summer and autumn, with less warming in spring. Annual rainfall is likely to decrease overall, dominated by 10–15 percent less rain in winter and spring. In contrast, summer could become up to 10 percent wetter, although this is less certain.

Key effects

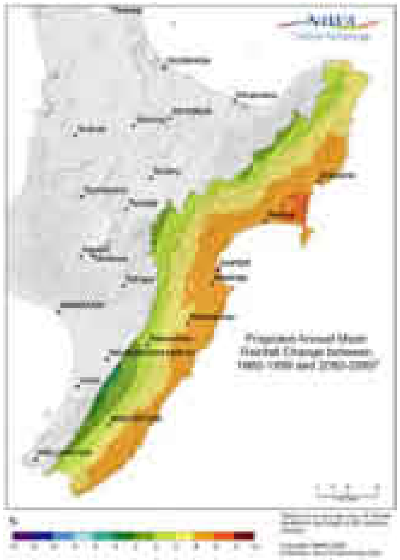
- A longer growing season and reduced frequency of frost.
- More frequent hot, dry, summer conditions and potential for more frequent heat waves.
- Lower rainfall and increased evaporation over the growing period, and likely increased drought frequency and severity.
- Decreased runoff into rivers and thus reduced river flows, on average. Uncertainty over rainfall changes in the western ranges means uncertainty about changes in runoff and river flows in the river catchments that extend back into the ranges.
- Depending on changes to weather patterns, there could also be the possibility of an increase in frequency and intensity of high rainfall events. Together with drier average conditions, this could lead to increased problems with erosion and flooding.
- Westerly winds are likely to become more persistent in spring and summer.
- Low lying coastal areas will increasingly be at risk of inundation from sea-level rise or more prone to salt water intrusion. The extent of this will depend on the amount of sea-level rise.

“I work on the assumption that our weather events are going to get more dramatic, we’re going to have more droughts, we’re going to have more weather bombs.”

The maps show the projected trend in annual-average rainfall that could be expected by 2050 and 2100, compared to the average for 1980–1999.



2050: Eastern regions of the North Island are likely to receive less total annual rainfall on average by mid century, but with considerable seasonal variations.



2100: Annual rainfall is likely to decrease by about 5 percent by late century along the coast, with less decrease inland. Seasonal variation will be high.

Likely impacts and opportunities include:

- With drier conditions on average, increased drought frequency, and potentially more wind in spring, there would be a reduction in pasture productivity. These impacts will be greatest in drier parts of the region.
- The expected drier average conditions, combined with possibly more intense rainfall at times, will increase the erosion and flood risk of most hill country farms. Windier springs could also increase the potential for wind erosion.
- Changes in pasture composition are likely, depending on grazing management.
- There could be greater problems with animal health and pests and diseases. Increased heat stress could also be a factor over time.
- The risk of fires in rural areas may also increase, with potentially severe effects.
- Changes in pests and diseases will occur, with the likelihood of more weed species and subtropical pests and diseases invading over time, possibly requiring new pest management approaches.
- Security of water supply is likely to be the greatest issue in the future. Drier average conditions, together with increased growth in demand for water, are likely to place increasing pressure on available water resources.
- Changes in rainfall, with the possibility of more extremes of wet and dry, will lead to consequences for local and regional infrastructure. This includes land drainage, flood protection, community water schemes, culverts and bridges, erosion control, farm dams, water reticulation and irrigation.

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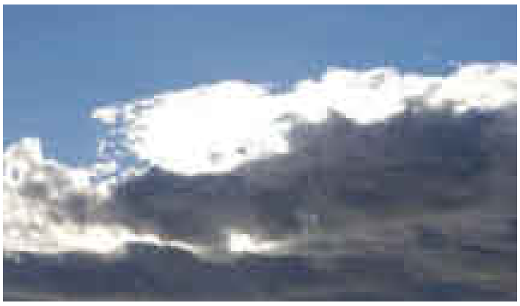


EARTHWISE CONSULTING

HAWKE'S BAY
REGIONAL COUNCIL

Sustainable Farming Fund
Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

Further reading

'A Dairy Exporter Climate Change Great Farming Guide'. Published by DairyNZ, May 2010.

For general climate change information go to: **www.climatechange.govt.nz**

'Climate Change Adaptation in New Zealand: Future Scenarios and Some Sectoral Perspectives'. February 2010. Published by New Zealand Climate Change Centre, National Institute of Atmospheric Research (NIWA) Wellington New Zealand, ISBN 978-0-473-16366-2 (print) 978-0473-16367 (online):

www.niwa.co.nz/our-science/climate/research-projects/all/adaptation-to-climate-variability-and¬change

Ministry for the Environment: **www.mfe.govt.nz/issues/climate**

'Inter-governmental Panel on Climate Change: 4th Assessment 2007 — Summary for Policy-makers **www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf**

New Zealand GHG emissions

This section covers:

- New Zealand’s GHG profile
- How GHG emissions are calculated
- New Zealand’s obligation under the Kyoto Protocol
- Global warming potential and CO_2 Equivalents.

This section describes some of the fundamental principles of how New Zealand’s emission profile is determined.

Tutor notes

Suggested activities:

- Profile New Zealand’s GHG emissions and discuss the contribution of agriculture.
- Compare New Zealand’s agricultural GHG emissions profile with global emissions.
- Discuss how GHG emissions are measured using an internationally agreed system at national and farm levels.
- Look at New Zealand’s obligations are under the Kyoto protocol.
- Determine New Zealand’s current position in relation to 1990 emissions levels.
- Discuss the concepts of ‘global warming potential’ and ‘CO_2 Equivalents’.

International agreements

In 1992, governments of the world adopted the United Nations Framework Convention on Climate Change (UNFCCC). This recognises the link between the effects of climate change and a country's level of development. Adverse effects threaten developing nations more than developed nations, which have more technological, economic and institutional capacity to respond to the changes.

The Kyoto Protocol

The Kyoto Protocol is an international agreement which provides strategies to reduce GHG emissions using an internationally agreed system. New Zealand accepted the Kyoto Protocol in 2002 and agreed to reduce GHG emissions to 1990 levels. New Zealand must achieve this initial target by 2012 or purchase carbon credits internationally for emissions above this level. The Kyoto Protocol has recently been accepted by Australia and is now supported by the United States (the US alone accounts for 36% of emissions from industrialised countries).

Further reading

Background information on the UNFCCC and Kyoto Protocol can be found at **www.mfe.govt.nz/publications/climate**

A useful summary is also provided by the Pastoral Greenhouse Gas Research Consortium (PGgRc) and available in their '5 year Science Progress Report 2002–2007' **www.pggrc.co.nz**

New Zealand's GHG position in 2009 compared with 1990

New Zealand GHG emissions are calculated annually for each of the major sectors. Agriculture has been described as the key area of concern for New Zealand's GHG emissions profile producing 47% of total emissions in 2008.

The table on page 21 shows that between 1990 and 2008 New Zealand's GHG emissions increased by 23%.

- During that time agriculture emissions rose by 9% while emissions from energy rose by 47%.
- Increased energy consumption is responsible for 78% of increased emissions since 1990.

Up until 2009, growth in forests planted in the 1990's has offset the increase in New Zealand's emissions and New Zealand is currently forecast to have a surplus of 11.2 million units for the Kyoto period (2008–2012). However these forests are largely radiata pine which will require harvest at some stage in the next 10–20 years and as such will release emissions.

New Zealand's net balance for the first commitment period will not be finalised until 2015 and will likely continue to fluctuate with economic growth and productivity.

Comparison of New Zealand's GHG emissions (1990 and 2008)

	Emissions (millions of tonnes of CO_2 equivalent)		
Sector	1990	2009	% change
Energy	23	33.8	+ 47 %
Industrial process and solvents	3.4	4.3	+ 27 %
Agriculture	31.9	34.8	+ 9 %
Waste	2.4	1.7	- 31 %
Total	**60.8**	**74.7**	**+ 23%**

From 'New Zealand's Greenhouse Gas Inventory 1990–2008 — **www.mfe.govt.nz**
Note: Land-use change and forestry not included.

The main agricultural GHGs are CO_2, CH_4 and N_2O. New Zealand agricultural practices produce half of our GHG emissions, of which approximately two thirds are belched as CH_4 from the digestive system of ruminants. One third is emitted as N_2O, mostly from animal urine, dung and in part from nitrogenous (N) fertilisers.

Global warming potential

In order to compare the relative climate change effects of different gases, the 'global warming potential' (GWP) rates them on a common scale. The use of the GWP for this purpose is internationally agreed.

- Over 100 years 1kg of methane emitted into the atmosphere has the same warming effect as for 21kg of CO_2.
- Using the same scale, 1kg of N_2O has the equivalent effect of 310kg of CO_2.

Quantities are compared as 'CO_2 Equivalents' or 'CO_2 Eq'.

Further reading

'Farming Carbon in New Zealand: Infosheet 3 Greenhouse Gases — International agreements' **www.carbonfarming.org.nz**

Potential impacts on pests and plants

This section covers potential climate change impacts on:

- Spread of insect pests and biosecurity
- Pasture productivity and composition
- Spread of pasture species.

This section describes the potential impacts of changes in temperature, rainfall and CO_2 concentration and how they are likely to impact on the productivity and composition of New Zealand pastures, pasture pests and weeds.

Tutor notes

Suggested activities:

- Discuss the potential for spread of existing pasture pests.
- Explain how climate change may increase biosecurity risk.
- Discuss how changes in temperature, rainfall and atmospheric CO_2 concentrations may impact on pasture growth.
- Discuss how changes in temperature, rainfall and atmospheric CO_2 concentrations may impact on pasture composition, including relative effects on C3 and C4 grasses and legumes.
- Provide an example of how climate change may alter the geographic spread of pasture species.

How might climate change affect insect pests in agriculture?

Increased problems with insect pests are likely. Recent experiences in Northland with tropical grass webworm, and crickets in Hawkes Bay, are indicative of what could occur more often. The spread of clover root weevil (right) and clover flea among others are accelerated with warmer average conditions.

Courtesy of AgResearch

There is also increased biosecurity risk as any new species entering the country are likely to be able to survive and reproduce better as temperatures increase.

How might climate change affect pasture growth?

The following is summarised from Clark et al, 2001[1].

Temperature influences a range of plant processes (for example, photosynthesis, leaf appearance, leaf extension and tiller production) with the ideal temperature range for these individual processes differing within and between species. For New Zealand pastures, the range is likely to be 16–20°C for ryegrass based pastures, a temperature band that is common to most of lowland New Zealand only in the summer months. Therefore a general increase in temperatures within the range predicted (1–2°C over the next century) would be expected to result in an increase in annual pasture yields with the biggest effect occurring outside the summer months.

Temperature also influences the botanical composition of pastures.

- In the north of the North Island higher temperatures mean that C4 species (such as paspalum and kikuyu) which have a higher temperature optimum for certain processes, and are highly competitive with C3 species such as ryegrass, can become major components of pastures.

1 'The Sensitivity of New Zealand's Managed Pastures to Climate Change in the Effects of Climate Change and Variation in New Zealand — An Assessment using the CLIMPACTS System' (Chapter 6 page 65–78). Published by University of Waikato, Eds R.A. Warrick, G.J. Kenny and J.J. Harman, ISBN 0–473–07988–7 June 2001.

- Although productive in the summer months, C4 grasses are often low yielding in the cooler months and generally have poorer animal performance characteristics.
- Higher temperatures resulting from climate change should favour C4 species at the expense of C3 species.

A key area of uncertainty is how plant species will respond to variability of temperatures, for example frequency of frosts and hot days.

Inadequate water supply places a major limitation on pasture production. Changes in the seasonal pattern of rainfall, as well as total rainfall received, have to be considered when assessing the effect of climate change.

- Legumes are generally less tolerant of water shortages than grasses and C4 species use water more efficiently than C3 species.
- Variability of rainfall between years is also high and any changes in this could have profound effects. For example, higher likelihood of drought in the east of the country is likely to have a greater impact on pasture than small changes in the annual mean rainfall.

The concentration of CO_2 in the atmosphere has a positive effect on photosynthesis — the so called ‘carbon fertilisation effect’.

- Atmospheric CO_2 influences water use efficiency and may therefore influence the competitive interactions between C3 and C4 species.
- Increases in CO_2 levels may also enhance the water use efficiency per unit of leaf in pasture plants.

Given these fundamental relationships, rising CO_2 levels and temperatures may benefit pasture productivity. A computer model named CLIMPACTS was developed to, among other things, integrate the impacts of temperature, rainfall and CO_2 and estimate the response of pasture production. Using mid-range scenario predictions, the model estimated that pasture productivity may increase as much as 20% by 2030 compared with 1990 levels. However reduced summer rainfall and increased likelihood of summer drought may encourage invasive annual and biennial weeds such as thistles and barley grass. This issue is explored further in Topic 4.

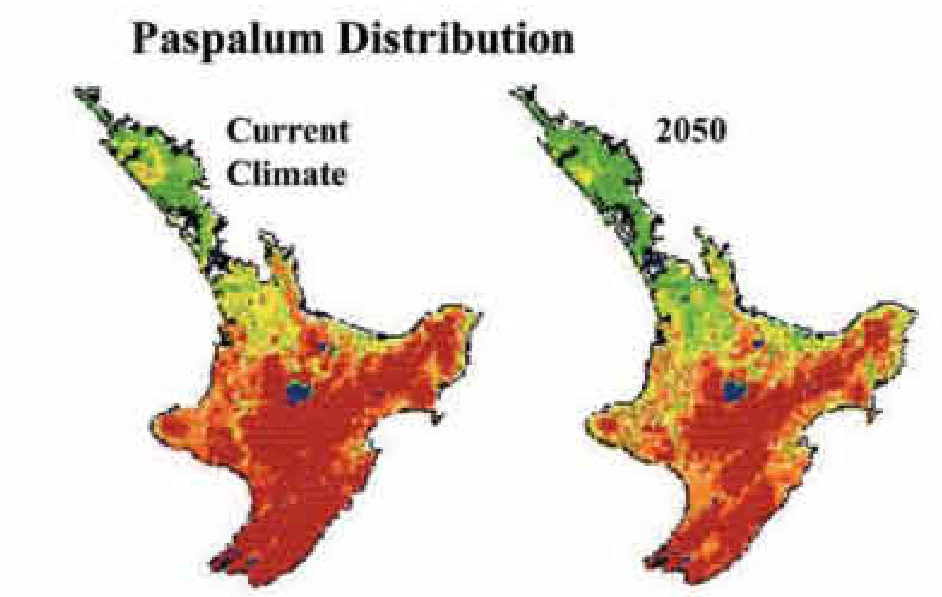
Scrub weeds and ragwort are unlikely to be affected much by climate change, except that warmer-zone species like woolly nightshade might spread further southwards. The same is true of many other warm-zone plant species. Higher CO_2 levels in the atmosphere seem likely to enhance the growth of broad-leaf species, including legumes, which will make worse predicted increases in thistles and similar annual or biennial species.

Changes in the geographical distribution of agricultural plants

Climate change in New Zealand is likely to change both the growing environments and botanical composition of plant communities, with implications for the geographical distribution of agricultural activities.

CLIMPACTS was able to provide an example for paspalum, showing a likely southward spread as New Zealand's climate becomes warmer. The present, and future, occurrence of this invasive species is far more probable for areas of the North Island than South Island. The maps below show the likely southern spread of paspalum in the North Island.

Change in the probability of paspalum presence in the North Island — current climate versus 2050



Light grey indicates the higher likelihood of paspalum

Further reading

‘Costs and Benefits of Climate Change and Adaptation to Climate Change in New Zealand Agriculture: What Do We Know so Far?’, April 2008. Contract report by EcoClimate Consortium: Integrated Research on the Economics of Climate Change Impacts Adaptation and Mitigation. The Ministry of Agriculture and Forestry, Wellington (112 pages). **www.maf.govt.nz/environment-natural-resources/climate-change/research-and-funded-projects**

The CLIMPACTS Synthesis Report ‘An Assessment of the Effects of Climate Change and Variation in New Zealand using the CLIMPACTS System;, June 2001. R.A. Warrick, A.B. Mullan, G.J. Kenny, B.D. Campbell, H. Clark, P.T. Austin, C.G. Cloughley, T.L. Flux, A.J. Hall, J.J. Harman, H.G. McPherson, P.D. Jamieson, N.D. Mitchell, P.C.D. Newton, A. Parshotam, A.S. Porteous, M.J. Salinger, C.S. Thompson, K.R. Tate, W. Ye. Published by University of Waikato.

‘Climate Change: A Guide for Land Managers: Regional Summaries’. Published by Ministry of Agriculture and Forestry. These are available at: **www.maf.govt.nz/environment-natural-resources/climate-change/resources-and-tools/** or by calling 0800 CLIMATE,
or through the Ministry of Agriculture and Forestry:
PO Box 2526, Wellington 6140
Freephone: 0800 008 333

‘A Dairy Exporter Climate Change Great Farming Guide’. Published by DairyNZ, May 2010.

Topic 2

Key Nutrient, Soil and Animal Processes

The key sections included in this topic are:

- Nitrous oxide
- Methane, carbon cycling and carbon calculators
- Soil carbon.

Understanding where and how GHG emissions arise from agricultural production systems is a key step in developing and implementing strategies to reduce these emissions.

Nitrous oxide (N_2O)

This section covers:

- N_2O in the nitrogen cycle
- Sources of N_2O emissions
- Dietary nitrogen and N_2O emissions
- Nitrification inhibitors.

This section addresses the sources and factors which influence N_2O production from pastoral systems.

Tutor notes

Suggested activities:

- Discuss the relative contribution of excreta and N fertiliser to N_2O emissions.
- Explain the conditions under which N_2O may be released from the soil in the context of the nitrogen cycle.
- Explain how the N content of forage and soil moisture levels may impact on N_2O emissions.
- Examine how nitrification inhibitors may reduce N_2O emissions and discuss limitations to their use.

Nitrous oxide (N_2O)

N_2O makes up one third of agricultural GHG emissions and is the most potent. Livestock excreta is the primary source of N_2O emissions with around 84% from dung and urine, and 16% from N fertiliser. Around 3kg of N_2O is equivalent to one tonne of CO_2 in terms of global warming potential.

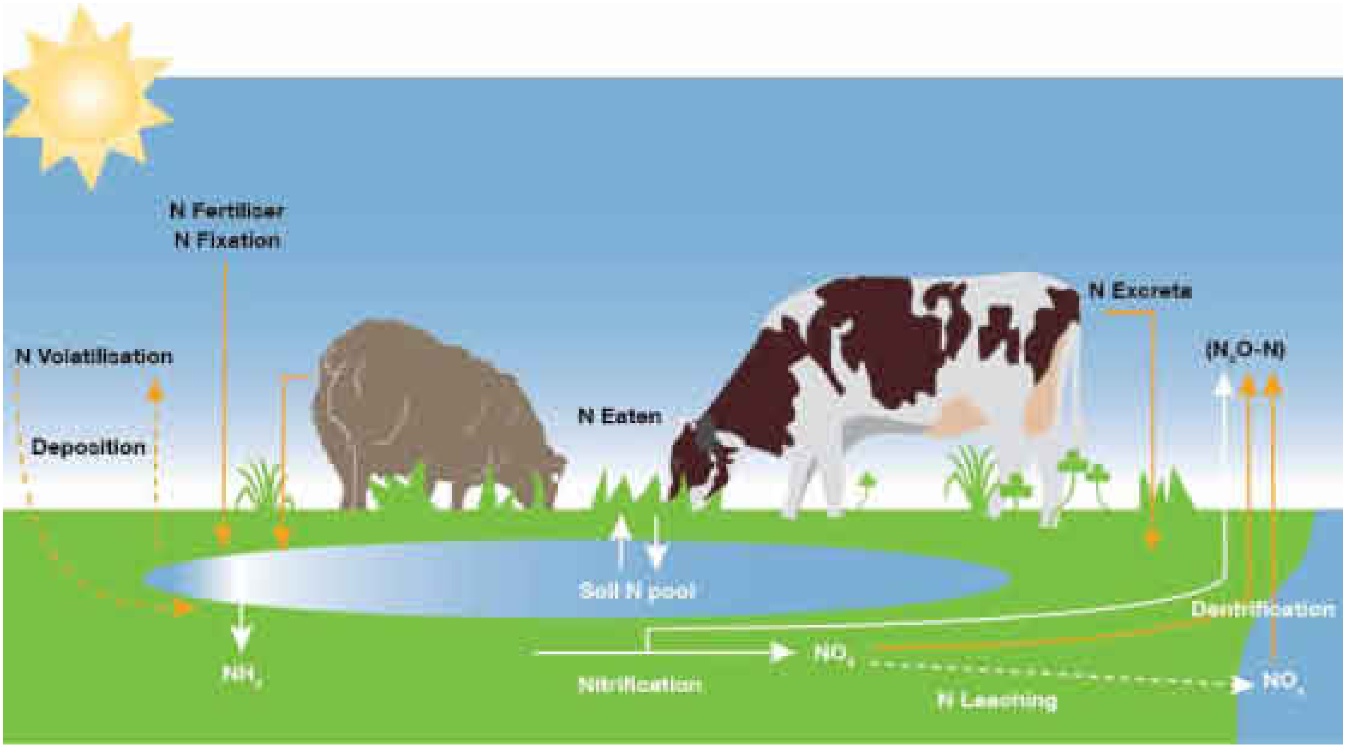
Soils contribute around 65% of the total N_2O produced by land-based ecosystems. N_2O gas is formed in soils during microbiological processes associated with the nitrogen cycle.

N_2O production by nitrifying bacteria may arise during:

- Nitrification — ammonia (NH_4) oxidation to nitrate (NO_3)
- NO_3 reduction in anaerobic conditions, or
- Dentrification (as shown in the diagram below).

Relatively high N_2O emissions rates are often seen between late autumn and early spring in New Zealand when soil moisture is high and evapotranspiration is low. The picture on page 32 shows the sources of N_2O emissions in a grazed pasture system.

Nitrogen cycle in a grazed pasture



Courtesy of MAF

Ruminants are not efficient users of N in their diet and the basic dilemma is that pasture plants require a significantly higher concentration of N to grow at optimal rates than is needed by the grazing animal. The maximum dietary N concentration needed by cattle and sheep is approximately 2.5%, but New Zealand pastures often have an N concentration of 3–4% (Pacheco and Waghorn, 2008)[1]. Consequently, more than 70% of the N consumed is deposited back onto pastoral soils as urine and dung, and this is potentially lost as leachate or gaseous emissions.

Given that N_2O accounts for 17% of national emissions, 84% of which is from urine, ruminant urinary N is responsible for around 11% of New Zealand's GHG inventory.

The table on page 33 summaries the issues associated with excess dietary N for the animal and environment.

1 D. Pacheco and G.C. Waghorn. 'Dietary Nitrogen — Definitions, Digestion, Excretion and Consequences of Excess for Grazing Ruminants'. Proceedings of the New Zealand Grassland Association 70: 107–116 (2008)

Consequences of providing diets with nitrogen in excess of requirements for production

What does it mean for the ruminant?

• Nitrogen in excess of requirements has to be disposed of, mostly as urinary N.
• High N intakes, or high ammonia absorption, can limit dry matter intake.
• High concentration of N can have negative effects on animal health, including:
  ◦ Nitrate toxicity
  ◦ Impaired fertility.

What does it mean for the environment?
• N consumed in excess of the animal's requirement is excreted as urea in the urine, which is concentrated in patches on paddocks. • Transfer of N fertility within a paddock. • Urine patches result in N losses to run-off and ground water.

Paecho and Waghorn, 2008

Note that nutritional recommendations for N are often expressed as crude protein (CP). To determine N content divide crude protein content by 6.25. For example, 23% crude protein in the diet is 3.7% nitrogen content.

- Very high pasture N concentrations can be avoided by reducing N fertiliser application rates and boosting legumes.
- Provision of supplements containing low concentrations of N (such as maize silage) will dilute high pasture N concentrations in the diet.
- Removing cows from water-logged pastures will lessen N_2O emissions and maintain sward quality.

There are particular situations in pastoral farming where the supply of N might be inadequate (for example, feeding maize silage to dairy cows in summer when pasture has a low CP content). Dietary supply of N is particularly important because as noted previously, no sizable, readily available body store is available for excess N, whereas excess metabolisable energy (such as in volatile fatty acids) can be stored in fat. See Kolver[2] for a detailed practical dairy cow feeding guide in relation to production.

2 Kolver E. 'Nutrition Guidelines for the High Producing Dairy Cow'. Published by Dairy Research Corporation.

Improving the efficiency of N fertiliser application to avoid excess N in the pasture will help reduce N losses. Reducing these losses so more N is used for pasture growth can benefit farmers while potentially reducing N_2O emissions and nitrate leaching.

Nitrification inhibitors

Nitrification inhibitors have been shown to be a viable strategy to reduce N_2O emissions. For example, in field studies, application of dicyandiamide (DCD) to grazed pasture soils reduced N_2O emissions from animal urine patches by an average of 70%. Some studies show reductions of up to 90% over a 2–3 month period. To date, most studies have been carried out on small plots at a small number of locations in New Zealand. Field scale research is currently underway over wider areas to determine potential N_2O reductions at a farm scale.

This work is required for on-farm validation and international acceptance of this GHG reduction technology.

A small amount of N_2O is emitted from anaerobic ponds used in dairy shed effluent systems.

Potential impact of nitrification inhibitors on the farm

Nitrification inhibitor studies revealed that nitrate leaching was on average around 50% lower, although the effect was much more variable. While N_2O emissions should be highest in autumn and winter, year-round feeding of dairy cattle outdoors means N excretion onto soils and N_2O emissions will also occur in spring and summer.

It is recommended that, for maximum benefit, DCD be applied:

- Within seven days of grazing
- Twice a year in late autumn and late winter (May and August)
- When the soil temperature is less than 12°C
- It is also best suited to dairy farm systems and is applied using boom spraying equipment.

Methane (CH_4), carbon cycling and carbon calculators

This section covers:

- Ruminant production of CH_4
- Carbon cycling in pastoral systems
- Carbon calculators
- Measurement of GHG emissions.

Tutor notes

Suggested activities:

- Explain the process of CH_4 production from the rumen.
- Discuss how carbon cycles around the pastoral grazing system.
- Introduce carbon calculators using an example farm or case study.
- Discuss the techniques used to measure GHG from grazing systems.

Methane (CH_4)

The following description of CH_4 production is taken from the New Zealand Pastoral Greenhouse Gas Research Consortium (PGgRc) '5 year Science Progress Report 2002–2007'.

CH_4 is produced as a by-product of the digestion of forage.

- Forage is chewed up and swallowed with large quantities of saliva.
- Once in the rumen the forage is subjected to the action of numerous species and types of microorganisms, such as fungi, bacteria, protozoa and Archaea-bacteria.
- Ruminants then return partially digested material to the mouth for further chewing that mechanically breaks down the forage into a mushy pulp.

Essentially the rumen is a fermentation chamber within which hydrogen is produced. CH_4 is then produced by a group of microbes, called methanogen, which gain energy by fixing hydrogen gas into CO_2 molecules in the rumen. Methanogen replace the oxygen atoms in CO_2 with hydrogen to form CH_4.

- CH_4 and other gases built up in the rumen are belched directly from the rumen.
- A small fraction (approximately 5%) can pass into the animal's blood stream and then leave the body via the lungs on the animal's breath.

Methanogen play an important role in maintaining optimum acidity conditions in the rumen. Without CH_4 or any other mechanism to absorb or remove the hydrogen gas, the hydrogen accumulation would be detrimental to the animal.

Successful mitigation of animal CH_4 emissions requires two things:

- A mechanism that inhibits or eliminates the methanogen
- An agent (biological or chemical) to mop up the hydrogen.

Managing ruminal hydrogen is critical to avoid reducing the rumen pH, leading to poor fermentation and lower feed conversion efficiency, and if left unchecked, acidosis and ultimately death.

CH_4 is the largest source of agricultural GHG emissions (65%) and the one we can do least about. $5 million per annum of research effort, coordinated by the Pastoral Greenhouse Gas Research Consortium (PGgRc) is going in to the development of technologies to reduce CH_4 emissions. PGgRc research predominantly focuses on animal CH_4 production through rumen manipulation and the knowledge gained can also be applied to enhance rumen efficiency and increase productivity. There is potential to produce a vaccine or similar to reduce animal CH_4 emissions, but such technology is at least 10–20 years away from practical application at farm level.

Calculating GHG emissions

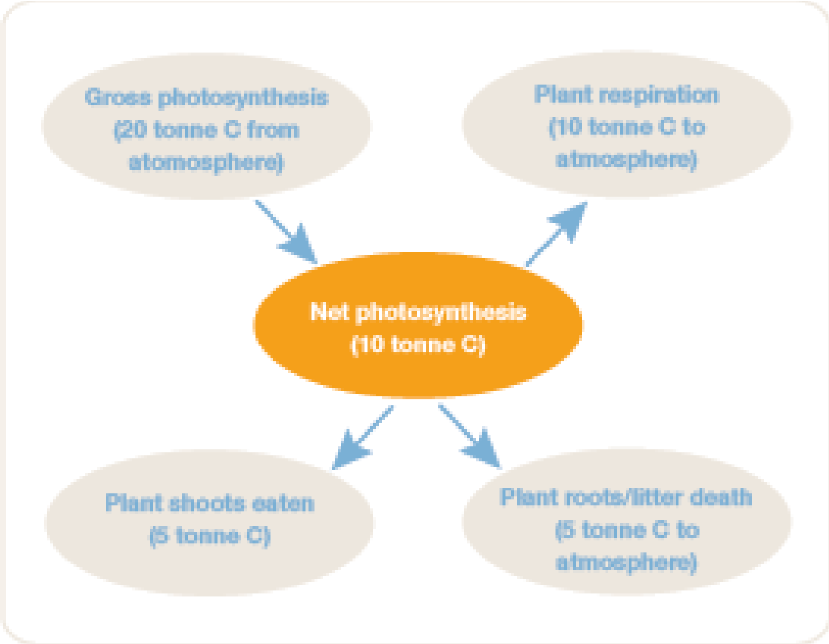
Carbon is everywhere and in everything we use. Pasture is no different. Carbon and N are cycled in agricultural production systems and knowledge of these cycles is used to calculate GHG emissions from these systems. CH_4 and N_2O are emitted as part of these cycles.

Carbon cycling in a grazed pasture

The carbon cycle with approximate quantities (tonnes carbon/ha/year) for a grazed dairy pasture are shown in the picture on page 39. The illustrates relative transfer of carbon between different sources and sinks, and in and out of the atmosphere.

- About half the CO_2 gas taken from the atmosphere by photosynthesis of plants is converted to a more complex form of carbon called 'biomass', or 'herbage' in the case of pasture. The rest is returned to the atmosphere as CO_2 through plant respiration.
- About half the carbon in herbage is stored as plant roots while the other half is in shoots that can be consumed by animals.
- Pasture that is not eaten dies and goes onto the soil surface as litter.
- Soil respiration also returns CO_2 to the atmosphere as roots and litter are broken down by soil microorganisms. In this case we have assumed soil carbon levels remain relatively stable unless productivity is changed (see section on 'Soil Carbon' page 43 for more detail).

Annual carbon fluxes and sinks/ha in a grazed pasture

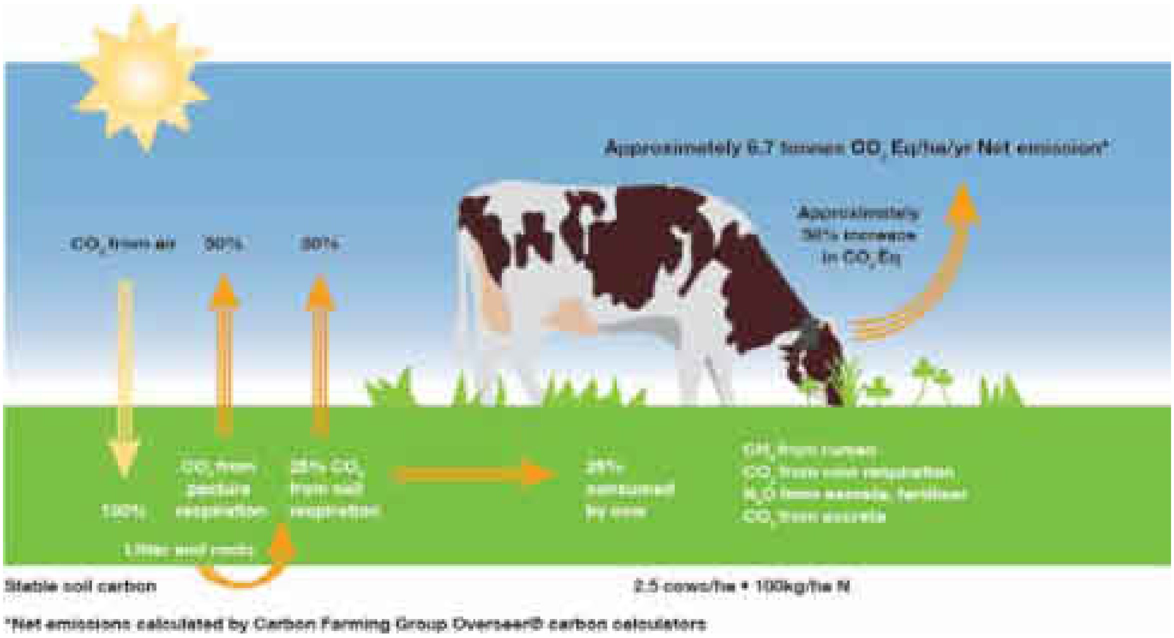


NZ Dairy, adapted from Harris, 2008

The grazing animal

If pasture was cut and left to decompose the carbon would return to the atmosphere as CO_2 and there would be no change in GHGs, only cycling. The digestion of pasture by ruminants makes the difference. Agricultural livestock transform pasture carbon into different GHGs more potent than the original CO_2 from which it came. CH_4 is more efficient at absorbing infrared radiation than CO_2. N_2O released from the breakdown of animal excreta and fertiliser is similar in this respect.

Carbon cycle under grazed pasture



Agricultural GHG or carbon calculators

Annual GHG emissions can be calculated from the inputs to the farm including:

- Energy (electricity and fuel)
- The amount of N fertiliser applied
- Livestock numbers and their production.

Several calculators are available including:

- Carbon Farming Group **(www.carbonfarming.org.nz)**
- Lincoln Carbon calculator **(www.lincoln.ac.nz/carboncalculator)**
- OVERSEER® **(www.agresearch.co.nz/overseerweb).**

Emissions are calculated as CO_2 Eq (as discussed on page 21). A New Zealand Unit (NZU) is equivalent to one tonne of CO_2 which is the standard measure used for carbon accounting in New Zealand. These calculators use internationally agreed protocols and are consistent with the methods used to calculate New Zealand's GHG emissions which are reported under the Kyoto agreement. They combine the sources of emissions to provide an overall emissions account of a farm. New legislation passed in September 2010 requires livestock emissions to be calculated from an average value for New Zealand conditions per unit of production. Livestock emissions can be calculated by multiplying the quantity of a product by an emissions factor for that product. This could be per kg milk solids or kg of meat (see below).

The Carbon Farming Group calculator provides a ‘snap shot’ of on-farm emissions. This analysis is sufficient to assess the relative scale of GHG emissions in relation to the Emissions Trading Scheme (ETS). Other calculators such as OVERSEER® and the Lincoln Carbon calculator require a higher level of detail and are more complex.

Annual GHG emissions — Case study

A dairy farm in South Waikato produces 210,000kg milk solids from 535 cows on 178ha and sends 80 cull cows to the works at 250kg carcass weight per head. Included in the operation is:

- A 40ha dairy run-off
- 140 yearling heifers
- 120 rising two year-old heifers.

Around 5,000 stock units are farmed in total.

Annual GHG emissions from the case study farm are described in the table below. Note that livestock are the source of 86% of emissions from the case study farm (1,606 of the total 1,876units). The Carbon Farming Group calculator was used to prepare this table **(www.carbonfarming.org.nz).**

Annual GHG emissions from a 535 cow dairy farm

GHG source (annual emissions)		Emissions factor	Tonnes CO_2 (NZU)
Petrol	1,500 litres	0.00234[1]	4
Diesel	11,000 litres	0.00268[1]	29
Electricity	62,240 kWh	0.00023[1]	14
Nitrogen	39 tonnes	5.72[2]	223
Milk Solids	210 tonnes	6.14[2]	1290
Cull cows	80 head	1.98[2]	158
Carcass weight (cull cows)	20 tonne	7.9[2]	158
	Total		**1876**

[1] From New Zealand Greenhouse Gas Inventory (unit of measure x factor = tonnes CO_2/unit of measure) **www.mfe.govt.nz**

[2] From Regulations for Agriculture in the NZ ETS. This can be found at: **www.maf.govt.nz/climatechange/agriculture/EmissionsFactors_AgETS.pdf**. Note that two calculations are required for sales of livestock to meat processors, number of head killed x factor and carcass weight of livestock x factor.

Measuring agricultural GHG emissions

The methods used by the carbon calculators are based on measurements of GHG emissions from ruminants. The following descriptions have been summarised from the '5 year Science Progress Report 2002–2007' of the New Zealand Pastoral Greenhouse gas Research Consortium (PGgRc).

Animal methane emissions

There are two main techniques for estimating animal CH_4 emissions:

- Sulphur hexafluoride (SF_6) gas tracer technique
- Direct time series measurements using a respiratory chamber.

The SF_6 gas tracer technique is the only standard method for grazing animals. It involves drenching with a slow SF_6 gas releasing capsule and attaching an evacuated tube yoke around the animals' neck with a sniffer pipe that constantly samples the air exhaled (see pictures below). SF_6 gas is released at a constant rate and measured to benchmark the CH_4 collected.

Cow, sheep and deer harnessed and yoked during trials to measure CH_4 emissions

Photo courtesy of PGgRc

The other far more sophisticated method involves placing animals in a special air-tight box with controlled air flow and the exiting gases are analysed in real-time (as shown in the picture on page 42). Although more expensive, this technique offers instant results that are far more accurate and responsive to changes. The SF_6 gas tracer technique integrates data over time whereas the respiratory chamber method provides a continuous stream of data with time.

A sheep in respiratory chamber

Photo courtesy of PGgRc

Nitrous oxide emissions

Measurements of N_2O emissions from the soil are carried out by covering pasture soil with an airtight cover and sampling the trapped gas above the soil for N_2O (shown in the picture below). There are variations on this basic concept which take in larger areas of pasture (up to $10m^2$).

Measuring nitrous oxide emissions with collection chambers

Photo courtesy of AgResearch

Soil carbon

This section covers:

- Soil carbon and productivity
- Soil carbon in New Zealand
- Impacts of management on soil carbon
- Soil organic carbon and organic matter (OM)
- Soil carbon trading and the ETS
- Soil carbon in other parts of the world
- Biological preparations.

Tutor notes

Suggested activities:

- Explain how building soil carbon aligns with good soil management and improves productivity.
- Relate typical soil carbon and organic matter (OM) levels in New Zealand soil to changes in soil carbon which might be expected from different management practices.
- Discuss the pros and cons of trading soil carbon and why soil carbon is outside the scope of ETS.
- Explain why there is less potential to build up soil carbon in New Zealand soils compared with Australian soils.
- Discuss the role of biological soil preparations in modern agricultural systems.

Soil carbon

Soils are vital to life on Earth and contain more carbon than vegetation and the atmosphere combined. Increasing soil carbon is beneficial for soil quality and functioning. Building OM builds soil carbon which improves the chemical, physical and biological fertility of the soil and is considered good soil management . The ability of the soil to provide nutrients and water to plants is enhanced as humus (OM) is increased. This also improves soil structure and strength, provides a better environment for microbiological activity and increase water holding capacity. Attention to this detail and improving these attributes will help the soil, and therefore the farm, tolerate some of the predicted extreme events of climate change such as weather bombs and droughts. Good soil management which builds soil OM is likely to increase productivity, reducing risk and costs in the future.

While changes in soil carbon content can have a large effect on the global carbon budget, they tend not to be significant unless physical changes take place such as cultivation, drainage or deforestation. This is because soil respiration, or more correctly, respiration of microbes in the soil is the main mechanism for moving carbon between the soil and atmosphere.

Life in the soil

The soil teams with life. It has been estimated that there might be as many as 100 billion bacteria in a single gram of forest or grassland soil! Known as 'soil fauna', these microbes are also extremely abundant and rich with as many as 10,000 bacterial species. Soil fauna break down carbon in OM (roots, plant litter etc), releasing it to the atmosphere as CO_2 and also releasing nutrients for plant growth. The bulk of CO_2 captured by plants during photosynthesis is returned to the atmosphere by plant respiration. In a hectare of grazed dairy pasture, microbial respiration in the soil turns over 15–18 tonnes CO_2 Eq annually. Soil typically contains 300–400 tonnes CO_2 Eq (80–100 tonnes carbon/ha) in the top 30cm.

Carbon in New Zealand soils

Soil and pasture carbon are not currently recognised under the ETS, as they are assumed, on average, to remain unchanged under grassland. This assumption is based on results from monitoring over many decades. Added to this is the fact that it is difficult and expensive to accurately measure and validate changes in soil carbon.

Carbon and changing management practices

Soil carbon under pasture is essentially stable unless there are changes in fertiliser policy, stocking rate and/or productivity. There is scope to increase soil organic carbon in pasture soil, but not indefinitely. Where changes in soil management do occur, changes in soil carbon levels are unlikely to become apparent or measurable for up to 10 years. For example, recent New Zealand studies[3] have shown that since 1990 dairy on flat-land non-allophanic soils have lost significant soil CO_2 Eq. Soil carbon had not changed for dairy on flat-land allophanic soils, non-dairy on flat-land non-allophanic soils and non-dairy on allophanic soils. Interestingly these findings were contrary to studies of New Zealand soils prior to 1980. Changes under pasture are likely to be subtle (4 tonnes CO_2 Eq/ha/year) unlike activities such as cultivation which may release 40 tonnes CO_2 Eq/ha/year in the first year, or during the growth of a forest which may accumulate as much as 35 tonnes CO_2 Eq/ha/year.

It should also be noted that there was a second problem concerned with the amount of carbon sustained in the soil. Changes in soil carbon are largely to do with altering the amount of OM in the soil. This is not made up of carbon alone, but contains considerable amounts of other minerals such as N, potassium and selenium. For every 1 tonne/ha of carbon in soil OM, that same OM typically also contains approximately 80kg/ha of N, 16kg/ha of potassium and 12kg/ha selenium.

Systems thinking

Changing crop establishment techniques can influence soil carbon. As cultivation intensity increases so does the loss of carbon through oxidation. Zero or no-tillage systems have the best potential to retain soil carbon levels under a cropping programme.

Other management practices within farming systems can also make a difference to soil carbon levels. For example, a closer look at crop residue management shows that burning cereal straw for electricity generation instead of coal would actually lead to considerably greater climate change mitigation than incorporating straw into soil. This demonstrates that all farm management practices need to be thoroughly analysed for mitigation benefit.

3 'Gains and Losses in C and N Stocks of New Zealand Pasture Soils Depend on Land Use'. By L.A. Schipper, R.L. Parfitt, C. Ross, W.T. Baisden, J.J. Claydon, S. Fraser, 2010. To be published in Agriculture, Ecosystems and Environment, Elsevier B.V. doi:10.10,16/j.agee.2010.10.005.

Soil organic carbon and OM

Soil OM is calculated from soil organic carbon. Hill Laboratories soil testing information shows that organic carbon x 1.72 = OM %. They have categorised New Zealand soils into five groups relative to organic matter levels.

Comparison of soil organic carbon and organic matter for New Zealand

	Organic C (%)	OM (%)
Very low	<2	<3
Low	2–4	3–7
Medium	4–10	7–17
High	10–20	17–35
Very high	>20	>35

Climate, soil type and rainfall have a strong influence on soil OM. Some data has come through from the Agriculture Research Group on Sustainability (ARGOS) which compares production systems across four sectors of New Zealand agriculture. Of particular interest are comparative data for a range of features of New Zealand pastoral farms which have either conventional or organic management systems. The table on page 47 shows that organic dairy farms had significantly higher OM than conventional dairy farms. Management systems had no effect on soil OM in sheep and beef farms. Data for kiwifruit orchards was similar to that for dairy farms indicating that as farming intensity increased so did the differences between organic and conventional management systems on soil carbon. The dairy farms in the ARGOS study would be classed as high OM and sheep and beef farms medium OM. While soil OM levels were higher under organic kiwifruit production, productivity was lower indicating with organic kiwifruit that soil carbon should not be considered in isolation and is associated with the production system.

While the ARGOS study reports differences in soil OM between conventional and organic dairy farms, it was commented that generally dairy farms retained good-to-excellent soil quality and showed that organic and conventional systems can produce similar soil quality. Further detailed analysis which includes productivity and profitability, needs to be carried out to properly compare conventional and organic farming systems as a wide range of factors are involved, soil quality and carbon levels being only one of them.

Effect of farming systems on OM (0–7.5cm depth)[1]

	Organic	Conventional	Significance (lsd)	Range
Dairy[2]	15.6	14.4	* (1.2)	5.8–32.7
Sheep and Beef[3]	8.4	8.4	n.s. (0.7)	4.6–19.4
Kiwifruit(green)[4]	9.8	8.8	* (0.05)	3.4–15.5

* Significant at 5% level (lsd = least significant difference); n.s. = not significant.

[1] Adapted from Carey et al 2008[4].

[2] 24 North Island dairy farms are compared (12 conventional matched with 12 organic).

[3] 24 South Island sheep and beef farms are compared (12 conventional matched with 12 organic).

[4] 24 New Zealand kiwifruit orchards (data shown for green kiwifruit only) (12 conventional matched with 12 organic).

Other parts of the world

In other parts of the world stories of 'growing soil carbon' abound so why can't we? Several reasons:

- New Zealand grassland already has relatively high soil carbon content (average around 11% OM).
- Adding more is not as easy as it might be in areas with very low carbon to start with (for example <3%OM).
- Carbon accumulation rates are greater in cooler climates, and in light, poorly drained soils.

Selling soil carbon

A change in management practice is required to effect a permanent change in soil carbon which may potentially be recognised by carbon traders. While agricultural soil carbon is outside the ETS, some farmers are looking to sell credits from soil carbon increase on the voluntary market. This is not straight forward at present. The best advice for pastoral farmers, especially those who feel they are increasing OM levels, is to ask for an organic carbon test every 4–5 years as part of the routine testing programme to establish trends for their property.

Alternatively, the second edition of the Visual Soil Assessment Field Guide[5] includes an environmental scorecard to assess the potential for carbon

4 'Soil Properties on ARGOS Dairy and Sheep & Beef Farms', 2007. By P. Carey, D. Lucock, J. Benge. Published in 2009 ARGOS Research Report: Number 08/04 ISSN 1177-7796 (Print). www.argos.org.nz/pdf_files/Research_Report_08_04_Soil_Properties_on_ARGOS_Dairy_and_Sheep_&_Beef_Farms_2007.pdf

5 'Visual Soil Assessment Volume1: Field Guide for Pastoral and Cropping on Flat to Rolling Country. Second Edition, 2009: by T.G. Shepherd. Published by Horizons Regional Council, Palmerston North (119p).

sequestration under pasture and cropping. In relation to this farmers should know what their OM levels are and if soil carbon is reducing, maintaining or rising. They can then monitor the impact of their management practices on soil carbon and in the future be in a position to take advantage of opportunities, or at least not be penalised, should soil carbon become part of the ETS.

Soil carbon in Australia

While the situation in Australia is likely to change with time and as government programmes develop, the following is a snap shot of the current situation.

To date there has only been limited sales of soil carbon from Australia on an unregulated, voluntary market. This is typically at a low value as there is little burden of proof or permanence required by the seller. The Chicago Climate Exchange was an example of that type of market.

Australia's equivalent to the ETS, the Carbon Pollution Reduction Scheme (CPRS), will not recognise soil carbon credits. Instead, the National Carbon Offsetting Standard has been developed to provide a means for accrediting voluntary markets for soil carbon. It seems likely that soil carbon credits will be saleable on a regulated voluntary market where land management practices have been changed and accumulated carbon can be measured. Reports of the potential value of these credits range from $10 to $25/tonne CO_2 Eq.

Land management changes include:

- Applying biological preparations in place of solid fertilisers (note 1 below)
- Replacing annual with permanent pasture (note 2 below)
- Moving from conventional cultivation to no-till (note 3 below) .

These are pilot schemes looking for government backing.

[1] Prime Carbon — Ken Bellamy **www.primecarbon.com.au**

[2] Australian Soil Accreditation Scheme — Dr Christine Jones **www.amazingcarbon.com**

[3] Carbon Farmers of Australia, Michael Kiely **www.carbonfarmersofaustralia.com.au**

Biological preparations

There is mounting evidence that soil OM levels may be improved on farms after the application of biologically based preparations. Many farmers testify to the value of these products, but they should be treated with caution. Seldom are results comparable, repeatable or measured with any accuracy. Farmers are advised to visit the farms involved and talk to the farmers, not just the ones the supplier recommends. If they are prepared to go ahead, farm trials should be carried out, splitting paddock applications or using some sample paddocks. Measurements should be taken (soil OM, pasture growth rate, grazing days) to compare the new product with your normal management or baseline situations. Unless this approach is taken and some sort of control is established, it will not be known if any benefits or problems that eventuated were a function of the product applied or some other variable like the weather.

Further reading

'5 year Science Progress Report 2002–2007'. Published by the New Zealand Pastoral Greenhouse Gas Research Consortium (PGgRc).
ISBN 978–0–473–13021–3 available from **www.pggrc.co.nz**

'A Literature Review of Soil Carbon under Pasture, Horticulture and Arable Land Uses'. Report prepared for AGMARDT by AgResearch. A. Ghani, A. Mackay, B. Clothier, D. Curtin and G. Sparling. October 2009.

Topic 3

Efficient Resource Use

This topic covers efficient resource use:

- Nutrient management and climate change
- Reducing N_2O emissions
- Reducing CH_4 and CO_2 emissions
- Energy and irrigation efficiency
- Soil conservation and riparian management.

Nutrient management and climate change

This section covers:

- Nutrient management
- Fertiliser decisions
- Nutrient budgeting and climate change
- Manipulating farm management to reduce emissions.

This section describes the role of nutrient management in reducing on-farm GHG emissions and includes an introduction to computer models of farm systems such as OVERSEER® and Farmax®.

Tutor notes

Suggested activities:

- Explain the fundamentals of nutrient management.
- Discuss how fertiliser application decisions are made.
- Examine how nutrient budgeting may reduce GHG emissions.
- Examine the importance of effluent management in nutrient budgets.
- Describe how the impact of changing farm systems and nutrient management can be assessed for a farm business.
- Relate some of the changes that can be made to a farm system to improve the efficiency of nutrient use and how that translates into reduced GHG emissions.
- Examine the relationships between GHG emissions, productivity and profitability in a farm system.

Nutrient management

Matching nutrient supply to demand is a key strategy to maximise returns from fertiliser inputs. This also helps to reduce emissions as excess application is avoided. For example, limiting losses of N fertiliser as N_2O and leaching:

- Reduces GHG emissions
- Maintains water quality
- Maintains efficiency of fertiliser use.

Efficient use of inputs is important for productivity as well as reducing GHG emissions.

Nutrient management basics

A good starting point to developing a profitable strategy for fertiliser application is to measure the level of soil fertility on the farm, in terms of pH, P, K, S, Ca, and Mg. These tests, along with past fertiliser history, will assist in establishing appropriate pasture fertiliser applications. Annual soil sampling is required to monitor an increase in soil nutrient levels from capital fertiliser inputs or to fine-tune maintenance requirements.

A key issue on dairy farms is effluent management. Areas to which effluent is applied should be tested separately as effluent is a source of carbon and nutrients, and will require specific treatment from fertiliser application. High N and K levels may be found in these areas so application of fertiliser should be adjusted accordingly. Excess N will lead to N_2O emissions when soils are wet. Recent trials have shown that strategic use of crops (such as maize) can improve utilisation of soil nutrients and address potential nutrient imbalances caused by effluent application. For more detail see **www.ew.govt.nz/PageFiles/1189/FAR%20best%20management%20practices%20-%20web.pdf**

Deciding on fertiliser nutrient requirements

Fertiliser nutrients required are determined for each individual farm based on:

- Knowledge of the farm's soils
- Animal production
- Farm management systems.

For example, the material soils are formed from determine:

- How much P fertiliser is required to increase soil test levels
- How well it retains sulphate sulphur against leaching
- Whether or not there is any K mineralised from the soil.

The amount of milk going off the farm and the stocking rate, milking times, effluent management, forages and supplementary feed used all affect additions, losses and movement of nutrients onto, off and around the farm.

Nutrient budgeting and GHG emissions

The potential for individual farms to reduce their GHG emissions will be specific to the production system, management goals and resources available on the farm. Customised computer models of New Zealand farms have been in development for more than 10 years now and are sophisticated enough to deal with most (but not all) of the specifics of individual farm systems. Two such models have been used to investigate how, among other things, nitrification inhibitors might be used to reduce or adapt to climate change. These were:

- OVERSEER® — developed by AgResearch, examines the impact of nutrient use and flows within a farm (as fertiliser, effluent, supplements or transfer by animals) and possible environmental impacts. The system is widely used by the New Zealand agricultural industry and can take account of the nutrients applied as effluent to provide an accurate balance. Fertiliser and nutrient management advice is freely available from the DairyNZ website **(www.dairynz.co.nz/page/pageid/2145836784).** OVERSEER® is also freely available **(www.agresearch.co.nz/overseerweb).**
- Farmax® — examines pasture production and economics, and how that might affect productivity and profitability. This is a support software package that can model a whole farm and is designed for systems analysis, both strategic and tactical, as well as monthly monitoring and reporting.

A model Hawkes Bay deer farm

This example is from a deer farm known as 'The Steyning' in Tikokino, Hawkes Bay. Modelling suggests that significant increases in profitability can be achieved on a 293ha deer farm while reducing both on-farm nutrient requirements and GHG emissions. Full detail can be made available if necessary. This farm modelling was carried out for MAF and will be published as a fact sheet in the near future.

A base farm situation of deer and bull beef was compared with six other options including:

1. The same livestock policy as the base model, but with no N applied and a maintenance phosphate input. The livestock numbers were also reduced so that the model was feasible.
2. An all deer policy but with no N applied and a maintenance phosphate and sulphur input. Livestock selling policies were the same as the base scenario but the overall numbers of deer increased to the feasible line.
3. The same deer numbers and policy as the base but a different purchasing strategy for the bull enterprise. No N applied and a maintenance phosphate input.
4. The same deer numbers and policy as the base but running a one year ewe flock instead of the bull enterprise. No N applied and a maintenance phosphate and sulphur input.
5. The same bull policy as for Scenario 3 but no deer enterprise. Bull numbers were lifted to the feasible line. No N applied and a required increase in the sulphur input to lift to maintenance levels.
6. The same policy as the base but after 10 years of increasing P levels in the soil (through the base scenario model), and therefore taking the pasture production from the current 94% of potential to 98%.

Figure 1 below shows the gross margins and GHG emissions for base situations compared with modelled scenarios. Figure 2 shows the impact of different farm scenarios on GHG production and efficiency. Both figures show a range of outcomes and the relationship between total GHG production and efficiency (kg GHG per kg output) and profitability as represented by gross margin.

The modelling showed there is the potential to increase profitability while reducing nutrient usage and GHG emissions on this farm, but there are trade-offs between nutrient use, GHG emissions and profitability. For example, while Scenario 5 was the most profitable, it also produced the largest quantity of GHG emissions per hectare.

Figure 1: Gross margin per ha for various scenarios and the associated GHG emissions — The Steyning deer farm

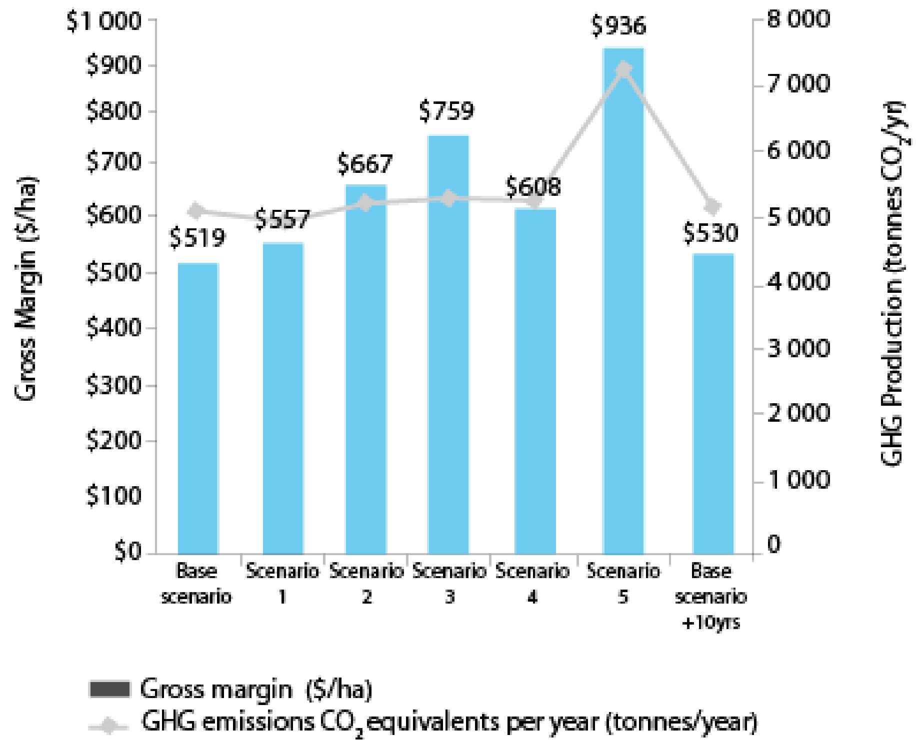
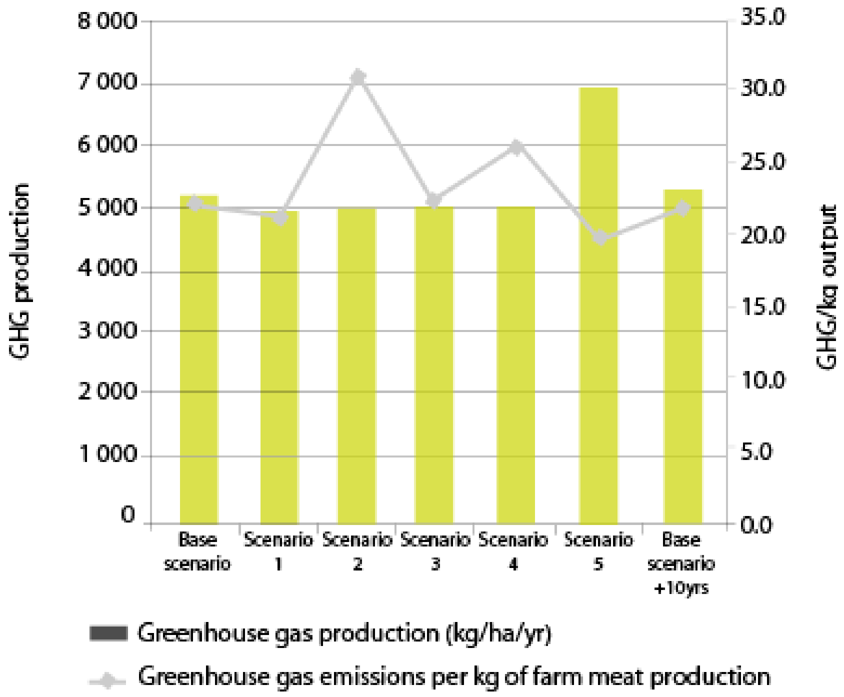


Figure 2: Effect of farm scenario on GHG production and efficiency



Waikato farms and nutrient budgeting

A further, more complex study involved a number of Waikato farms. This farm modelling was carried out by AgFirst Waikato for Environment Waikato, Ballance Agrinutrients, DairyNZ and Fonterra to investigate the costs for farm businesses of increased nutrient efficiency[1]. Ten Waikato dairy farms and four sheep and beef properties were used. The target of the modelling was to reduce N leaching.

A combination of the following had the greatest impact in reducing N leached from the case study farms:

- Reduced N use
- Better effluent capture and management
- Grazeable forage crops
- Slightly lower stocking rates.

The study found that the most intensive dairy farms suffered a 7% reduction in their return on assets when modelled to improve nutrient efficiency, while average to low intensity farms showed only a small change. Notably GHG emissions were reduced by 12% when nutrient efficiency increased as compared with existing operations.

1 'Upper Waikato Nutrient Efficiency Study'. February 2010. A. Dewes, A Stafford, R. Abercrombie, C Rutherfod and M. Scarsbrook. Published in Proceedings of the Fertiliser and Lime Research Centre Workshop 2010: Farming's Future: Minimising Footprints and Maximising Margins, Massey University, Palmerston North. www.massey.ac.nz/~flrc

Reducing N_2O emissions

This section covers:

- Nitrification inhibitors
- Manipulating farm management to reduce emissions
- Grazing management
- Soil quality and N_2O emissions
- Effluent management
- Management of fertilisers
- Enhancing N-fixation by legumes.

This section focuses on the influence of farm management practices on N_2O emissions and how changing the management policies may impact emissions productivity and profit.

Tutor notes

Suggested activities:

- Discuss the interactions between GHG reducing strategies (such as nitrification inhibitors) and farm productivity and profitability.
- Explain the key role grazing and soil management has to play in managing N_2O emissions, soil carbon and soil quality.
- Discuss the importance of effluent management in reducing N_2O emissions.
- Examine the impact fertilisers may have on GHG emissions and how emissions from fertilisers can be minimised.
- Discuss wider farm systems thinking, including choice of forage and the place of wetlands in relation to N_2O emissions.

Reducing N_2O emissions

The strategy with the most potential to consistently reduce GHG emissions and maintain or improve profitability was predicted to be increasing breeding worth (BW) of the herd. As BW increases, the efficiency of conversion of DM to milk increases and CH_4 losses are reduced.

What other management options are there to reduce N_2O emissions?

The greatest emissions occur after grazing events, particularly on poorly drained soils during winter. Therefore avoiding pugging and using on-off grazing in wet conditions, will reduce emissions. Ideally the effluent from a stand-off area should be captured and spread back onto dry soils. Studies have shown that emissions may be more than doubled when urine is applied to wet soils.

Increasing soil OM reduces the susceptibility of soils to compaction by increasing the resistance to traffic. Increasing moisture levels reduces soil strength and so pugging, compaction and N_2O emissions are more likely.

Rating the soil for potential soil carbon accumulation and GHG emissions

An improvement in soil carbon will lead to a reduction in emissions. Attributes to assess soil carbon and potential GHG emissions include:

- Soil texture (clay content)
- Soil colour and earthworms (aeration, OM)
- Root activity (depth and density)
- Pasture growth
- The amount and form of N applied.

The second edition of the 'Visual Soil Assessment Guide' provides photos for visual assessment of soil quality to assess productivity and soil health.

Effluent management

Good practices for effluent capture and treatment will help make the most of fertiliser and carbon values while minimising N_2O emissions. Effluent applied to land at rates that exceed soil water holding capacity and pasture uptake of N will create the greatest potential loss to the atmosphere as N_2O. Industry guidelines should be used for good practice when managing farm dairy effluent. This includes avoiding N fertiliser use in cold and wet conditions to ensure nutrient is taken up by actively growing pasture and not lost to leaching and/or the atmosphere through denitrification.

Fertiliser

Emissions from conventional, synthetic superphosphate and urea fertilisers include CO_2 released during manufacture and N_2O during its use. These emissions can be reduced by:

1. Reduced reliance on fertilisers produced using non-renewable fossil fuel sources such as urea and superphosphate. Alternatives include:
    - Rock phosphate
    - Lime fortified superphosphate
    - Worm casts
    - Animal manure
    - N from legumes.

    Retaining crop residues, using cover crops and fallow periods can also improve soil fertility. These sources require less energy from fossil fuels as compared with synthetic fertilisers.
2. Boosting legume (white clover) growth. Clovers provide very high quality feed for animal production, as well as making a major contribution of N through their N-fixing root nodules. On average, for every kg of N fertiliser used, clover N fixation is reduced in the short-term by about 0.5kg N. When N fertiliser is withheld, clovers begin reverting to normal N-fixation patterns. Some farmers are boosting legume production and N-fixation through annual reseeding of clover. Other factors that limit white clover growth include:
    - Moisture stress
    - High temperatures
    - Cultivar choice
    - Competition from grasses (shading, especially during establishment)
    - Pests and diseases
    - Soil acidity ($pH < 5.8$)
    - Low soil carbon
    - Low soil fertility (other than N) including low calcium levels and poor soil aeration.

Soils which support a proportion of clover (30% of DM) are likely to have:

- Higher OM
- Better structure
- Lower fertiliser N requirements
- Lower N_2O emissions than those with low clover (5% or less of DM).

3. Improving fertiliser application accuracy using SPREADMARK certified equipment and GPS. Basic fertiliser optimisation includes SPREADMARK accreditation and means that spreading operators have been trained, their equipment independently assessed and systems audited **(www.fertqual.co.nz/page.php?5).** SPREADMARK certification ensures the equipment operates within an expectation of accuracy to minimise under and over application (or 'striping') of fertiliser application.
4. Ensuring the timing and rate of N application is optimised for pasture response. Best practice guides should be used and these are available from industry groups, such as DairyNZ, Beef+Lamb New Zealand, regional councils or fertiliser suppliers.

   The following points are from best practice guides indicated in Further Reading at the end of this section.

   - **Rate —** N fertiliser is most efficient when applied between 20–40kg N/ha. Annual applications of N fertiliser should not exceed 150–200kg N/ha to reduce the risk of nitrate leaching and associated environmental problems.
   - **Timing —** It is best to apply N fertiliser when the pasture cover is between 1,500–1,800kg DM/ha. This ensures there is sufficient plant leaf area for photosynthesis so that plant growth to occur.
   - **Grazing interval —** Allow sufficient time between application and grazing for the N response to be expressed. Short grazing interval (14 days after N application) will result in reduced response and potentially high N levels in the urine as N concentration will be high in pasture.
   - **Temperature —** In spring time, it is best practice to apply N fertiliser when the soil temperature is above 4°C. This will ensure plant uptake of N occurs. In autumn, N fertiliser should be applied before soil temperature drops below 7°C.

Reducing CH_4 and CO_2 emissions

This section covers:

- Animal productivity and CH_4 emissions
- The role of feed budgeting
- Waste management
- Reducing CO_2 emissions
- Opportunities for energy savings
- Irrigation efficiencies
- Biochar.

This section relates how important efficiencies in the use of feed and energy on the farm may contribute to reducing GHG emissions and farm probability.

Tutor notes

Suggested activities:

- Examine the relative contribution of CH_4 and CO_2 to overall farm emissions.
- Explain how improving efficiency of feed conversion reduces GHG emissions per unit of output, and farm profitability.
- Discuss the importance of feed budgeting in maximising conversion of feed to saleable product.
- Discuss how waste management relates to emissions from the farm.
- Examine opportunities to improve energy efficiency on the farm and how that contributes to reduced CO_2 emissions.
- Describe how water use efficiency of irrigation systems impacts on farm costs and emissions.
- Discuss the potential role for biochar to address GHG emissions.

Reducing CH_4

Matching animal nutrient requirements to demand ensures efficient utilisation of feed and minimises the amount of CH_4 emitted per unit of output. By improving typical livestock key profit indicators such as lambing percentage, liveweight gain and milk solids per cow, CH_4 emissions will be reduced and productivity and profitability will also be improved. This is a common focus of existing farm business managers. For sheep and beef farms, a shift away from sheep and deer toward beef would reduce emissions cost per kg of meat produced.

As for other aspects of farming, maximising the conversion of feed (DM) into saleable product is key to maximising farm profitability. Avoiding wastage and shortages, or allowing feed quality to drop will reduce income and farm efficiencies. Maximising feed conversion rates also reduces GHG emissions per unit of output. Implementing good feed budgeting and management skills to improve these efficiencies will result in improvements to GHG emissions as the amount of feed used for animal maintenance is reduced relative to the proportion used for production.

Feed type can also influence GHG emissions. For example, feeding condensed tannins from plants such as lotus or sulla reduces CH_4 emissions in comparison to ryegrass by about 15%. Offering these feed types is outside normal practice at present and would require specialist production systems. However, it may be that future production systems need to become more sophisticated as environmental concerns such as GHG emissions gain increasing recognition in our markets.

Waste management

With the use of manure digestors and/or the pyrolysis[2] of manure, much greater reductions in GHGs could be achieved as well as providing a local energy source. Having the capacity to store manure in a sealed anaerobic digestor and to time the application can mitigate both CH_4 as well as N_2O emissions from the soil. This is because the nitrogenous material breaks down under conditions that are less favourable for N_2O formation.

2 Pyrolysis is the burning of biomass like manure without oxygen. This process is used to produce biochar (see later in this section).

Carbon dioxide

Energy

On-farm energy sources (fuel and electricity) make up the bulk of CO_2 emissions from the farm. Investment in technology can improve energy efficiency in a number of ways:

- 25% electricity savings are possible from using heat recovery systems, variable speed vacuum pumps, milk vat insulation and energy efficient lighting in milk harvesting systems
- Exploiting renewable energy sources such as wood, solar, wind, water or even biogas from effluent for power generation
- Investing in fuel efficient farm machinery
- Adopting no-tillage techniques can save two thirds of fuel used (17l/ha) in comparison with conventional cultivation (50l/ha) while minimising losses of soil carbon, retaining soil structure and long term viability of cropping soils
- Maximising irrigation water use efficiency. For example, uniformity of application is estimated to be typically 70%. Increasing this to 90% could increase the total area that can be irrigated with the same amount of water by around 50%, improving energy efficiency of irrigation.

Sheep and beef farms will have the best chance of reducing GHG from energy use as energy use is low (house, woolshed, water reticulation and farm vehicles). Electricity could be generated on-farm from wind, solar and small hydro-generation. Biodiesel and ethanol could be used for vehicles. These sources of energy would have low or no GHG emissions and may be viable as energy prices increase.

Irrigation efficiency

A major potential for savings (electricity and water) could come from improved irrigation efficiency. A recent survey found that the total cost of water applied ranged from $1.60 to $2.60/mm/ha which indicates potential for improvement. The main cost was the amount of energy used for pumping. Focusing on maximising water use efficiency is the key. This requires rainfall and soil moisture monitoring in relation to soil water holding capacity so that over and under application is avoided. It also relates to the efficiency of the system being used to apply the water. Poor irrigation design and maintenance result in uneven application.

While scheduling irrigation application depth and timing to optimise pasture response is critical, accuracy and uniformity are important to irrigation efficiency and cost. The less uniform the application, the greater the depth of water required to get the same pasture response. For example, if the goal is to irrigate 90% of a field that has a 50mm soil water deficit, increasing uniformity from 70% to 90% would decrease the required average application depth from 95mm to 60mm and could increase application efficiency from 51% to 83%. It would also decrease the irrigation time and therefore increase the total area that can be irrigated (McIndoe, 1998).

List of websites with information on how to save energy

Website	Description
www.dairysavings.co.nz	Genesis Energy tips to save power and savings calculator
www.meridianenergy.co.nz/yourfarm	Meridian Energy power saving ideas
www.maf.govt.nz/climatechange	Case studies on energy efficiencies on farms
www.ruralenergy.co.nz/dairyaudit/index	Technology for energy saving on dairy farms
www.energywise.org.nz	General tips on energy efficiency
www.emprove.org.nz	Tips for reducing business energy use
www.eeca.govt.nz	Energy Efficiency and Conservation Authority
www.4million.org.nz	'4 million careful owners campaign' — how individuals can cut energy use
www.agrilink.co.nz	Energy reports and tools

An excellent guide on emissions efficiencies is also available at:
www.ew.govt.nz/PageFiles/1189/farmmanagementissues5.pdf

Biochar

Research into systems incorporating biochar may also provide strategies for reducing the impact of GHGs (Lehmann, 2007, Hedley et al, 2008). This may occur as carbon could be stored as biochar and added to soils to build up soil carbon. New Zealand has recently established a biochar network to share knowledge and international research in this area **(www.biochar.co.nz/index.html).** However, most of these strategies currently have minor impact or are not practical. Some research in Western Australia has shown crop yield improvements from incorporation of biochar into soil (see **www.anzbiochar.org/** for details).

Further reading

'Visual Soil Assessment' Volume 1, Second Edition. Field Guide for Pastoral and Cropping on Flat to Rolling Country. 2009. T.G. Shepherd. Published by Horizons Regional Council, Palmerston North (119p).

'Getting the Bangs for your Fertiliser Bucks'. Ants Roberts, Ravensdown Fertiliser Co-Operative Ltd, PO Box 608, Pukekohe available from **www.side.org.nz**

'Using Nitrogen: What is Best Practice?'. K. Cameron, H. Di, J. Moir, R. Christie and R. Pellow Lincoln University and Fertiliser Co-operative Ltd. Available from **www.researcharchive.lincoln.ac.nz/dspace/handle/10182/576**

Soil conservation

This section covers:

- Managing soil losses from earthworks, pugging, cultivation and slippage
- Integrated land management
- The role of planting trees in land management
- Steepland soil protection
- Co-benefits of integrating forestry into farm properties and businesses
- Forests and carbon footprints
- Riparian management and wetlands.

Tutor notes

Suggested activities:

- Discuss how soil conservation relates to projected changes in the climate, emissions, soil carbon and productivity.
- Describe how matching land use to land capability could improve the sustainability of land management, especially in steepland.
- Examine the range of benefits afforestation may provide to farm businesses in addition to stabilising at-risk soils.
- Determine how forest and land management practices impact on the carbon footprint of agricultural products.
- Discuss management of riparian areas in relation to on-farm and wider community benefits.
- Explain the potential to gain carbon credits from plantings for soil conservation.

Soil conservation

Soil is generally lost from a farm when exposed to rain, wind or flowing water as a consequence of earthworks, pugging, wallowing, cultivation or slippage of unstable soil mass. Soil may be lost from a farm due to erosion by water and wind. These losses tend to remove topsoil and smaller soil particles where nutrients and OM are concentrated. Therefore soil erosion represents a serious loss of productive wealth from the farm. These losses may be exacerbated by the more intense rainfall events expected as a result of climate change. However, the principal mechanism of protection remains the same in that soil cover should be maintained and exposure of bare soil should be minimised.

Earthworks

Installing tracks, races and dams require earthworks and are part of farm development. Good practice guidelines should be followed. Special care should be taken to ensure spoil from the works is positioned to be secure if there is an intense rainfall event.

- Simple sediment control measures to divert run-off away from earthworks and trap sediment leaving earthworks should be used.
- Prevent entry of run-off from earthworks into waterways.

Pugging

Soil pugging may occur from grazing of wet soils. Pugging compacts and seals the soil so water infiltration is reduced and run-off is increased. It should be avoided for soil health reasons as soil structure, porosity and aeration is reduced. Pugging destroys soil structure then reduces OM and soil carbon levels, releasing CO_2. Surface water flow may wash soil away, especially if pasture cover is low or has been damaged and bare soil is exposed. As pasture cover and soil recovers, the risk of soil erosion is reduced. In some cases farmers nominate sacrifice paddocks, where stock grazing and feeding out is intensified and pugging and soil damage is expected. These areas should be located in zones which are not at risk from flooding or on sloping land at risk of erosion.

Cultivation

- Removes vegetative cover
- Reduces particle size
- Destroys soil structure
- Oxidises soil carbon.

In some cases cultivation is necessary to establish new pasture or a crop, but only if the soil requires levelling, liming or perhaps where a thatch has developed. In all other cases reduced or no-tillage could be used to replace existing vegetation. Cultivation places the soil at risk from erosion by wind and water, and this represents a loss of soil fertility and carbon. Cultivated soils on sloping land are especially vulnerable. As reduced and no-tillage systems provide less control, a higher level of management input is required for success. Monitoring for insect pests such as slugs and springtails during establishment is critical to avoid crop losses.

Further reading

Case study — Franklin Sustainability Project. (Produced a booklet titled 'Doing it Right' which would be useful): **www.maf.govt.nz/mafnet/publications/rmupdate/rm6/rm6007.html**

Case study — Landwise Initiatives: Reducing Wind Erosion Risk through Improved Land Management Practices and Introduction of New Crop Establishment Techniques (see **www.landwise.org.nz/**).

Slippage of unstable soil mass

The strengthening effect of tree roots and protection provided by forest canopies can significantly reduce erosion and soil loss.

The scope of improvement has been evident in surveys of Manawatu and Wairarapa hill country farms. In comparison to unplanted sites, wide spaced poplars, willows and eucalypts reduced soil slippage by 95%.

Plantings reduced:

- Gully erosion by 50%
- Streambank collapse by 24%
- Mass movement of footslopes by 67%
- Mass movement of hill faces by 71% (Hicks, 1992; Douglas, 2009).

Soil conservation benefits are most significant on steeper unstable soils. For example, in the eastern North Island and inland Manawatu where the soils are derived from recent sedimentary parent material (mudstones and sandstones) which are unstable on slopes over 30 degrees.

Farm focus — integrated land management approach

Tree root systems and other benefits of woody vegetation cover can make steepland soils relatively resistant to surface erosion and slipping. This results from:

- Tree roots reinforcing the soil as they penetrate upper soil layers and bond them to more stable subsoils.
- Root mass created by trees covers the erodible soil and helps to hold the soil layer in place.
- Trees reduce soil moisture through transpiration, where water is taken up and used in the trees' growing process.
- Trees provide a permeable forest floor that can aid water adsorption and storage. The litter and leaf matter on and around trees helps prevent the impact from water droplets hitting open soil. It also limits the effect of water washing away surface soil particles as it passes over.

Some key approaches

There are different approaches to stabilising soils with vegetation — the approach you take will depend on your property and particular approach to farming. Three general approaches are identified below.

1. Pole planting

   This is most commonly done using open planted poplar or willow poles. It provides the opportunity to maintain ongoing grazing, while stabilising the site.

   There are many benefits of planting poplar or willow poles.

   - Erosion prone hillsides can be stabilised and sustained as farmland, because the extensive root systems of these trees bind and hold the soil in place.
   - Poles can protect farm assets like fences and tracks prone to slip damage. They work as wind shelterbelts, reduce damage to watercourses, provide shade and shelter for stock, and can sometimes be cropped as timber.
   - Poplars and willows produce useful stock feed, which can be an extra reserve during droughts. For example, about 1.4kg of fresh poplar leaves maintains a ewe for a day.

2. Afforestation for timber production

   Establishing plantation forests on steep slopes utilises the beneficial effects of trees on slope stability. Soil stability is reduced for a period after harvest as the second crop or ‘rotation’ establishes, but does not drop to the original level without tree cover.

   Key points such as species, area, location and access need to be carefully considered to ensure small timber plantations or ‘woodlots’ will be practical to manage and provide good returns. If you want to keep steep land in production and not lose it to possible soil erosion in the future then forest plantings are a good solution.

3. Native forest cover

   Encouraging the return to native forest cover for some areas of the farm may be the best option where values such as wildlife and landscape are important to you. It is a good option where steep areas in need of protection don’t provide significant grazing and aren’t practical for afforestation.

Early stages of native regeneration may already be occurring, and it may be just a matter of fencing to keep stock out to speed up reversion to forest. Where regeneration is not occurring and seed sources are not close to or on the site, planting will be required.

Steepland soil protection — help is available

A range of support services and information are available to assist you on your property. These are summarised in Appendix One. In the first instance landowners should be encouraged to contact land management officers at their regional council.

Benefits of integrating forestry into farm properties and businesses

Trees and forests in the landscape provide a wide range of benefits and environmental services, in addition to the production of wood and reduction in carbon. These benefits are currently receiving greater recognition as farmers develop strategies to cope with climate change.

Improved biodiversity

Forests provide a more diverse environment than pasture systems, with greater diversity of native birds, plants and invertebrates. Forests can also provide shelter for existing native forest remnants, and benefit aquatic biodiversity through their positive impact on water quality and flood risk. As the canopy of a new forest closes, light hungry weeds such as gorse, nodding thistles and ragwort disappear.

Stock shelter and shade

Shelter and shade provided by forests and trees can improve animal welfare and production. For example, planting three or four deciduous trees by a fence and pruning up to 3m could provide valuable shade to livestock in the summer with minimal impact on pasture production, machinery movement and the stock. Studies have shown that cows provided shade produce more that those without in a moderate Waikato summer.

Shelter can also reduce water loss and improve pasture and crop production. Well planned shelter can minimise losses from tree competition with pasture and provide a significant overall benefit to pasture production, stock and people on the farm. Shelter designed to fit with irrigation systems can reduce losses from uneven distribution and evapotranspiration.

Income diversification

Forests have considerable flexibility over when they are harvested, allowing timing of harvest to be scheduled to coincide with a period of higher timber market prices or when revenue from other farm income sources is lower. Trees can also help manage revenue and tax position. For example, there is potential under the ETS to improve cashflow by offsetting liabilities and/or gaining potential income from forest carbon credits.

Carbon footprint

The carbon footprint of farm products should also be considered. At this stage planting forests has not been accepted internationally as a method to reduce the carbon footprint of a product. However, the carbon released when a forest is harvested and the land use is charged to agriculture will be counted against the produce from that area for a period of 20 years after the forest is cut down. Under the New Zealand ETS a deforestation penalty applies to forest land cleared after January 2008 for agriculture. This could amount to a cost of $15,000/ha or more. While a new forest may not directly reduce the carbon footprint of farm products, under the New Zealand ETS the costs associated with addressing carbon emissions may be offset by income from farm forestry.

Planting a new forest on a farm will not reduce or 'mitigate' the output of GHG emissions from the farm but could offset GHG emissions and any associated costs

Riparian management

Note this is largely taken from Taranaki Regional Council publication: **www.trc.govt.nz/assets/Publications/information-sheets-and-newsletters/landmanagement-information-sheets/riparian-management-information-sheets/**

Riparian management is the term used to describe the management of strips of land that run either side of rivers and streams. It generally involves fencing and planting of strips either side of the stream. Riparian management has been implemented, to a greater or lesser extent, in many countries besides New Zealand. Its environmental effects have been the subject of much scientific study. Below are some of the findings.

Improving water quality

Dense ground cover on banks (such as ungrazed pasture) filters sediment out of surface runoff. Sediment levels in waterways are thereby reduced. Swamp vegetation (such as rush) on or near streambanks helps remove nutrients, particularly nitrogen, from emerging groundwater before it enters streams. Where fences deny or restrict stock access, animal dung and urine are eliminated from waterways. Water contamination by organic pollutants, and also by associated pathogens, is minimised. Tall-growing riparian vegetation (such as trees) minimises daily temperature fluctuations by reducing solar energy input to waterways. Water temperatures are kept cool and less algal growth occurs.

Controlling streambank erosion

Shrubs and trees with extensive fibrous root systems stabilise streambanks. Bank collapse is greatly reduced, and channel migration largely controlled, protecting adjacent farmland and buildings. Dense vegetation, such as rank grass or low shrub cover, traps silt and stores it temporarily on banks. Eventually, the build-up is scoured away and transported out to sea by a large flood.

Reducing flood impact

Removal of inappropriate vegetation, like crack willows or blackberry, enables free passage of water through floodplains. This reduces overbank flooding and silt deposits on adjacent river terraces.

Enhancing habitat

Restoring riparian vegetation, whether indigenous or exotic, creates habitats for wildlife. Corridors for bird and fish migration can be formed from the mountains to the sea, if continuous riparian vegetation is restored. Food, shelter and seclusion are created for waterfowl, fish, crustaceans and insects.

How does it benefit the farm?

Whatever is spent on it, riparian management gives a return on investment. Here are some of the ways.

- Clean water brings fewer blockages in pipes that draw water for stock, irrigation or dairy sheds, with less wear and tear on pumps and spray-lines.
- If cattle are not able to drink directly from the stream then they will not be exposed to liver fluke.
- Streambank fences enable easier stock control when mustering, keep sick stock out of streams, and reduce stock deaths by drowning, falling down steep banks, or getting bogged.
- Trees on banks, as well as shading and sheltering stock in the adjacent paddock, can provide timber for on-farm use.

Perhaps most importantly, streambank management gives better product quality, together with the marketing advantage of a 'clean green image'. Improved milk grades are obtained where dairy sheds no longer draw water from contaminated streams. On sheep and beef properties, stock are in better health and have faster weight gain when water sources are no longer contaminated by pathogens. Processing plants are increasingly likely to pay a premium for produce from farms demonstrably managed in a way that doesn't damage the environment. In future years it will be easier for them to export, now that overseas markets are starting to demand evidence that what's being purchased is contaminant-free and environment-friendly.

Off-farm benefits

Downstream neighbours will have cleaner water if stock are kept out of watercourses on the farm. Upstream neighbours will have less flooding, if fallen trees and other obstructions are removed. Neighbours on opposite banks will have less bank erosion, if the channel in between is kept clear.

Clean reticulated water is better for stock health.

Costs

Management of streambanks obviously doesn't come cheap.

- The single greatest cost is fencing. This can be as great as $16 a metre for a standard post, batten and wire fence — but can also be as little as $2 a metre, if a farmer builds low-cost systems himself.
- Alternative water supply can cost more than $1000 a paddock if a pump, pipe and trough are installed in each — but less than $100 a paddock by gravity-feeding a trough that can be shared between paddocks by innovative fence design.
- Revegetation costs at least $1000 per hectare or more for close-planting of commercial timber species by contract labour — or virtually nothing by waiting for natural regeneration of native shrubs.

A further cost is loss of grazing which must be weighed up against stock, soil and water health benefits. Lost pasture tends to be of moderate quality, due to wetness and weed infestation along the banks.

Streambank management

The banks of streams that flow year-round, through valley bottoms, river terraces, floodplains and wetlands, can be easily managed. They occupy just a small part of farms, are accessible, and can be fenced without huge expense or unnecessary disruption to grazing management. Fencing off and planting riparian areas will keep stock out of waterways but brings other issues, such as access for cleaning weeds from waterways. Help is available from regional councils to advise on appropriate plant species, planting design and, in some cases, funding for fence construction.

Wetlands

Management of wetlands can be integrated into a water management strategy on the farm, especially where natural springs occur and trace their way down to more established waterways. Fencing off these wet areas reduces soil damage and water contamination from livestock wallowing, and removes the risk of stock (such as woolly sheep) becoming trapped in bogs. Wetlands are also important to water quality, helping to filter out sediment, nutrients and other contamination. These contaminants can cause serious water quality problems if they reach high concentrations downstream (such as algal blooms). If the nutrient-rich run-off flows through a wetland first, wetland bacteria can remove most of the N and phosphorus from the water.

Wetlands can be likened to giant sponges because of the way they absorb and slowly release run-off. As floodwaters reach a wetland, the wetland plants trap the water and slow down the flow, forcing the water to seep through the soil and roots of wetland plants rather than rushing downstream. In this way, they help protect downstream areas from flooding, and through the slow release of water, they can maintain water supplies throughout dry summer periods.

Kyoto compliance, soil conservation and riparian plantings

Wide spaced planting of trees, such as poplar poles, may also attract carbon credits where areas are larger than one hectare, tree height will be over 5m and the tree canopy will cover 30% or more of the area. For example, 50 poplars per hectare with a canopy radius of 5m equates to 39% cover, enough to be Kyoto compliant. Areas such as this could be entered into the ETS to claim carbon credits which may be used to off-set emissions from livestock (see Topic 4).

How does riparian management relate to the ETS?

Where plantings are larger than one hectare and on average at least 30m wide, they may also be eligible for entry into the ETS. Gaps of up to 15m wide are allowable so waterways would be acceptable as long as the tree canopy covered 30% or more of the area. Carbon credits could be claimed with this design.

Further reading

Soil Erosion — **www.mfe.govt.nz/issues/land/soil/erosion.html**

Soil Conservation Technical Handbook — **www.mfe.govt.nz/publications/land/soil-conservation-handbook-jun01/index.html**

Managing waterways on farms: A guide to sustainable water and riparian management in rural New Zealand — **www.mfe.govt.nz/publications/water/managing-waterways-jul01/**

Appendix one

Steepland soil protection — extra information

Pole planting

Title	Publishing	Notes
Poplar and willow varieties and their attributes	Greater Wellington Regional Council — Land Management, Masterton	Two page guide on pole species and planting guidelines
Poplar & Willow Management	Greater Wellington Regional Council	
Taranaki Regional Council Sustainable Land Management Infosheets	Taranaki Regional Council, Land Management Section: No 20.Poplars & willows for fodder No 31: Poles — why plant them? No 32: Pole planting — what are the benefits? No 33: Pole planting — general principles & practices No 34: Pole planting — maintenance No 35: Poplar & willow varieties available from the Taranaki Regional Council No 36: Poplars for timber production **www.trc.govt.nz/ACTIVITIES/LANDMAN/DEFAULTACT.HTM**	Brief 2–3 page information sheets Can be downloaded from website
Afforestation		
Radiata Growers Manual	Piers McLaren, Forest Research, Bulletin No 184, 1993	
Native Trees — Planting & Early Management for Wood Production	David Bergin & Luis Gea Forest Research, Rotorua, 1995 NZ Indigenous Tree Bulletin No3	
Trees for the NZ Countryside – a planters guide	John & Bunny Mortimer Silverfish 1984	

Title	Publishing	Notes
TRC Sustainable Land Management Infosheets	Taranaki Regional Council, Land Management Section. No 6: Radiata Pine No 8: Douglas Fir No 13: Eucalyptus **www.trc.govt.nz/ACTIVITIES/LANDMAN/DEFAULTACT.HTM**	
Blackwood: A Handbook for Growers & Users	Ian Nicholas & Ian Brown, Forest Research Bulletin No 225, 2002	
Native forest restoration		
Managing your Bush Block: A Guide to Looking after Indigenous Forest Remnants in the Wellington Region	Greater Wellington Regional Council	
Restoration Planting: A Guide to Planning Restoration Planting Projects in the Wellington Region	Greater Wellington Regional Council	
Restoring our Natural Heritage: A Guide to Greater Wellington's Biodiversity Assistance for Private Landowners	Greater Wellington Regional Council	
Native Forest Restoration: A practical Guide for Landowners	Tim Porteous, Queen Elizabeth the Second National Trust, Wellington, 1993	Currently being revised
Other information		
TRC Sustainable Land Management Infosheets	Taranaki Regional Council, Land Management Section: No 7: Land Resource Inventory Mapping **www.trc.govt.nz/ACTIVITIES/LANDMAN/DEFAULTACT.HTM**	Brief 2–3 page information sheets Can be downloaded from website
NZ Land Resource Inventory (NZLRI) Sheets & Key	Landcare Research, Palmerston North	
Soil Conservation Technical Handbook	Ministry for the Environment 2001	

Topic 4

Adapting to the Impacts of Climate Change

This topic covers:

- Adaptation and mitigation to the impacts of climate change
- Opportunities
- ETS, forestry and carbon footprinting.

Introduction

Topic 1 identified potential risks to agriculture associated with expected changes to the climate. The difficult issue that land managers are likely to have to grapple with (and indeed are grappling with) is climate variability, that extreme weather events such as droughts and floods are likely to occur more often than in the past. This topic will demonstrate how several of the major impacts predicted to occur with a changing climate might be addressed.

Two key aspects of addressing climate change are adaptation and mitigation. You could look at climate change in the same way you deal with workplace risk:

- Identify the hazard
- manage or adapt to the hazard
- mitigate or reduce the cost

The same goes for the impacts of climate change. If it is not possible to avoid the risk then the risk must be managed.

- **Adaptation** to the risk involves adjustment of management practices to live with the consequences of the risk (in this case the impacts of climate change).

- **Mitigation** relates to actions to reduce or offset emissions. Effective mitigation will require international cooperation and action.

Adaptation to the impacts of climate change may be both physical and financial. For example, planting trees on unstable land to reduce soil erosion, or buying a farm in a strategic location to provide alternative grazing in a drought or when a flood hits.

Mitigation is likely to involve changes in technology used to achieve an outcome, such as using no-tillage instead of cultivation to reduce emissions when establishing crops or renewing pasture. It may also involve establishment of a new forest to gain carbon credits to offset emissions.

Adaptation to the impacts of climate change

This section covers:

- How farm systems can adapt management policies to cope with the impacts of climate change
- Case studies for a range of farms with varying degrees of adaption to the effects of drought
- Precautions that can be taken to reduce the impact of floods and recover from their effects
- The concept of time horizon and scale in developing proactive responses to anticipated risks.

Tutor notes

Suggested activities:

- Examine the range of strategies available to the farmer to ensure livestock productivity and farm profitability is maintained in the event of a drought.
- Discuss the impact that intense rainfall events may have on the farm, catchment and region in relation to flood risk, stock management and infrastructure, and how the impact of floods could be managed at these different levels.

Drought and water resources

Drought frequency and severity could increase in regions that are currently drought-prone. More frequent and severe droughts are likely over time. For example, what are currently defined as one-in-20 year droughts could occur on average once every 5–10 years. Droughts could also begin earlier in the season. There would likely be increased pressure on water resources in these drought-prone areas. Strategies to deal with the effects of droughts include:

- Adjusting livestock policy to make better use of available water (rainfall and soil moisture). This may involve switching to autumn calving or lambing in warmer regions, altering mix of age class and species so that destocking occurs before summer dry but retaining the flexibility to hold or buy stock to capitalise on good summer growth.
- Moving away from traditional ryegrass/white clover based pasture to deeper rooting drought tolerant species such as lucerne, chicory, paspalum and cocksfoot.
- Improving soil OM and structure to increase waterholding capacity and ability to maintain moisture reserves for longer periods without rain.
- Installing irrigation — this enables the farmer to avoid and/or better cope with droughts, depending on severity. It requires significant capital and management investment and, depending on the system, may have significant running costs due to labour, electricity and maintenance requirements. Careful planning is required, along with assessment of the likelihood of droughts and possible access to water. Installation of irrigation is a major decision. A suitable framework is described at: **www.ritso.org.nz/PDFs/Financial_Decision_Making_Framework.pdf**
  and the Irrigation Manual:
  www.irrigationnz.co.nz/publications/reports-presentationsSearchForm?Search=manual

Three case studies are provided on the following pages which describe how the impacts of increased droughts and reduction in water resources may be addressed in a farm system. These case studies demonstrate proactive management that may improve match feed availability and livestock demand in a changing climate.

- Case study 1 focuses on making the most of effluent on a dairy farm.
- Case study 2 looks at feed management policies to cope with drought on a diary farm.
- Case study 3 focuses on significant changes to stock management policies in the face of increased droughts on a dairy farm.

Case Study 1 — Making the most of dairy farm effluent

The farm

- Organic dairy farm at Wharepapa South, Waikato.
- Total of 400 hectares: 265 effective are milked off, 80 effective graze heifers and some sheep and beef cattle.
- The milking platform ranges from flat to hill country.
- Run organically for 10 years and in the fourth year of certification.
- Converted from sheep and beef to dairy four years ago.

The farmers

- Russell and Deanna Bayley.
- Participants of the Organic Focus programme, which monitors and benchmarks a range of data from their farm.

In 2008, Russell and Deanna Bayley's farm was severely affected by the Waikato drought. Their organic farming system presented particular challenges, including the difficulty to find organic supplements and grazing.

Afterwards, the couple decided they needed to adapt and implement a more flexible farming system to ride out future weather extremes and remain profitable.

They chose a system that stores effluent during winter and spring to be applied to pasture in summer. This gives the soil water and nutrients in drier months to boost pasture growth.

The farm and the changing climate

The Waikato region is expected to experience higher temperatures and more rainfall spread unevenly across the year; winter will be wetter, but spring and summer will be drier.

While climatic change experienced in any given year will probably be quite low, more frequent extreme weather events (such as drought and heavy rainfall) are expected and will pose a significant threat to farming.

Russell recognised this threat, especially after the 2008 drought when the farm very quickly went from feast to famine.

The farm's previous effluent system

Previously, the farm had nowhere to store effluent from the dairy shed and feed pad for longer than a few days. Effluent was gravity fed from the dairy shed to a 100,000 litre storage tank where it was pumped into a separator. The liquid component was then pumped into a 75,000 litre tank and used to wash down the feed pad or pumped onto paddocks.

Although relatively efficient, the system's low storage capacity meant effluent was irrigated onto the farm all year round. The fact that effluent was applied to already saturated soils and nutrients were leaching from soil into waterways contrasted with Russell and Deanna's philosophies of organic farming.

The redeveloped effluent system

The core of the effluent system was kept the same. There are still two tanks, separator and recycled liquids to wash the feed pad. The significant change was the new four million litre storage pond, which holds about six months' worth of effluent.

Rather than pumping effluent straight onto the farm, a pipe pumps it to the storage pond on a hill behind the dairy shed and feed pad. From here, it is gravity fed to a travelling irrigator and spread onto paddocks.

Previously, effluent was spread over just 38 hectares. The area over which effluent is applied has been enlarged to 88 hectares because potassium levels in the soil were becoming concentrated, which was unsustainable in the long term. It is unlikely the farm can significantly reduce its fertiliser use because effluent is now spread less frequently.

The cost

Storage pond construction	$5, 000
Storage pond installation	$15, 000
Pipe work to extend the effluent area	$20, 000
Total	$40, 000

The storage pond is located on land with a high clay content so lining was not required, which reduced the total cost.

Great effluent storage boosts flexibility

Russell no longer has to spread effluent when soil is too wet to absorb more water or nutrients.

'We can hold all of the effluent that is produced on the feed pad and in the milking shed during the winter and spring period until the summer, when the soils are starting to get dry. The larger effluent area means that we can utilise the nutrients that our cows are producing more effectively.'

There is also no extra ongoing work for farm staff.

The redeveloped system has quickly proved its worth. Russell was able to hold off applying effluent to the soil until December and then apply it continuously over summer.

He and Deanna may install another storage pond higher on the farm to gravity feed effluent to new areas.

Good advice from the farmers

- Talk to other farmers about their effluent systems. Use the experts to design your system, but stay involved and provide your input.
- If converting a farm, find out where the climate and industry is headed and design an effluent system (and other systems) accordingly. It's easier and cheaper to set up an effluent system at the same time rather than later on.

For more information

Agricultural effluent discharge is regulated by regional councils and must comply with the Resource Management Act. Check the discharge rules for your area by searching ‘farm effluent discharge’ in the regional plan available from your regional council.

Case Study 2 — Planning and monitoring improves farmers adaptability to climate variability

Business/farm details

Hamish Putt runs a 94 hectare dairy operation in the Waikato. He runs 298 milking cows and produces around 1100kgMS per hectare per year, which is above average for the region. He only milks once a day.

Planning for the unexpected

Hamish's general farm production plan is based on anticipation of relatively regular seasonal climatic changes:

- Frosts and rain in the winter
- Mild but windy spring
- Dry period in the summer.

Variation within this pattern is expected (for example, timing of the 4–6 week dry period shifts slightly each year), making flexibility an essential aspect of the plan.

Variation in precipitation in particular is managed with feed budgeting from March through to October. The feed budgets address worst case scenarios, including low growth rates and poor quality silage.

Hamish anticipates more variability due to climate change: summers may become warmer and drier, winters may become wetter. His recent experience suggests that, the differences between high and low and wet and dry seem to be higher.

Hamish thinks the increase in variability between and within seasons may pose a significant threat to production unless he adapts some of his farm management practices.

Responses to drought and dry production conditions

Hamish's father has farmed for 50 years and considers the 2008 drought the worst he's seen. Hamish still believes, however, that some of his management practices will enable him to respond in an efficient and effective manner:

1. Monitoring pasture growth rates and soil moisture levels. Hamish deploys a very comprehensive monitoring system to continually assess the state of his farm. Pasture monitoring enables Hamish to use pasture more efficiently during the summer dry period and maintain production levels.

    - Continuous assessment of soil temperature, soil moisture, and pasture growth rates enable both effective pasture use and paddock rotation, and can provide feedback that contributes to the early identification of conditions that threaten production.
    - Early identification of dryness or drought enables Hamish to purchase feed before more widespread demand leads to increased prices. He prefers to buy off-farm feeds during the summer and retain feed produced on the home farm as winter feed to extend the number of productive milking days.
    - Pasture cover and growth rate monitoring is used to create 10-day grazing plans. Data from a pasture monitoring instrument (towed behind a farm truck through paddocks) is analysed in a feed budgeting programme developed by Hamish (which is similar to ready-to-use programmes that are commercially available). The resulting plans allot day and night paddocks based on pasture height to increase the efficiency of grazing in paddock rotation.

2. Herd management

    - Herd pregnancy testing is conducted as early as possible. This helps direct feed to the productive cows and improves the efficiency of allocating feed supplements.
    - Once-a-day milking allows the herd to rest and there is more flexibility for management responses to adverse climatic conditions.
    - Earlier culls allow for improved efficiency of dry matter/milk outputs when feed is limited.

3. Cropping as a feed buffer

    - Hamish is shifting his management emphasis to include cropping on the farm as a buffer against low pasture growth and reduce the costs of other feed brought into the feeding system. He established his first six hectares of crop last year. The cropping also contributes to a pasture redevelopment programme by removing excess nutrients and controlling plant pests before he reseeds pasture species.

4. Broader networks for supplying feed supplement

    - Networks for supply of feed that extend beyond the region have proven very important for Hamish. He expects that climate change will have uneven effects across years for different regions, so being able to source feed from areas not affected by drought will be increasingly important.

5. Pasture management

    - Hamish is also adding pasture species with deep roots, such as plantain and chicory, to retain pasture cover during drier conditions. Dominant species such as white clover often grow poorly in dry conditions. He believes greater diversity in pasture species composition will improve the performance of his pasture when growing conditions are not ideal.

Even though Hamish has an almost scientific approach to the management of his farm and employs a range of management strategies and tactics, his main weapon to combat adverse climate conditions is a philosophical one:

‘Take it easy and get out of it. I think that’s the advantage of once-a-day milking. You milk them early in the morning, you feed them as best you can, and then you leave the place, because if you stay here you’d go crazy. I think that’s vital though. So many farmers were just so stewed up about it. If you were to stay here and look at it all the time, there’s nothing you can do. All of my planning was done at night on the phone when it’s dark and you can’t see what’s going on out there. And then you just sort of try to concentrate your work in the morning and leave the farm in the afternoon.’

Case Study 3 — Building drought resilience in a dairying system with autumn calving

Business/farm details

Allan Cole operates a 135 hectare dairy farm in Pukekohe, south of Auckland. He runs 443 cows on the property and is one of the few farmers that managed to come through the 2008 drought with minimal impact on production. Alan is developing a strategy, including maize silage and autumn calving, that shifts production to take advantage of more favourable periods in the regional climatic pattern.

The climate for production

Alan's standard management plan anticipates the potential impacts of a dry summer period. In most years, a dry spell lasts 4–6 weeks and causes feed deficits that require advance planning. While an affordable supply of supplement is available in most years, during the 2008 drought the high demand for supplement from the large number of affected farmers caused significant price increases. It challenged Allan's ability to react quickly and obtain his farm goals, but 2009 conditions have provided a recovery.

Allan sees substantial variability in the amount and timing of rain during the summer, which he believes has recently become more and more noticeable. These climatic trends have encouraged him to adopt changes in his management practices. Alan's observations of weather patterns indicate that his response will relate to regional climate change projections.

Responses to the drought and dry production conditions

Alan believes that his autumn calving strategy had the most positive impact on the farm's performance during the 2008 drought. The farm has always had some autumn calving which allows cows to be dried off and pasture growth to be conserved during the dry summer months.

In 2008 Alan was even more vigorous in drying off cows early. When in the late summer the rains had not come, the decision was made to dry cows off and send most of the autumn calves away for grazing. This decision was consistent with his farm plan and did not have a negative impact on his operation.

This and future years, Alan will move to all autumn calving so that stock are dried off during the problem months of January to March. This allows the farm to maximise production during the growing season.

In addition to his autumn calving stagey, Alan has decided to increase his home grown feed. He planted maize for the first time in 2008 as a buffer against the expected drought. Just over three hectares yielded a 60 tonne crop that was cut in February. Maize was added out of a desire to find the cheapest option for additional feed during the dry period. This brought the extra benefit of improving the effluent paddocks and contributing to a four-year regrassing programme.

Using effluent paddocks for maize cropping has improved feed outputs without negatively affecting other farm activities.

Alan is also working to reduce the costs of maize cropping by coordinating with nearby farmers to get better economies of scale. This project is enhanced by operating through a single contractor for all of their farms. The participating farmers also benefit from the sharing of knowledge and experience. The cropping has already proven to be a success in responding to drought and feed shortages.

'You're always looking out farther. You know if a dry spell's coming you've got these options and you need to act quicker than you normally would.'

Alan noted the need to plan ahead to set a maximum amount or percentage of the payout you are willing to use for off farm feed. It may not always be possible to maintain satisfactory levels of production in very difficult growing conditions and farmers should have an established plan to inform the financial considerations of buying supplementary feed, early culling and destocking.

Intense rainfall

All regions of New Zealand can expect greater flooding and erosion risk with any intensification and increased frequency of rainfall events. Low-lying coastal land will be more prone to storm surges and flooding.

Several strategies to deal with the effects of flooding include:

- Establish what your risk of flooding is. Get information from local regional council and neighbours. Old photos may also be useful.
- Schemes coordinated at the regional or catchment level are required to reduce the effects of floods as the threat is related to river systems over a wide area.
- Slowing overland water flow improves the ability of the soil to absorb water. This reduces peak flows and potentially floods downstream. Slowing water flow can be achieved by planting or allowing vegetation to establish in water catchments. In some situations, it may be possible to install interception drains across slopes to stop water heading directly down the slope.
- Cutting down dangerous trees and keeping waterways clear of weeds in readiness for a storm can reduce the risk of blockages forming in waterways and the occurrence of flooding.
- Individual farms can minimise impacts by maintaining existing channels for flood waters to pass through. Attention is generally paid to detail such as placement of wires on the downstream side of posts so there is less chance of flood waters and debri taking out posts, and locating storage areas for supplementary feed as much as possible out of flood water flows.
- Exposed or bare soil is susceptible to damage from intense rainfall. Damage occurs both at individual soil particle level and field level. Individual soil particles are broken down by the direct impact of raindrops and secondary splashing. This process also lifts fine soil particles up into surface water which may then be carried away as suspended sediment in flood water. Bare (cultivated) soils on slopes are most at risk as soil may be carried away in overland water flow. Adaptation to this risk could involve using minimal tillage or no-tillage techniques to establish new pasture or crops. These techniques leave residue from the previous crop or pasture on the soil surface which protects soil particles, improves infiltration and reduces overland waterflow.
- Floods may have secondary effects. For example, farms not directly affected by flood waters may be impacted by loss of infrastructure services such as electricity supply. In this case a standby generator may be purchased,

perhaps the costs shared among two or three farms as a backup supply to ensure milking sheds can be operated. Preparation needs to made for this by installing external plugs — this is most conveniently done when sheds are built.

- Other effects of floods include the prospect of dealing with the sediments deposited by floods. Some valuable experience was gained through coping with the the 2004 Manawatu flood. The chart on page 95 shows how best to regrass a range of sediment deposits.
- Some farmers are exploring, and acting on, options to take advantage of areas with complementary pasture production characteristics. This may help manage risk from floods as well as droughts. Options of joint ventures, buying another farm or relocating may provide grazing or supplementary feed in times of drought.

Further reading

'Dairy Floods Checklist — Preparing and Responding to Floods'. Published by DairyNZ, 0800 4 DairyNZ (0800 4 324 7969).

'Adapting to Climate Change in Eastern New Zealand: A Farmer Perspective'. July 2005. Complied and written by Gavin Kenny. Published by Earthwise Consulting Ltd, Hawkes Bay. ISBN 0–473–10069–X.

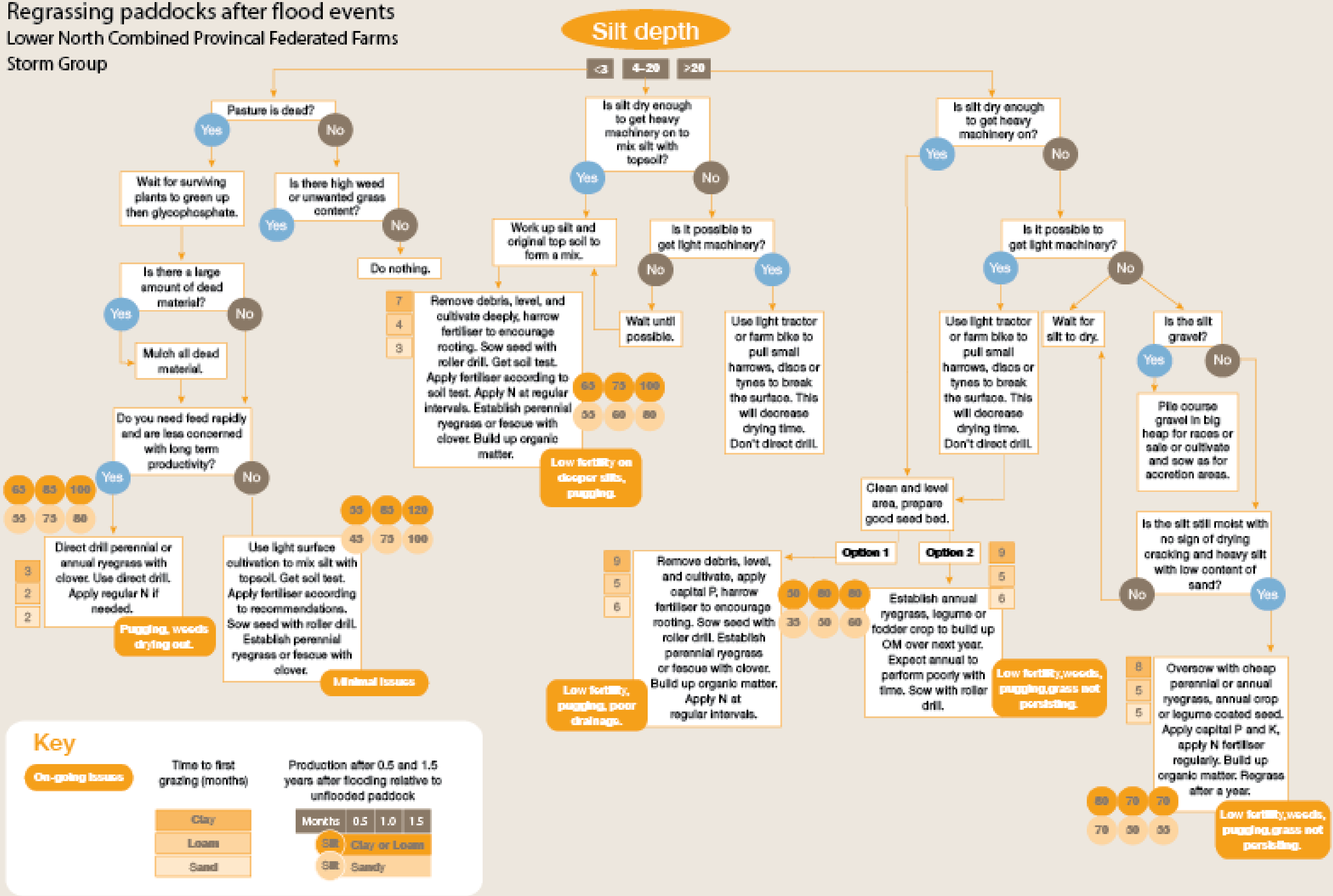
Drought management — go to **www.beeflambnz.com/main.cfm?id=392**

Droughts and floods — go to MAF adverse events **www.maf.govt.nz/mafnet/rural-nz/adverse-events/**

Managing flood risk — A process standard, 2006, Standards New Zealand.

Regrassing paddocks after flood events

Lower North Combined Provincal Federated Farms Storm Group



Dealing with Insects and plant pests

Climate change is likely to increase problems with insect pests and pasture weeds. This effect may be compounding. For example pastures which are moisture stressed are more likely to be effected by pests such as Black Field Crickets which flourish in the new habitats created by cracks formed in drying soils.

Individual farms can minimise impacts of introduced pest insects or plants by:

- Sowing alternative species, perhaps as part of a cropping programme. Pasture species such as cocksfoot, fescue and phalaris are more tolerant of insects, as are herb species such as plantain and chicory.
- Addition of a cropping/pasture renewal programme provides an opportunity to control pasture weeds and may break the lifecycle of pests. Care should be taken to use techniques such as direct drilling where practical to maintain soil structure. This may require increased use of agrichemicals.
- In warmer areas where pest problems are more prevalent, use grass seed with modern endophytes such as AR37, instead of older endophytes such as AR1.
- Establishing farmer interest groups with technical input from funds such as the MAF Sustainable Farming Fund can focus on-farm practical research on managing new challenges such as invasive weeds. For example, the Northland Kikuyu Action Group (KAG) have explored various pasture renewal and management strategies through structured implementation and monitoring programmes using MAF funding in this way.
- Investigate possible biocontrol of existing and expected pest insects and plants. Identify how any biocontrols might be affected by droughts and floods.

The case study described on the following page describes possible outcomes by forming a community group to address a problem with pasture management in a specific region.

Further reading

Case study — ‘Farming in a Subtropical Environment: A Farmer’s Perspective. Paper in Proceedings of New Zealand Grassland Association 71:17–20 Alternative Case Study Cost-effective processes for kikuyu elimination in pastures. Pamphlet 7. Published by the Kikuyu Action Group. **www.enterprisenorthland.co.nz/downloads/kikuyu_newsletter_july2008.pdf**

Available as PDF (kikuyu_newsletter_july2008.pdf)

Possible impacts of climate change on biocontrol systems in New Zealand.

P.J. Gerard, J.M. Kean, C.B Phillips, S.V. Fowler, T.M Withers, G.P. Walker, J.G. Charles, 2 September 2010. Ag Research Report for MAF, available MAF website.

Threat to pasture

The greatest threat to production from New Zealand’s temperate pasture (ryegrass/white clover) is the risk of reduced water availability and invasion of plant and insect pests as eluded to above. The severity of these risks and the likelihood of them occurring depends on the region you are in. Experience to date suggests that while changes for New Zealand may occur over tens of years (for example, 1°C increase in temperature by 2050) which may in fact lead to a general yield increase, changes at regional level are likely to be more severe. For example, extended dry periods or droughts cause major constraints to pasture availability on non-irrigated land which may lead to crop failure and death of plants and reduce production in the following season as well. Eastern regions such as Gisborne to Wairarapa, and Canterbury are likely to experience lower annual rainfall and pasture productivity. As a result, pasture composition may change with possibly lower legume (clover) content and increased incidence of sub-tropical grasses such as kikuyu and paspalum. This would have a greater negative impact on dairy producers than sheep and beef producers, because of the high dependency of dairying on maximising pasture utilisation.

Warmer and wetter average conditions could lead to yield increases in western regions of the lower North Island, in the West Coast, and parts of Otago and Southland.

Animal health

Aside from the effects of increased variability of pasture production, livestock will be directly affected. For Waikato and Bay of Plenty, heat stress will likely become more of a problem for cattle. Most of the North Island and warmer regions of the South Island could experience an increased incidence of diseases such as facial eczema. A warmer, wetter climate in western parts of New Zealand will increase problems with internal parasites. Heat stress, facial eczema and internal parasites will reduce animal production. Individually the impact of these animal health issues may be hard to identify until they become serious. As the effects of climate change are felt at the farm level, awareness and responsiveness to these issues should increase.

- Providing animals with access to shade will reduce heat stress. At the lower end of response this may simply result in deciduous shade trees being planted at intervals along fence lines. At the other end of the spectrum, providing housing for animals has gained popularity in recent times with herd homes appearing on dairy farms around the country. These examples show the range in potential response strategies. They also provide a contrast in terms of timing. Increasing the number of shade trees on a property requires planning and anticipation as it will take at least 10 years for trees to reach sufficient size to provide effective shade and it may be difficult to provide all animals with shade. In contrast a herd home could be installed within a season and is more likely to be able to accommodate all animals.

- Raising the level of monitoring for on-farm temperatures, facial eczema spores in pasture and internal parasites in faeces would be a possible response to increased risk of these animal health issues occurring on your farm. Increased monitoring quantifies the risk so that management can anticipate problems and respond to them quickly when required.
- A longer term strategy may be to move to more heat tolerant breeds such as Jerseys which are lighter in colour and smaller in stature and better able to keep themselves cool than larger and darker coloured breeds.

Crops

Reduced availability of water for irrigation for all crops may constrain arable production and switch land use away from ryegrass/white clover pasture to deeper rooting crops with less water requirements, such as lucerne. As less rain falls, crop demand increases against a possible decrease in supply. Wetter and warmer conditions could lead to increased problems with pests and disease in arable and horticultural crops in some northern regions and the west of the North Island.

Response strategies may include:

- Increased vigilance and perhaps upgrading of systems to more accurately identify periods of increased susceptibility of crops to disease, and improved monitoring of pest numbers in crops to relate to threshold levels for preventative spray application programmes.
- Look at growing alternative crops or more water efficient varieties as a possible response to constraints on water supply and rising temperatures.
- Greater use of reduced or no-tillage systems rather than cultivation for crop establishment to conserve soil moisture and soil carbon and reduce potential for erosion.
- Increase autumn/winter sowing of crops.
- Increased use of precision agriculture technologies to improve efficient of inputs such as water, tillage, fuel, seed, fertiliser and agrichemicals

Infrastructure

Changes in the seasonality and/or frequency of high intensity rainfall events will potentially have consequences for farm infrastructure, including:

- Land drainage
- Flood protection
- Community water schemes
- Culverts and bridges
- Erosion control
- Farm dams
- Water reticulation
- Irrigation.

Opportunities

This section covers:

- Projected increases in pasture production and how farm systems may need to adapt to capitalise on this
- The opportunities of an increased range of crops becoming available to farmers as a result of climatic changes
- A wider discussion on how farmers may adapt to climate change over a series of time horizons
- Changes New Zealand farmers have noticed with a changing climate and the supporting strategy of 'smart farming' to cope with this.

Tutor notes

Suggested activities:

- Discuss how future farming systems may have to adjust to changing pasture production as a result of climate change.
- Discuss the range of opportunities climate change may offer farmers in some regions.
- Compare response strategies in terms of their time to implement and relative impact on the farm system.
- Discuss how some farmers perceive their climate has changed to date and the responses they have made to these changes.

Possible opportunities which may result from predicted changes to the climate

Temperate pasture

The current ambient levels of CO_2 in the atmosphere are below optimum for the growth and yield of most plants in much the same way as N is generally a limiting factor to pasture growth. The direct effect of increasing atmospheric CO_2 is:

- To enhance the rate of photosynthesis (which makes more carbon available for accumulation as carbohydrates)
- To increase water use efficiency (by reducing the stomata on leaf surface through which water vapour is lost from the plant to the atmosphere).

A CO_2 enriched environment is generally beneficial to plants. This relationship is exploited in the horticultural industry as artificially high CO_2 concentrations are used in glasshouse production systems to increase productivity of crops such as tomatoes, lettuce and carnations. The range of response depends on the plant type. So-called C3 plants (such as temperate grasses and legumes and arable crops such as wheat and barley) respond more than C4 plants such as maize and sub-tropical grass species.

A study of five sites across New Zealand indicated that pasture DM production would be 8–10% higher in 2020 as compared with 1990, and 23% higher by 2050 (Clarke et al., 2001). Larger increases are expected for relatively cool moist places (such as Gore) and smaller increases in places which are already warm and dry (such as Gisborne). A 10% rise in legume content of pastures would be expected which could in turn improve N availability to grass species. There may be opportunity to increase productivity under a regime of higher CO_2 concentrations, provided other factors (such as water) are not limiting.

Pasture yield may also increase with higher temperatures. However, throughout much of New Zealand, especially the South Island, temperature may also be a limiting factor to growth as there may be insufficient warmth to complete the plant's stages of growth, or frost may severely curtail growth.

Crops

Generally crops are expected to benefit from a warming climate as the range that can be grown and extent of regions they may grow in is expected to expand. One such example is maize for grain. In the South Island maize production is marginal and only grown as a silage crop due to lack of warmth during the growing season to mature the crop. The area under maize has in fact increased in the last 10–15 years as more suitable (shorter maturity length) varieties have become available. There could be yield and quality benefits to some of the temperate grains in the South Island with hotter, drier conditions.

Further reading

For more detailed analysis get a copy of ‘Climate change: A Guide for Land Managers’ for your region. These are available at:
www.maf.govt.nz/climatechange/reports/

or by calling 0800 CLIMATE, or through:

The Ministry of Agriculture and Forestry
PO Box 2526
Wellington 6140
Freephone: 0800 008 333

These are available from the ‘Climate Change Information for Tutors’ USB stick — contact Ruth McLennan **ruthm@agito.ac.nz** and
www.ruralsource.co.nz.

The publication ‘Climate Change Adaptation in New Zealand: Future Scenarios and some Sectoral Perspectives’ has more detailed analysis of how pastures, crops and forestry may respond to predicted future changes in the New Zealand climate.

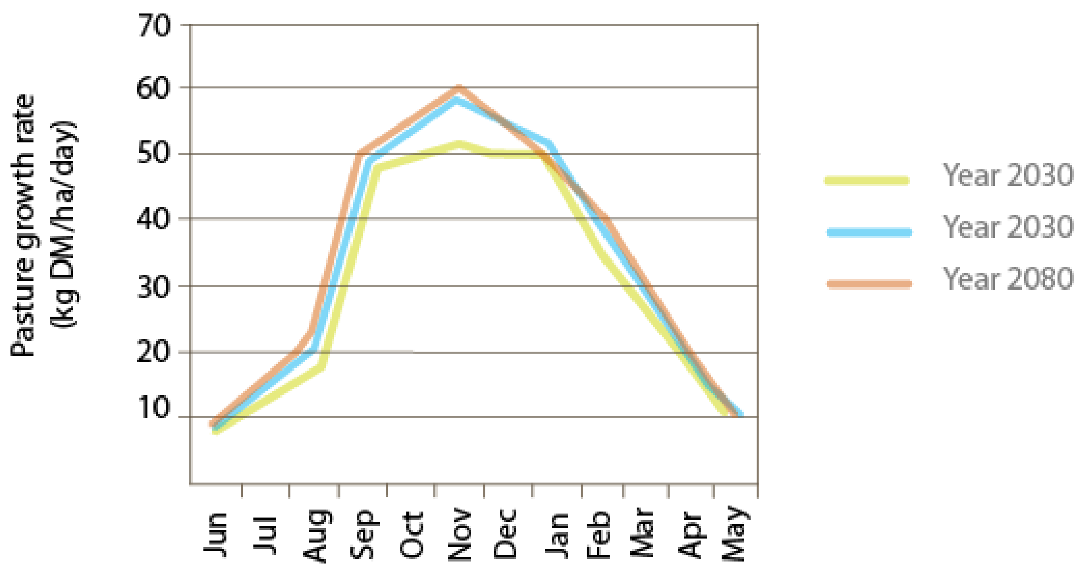
This was published in February 2010 by the New Zealand Climate Change Centre, National Institute of Atmospheric Research (NIWA) Wellington, New Zealand.
ISBN 978–0-473–16366–2 (print) 978–0473–16367 and is available from:
www.niwa.co.nz/our-science/climate/research-projects/all/adaptation-to-climate-variability-and-change

Foundation for Arable Research (**www.far.org.nz**) have specialist cropping infomation

Case study — An example of adaptation to climate change for a Manawatu dairy farm

The consensus from most farmer groups who have focused on how they might deal with climate change is that adaptation will occur through ‘business-as-usual’ adjustments to management policies. This concept was demonstrated using a Manawatu dairy farm as a case study. This region is predicted to maintain or slightly improve production in an average year, although production could drop by 60% in the driest years. The computer model ‘EcoMod’ was used to provide growth rates and metabolisable energy concentration information for farm scale systems modelling. The graph below shows an example of the data used for comparisons. This information was used to simulate practical farm systems using the computer model Farmax Dairy Pro. Note that this comparison was also carried out for sand soil type as a contrast.

Predicted monthly pasture growth rate for clay under three climate scenarios for a Manawatu dairy farm



Features of dairy farm adaptation

Two farm management approaches were compared using Farmax Dairy Pro to highlight adjustments that might be made to cope with climate changes. The baseline or unadapted system was simulated using the same cow numbers, calving date, supplements fed and grazing management as in 2000, but with the 2030 and 2080 pastures. This was compared to an adapted system where changes in the same factors were made to optimise productivity. The table on page 105 compares key statistics of unadapted with adapted systems.

Effect of adaptation on estimated change in production and profitability for a Manawatu dairy farm compared to 2000 for clay soil

	Unadapted system		Adapted system	
Year	**2030**	**2080**	**2030**	**2080**
Milk solids (kg/ha)	-17	-67	+85	+64
Milk solids (kg/cow)	-9	-35	+15	+31
Profitability ($/ha)	-90	-337	+233	+262

Key points — unadapted system

- Total and monthly milk solids production per cow and per hectare declined in both 2030 and 2080 compared with 2000 estimates. The difference was most marked when comparing 2000 with 2080, and is linked to the marked reduction in pasture quality by 2080. The reduction in pasture quality led to lower energy intakes. Reductions in farm profitability were observed for both 2030 and 2080.
- Average pasture cover increased throughout the year in both 2030 and 2080, resulting in more decay and accumulation of dead matter in the sward. Pasture utilisation dropped by about 13% for 2030 (65%) and 2080 (62%) compared to 2000 (75%) levels.

Key points — adapted system

Key adaption measures included the following:

- Increased late winter pasture growth allowed calving date to be brought forward by 10 days in 2030 and another 5 days in 2080.
- Increased summer and autumn growth allowed increased summer feeding for both 2030 and 2080.
- It was also possible to lift cow numbers by 8% in 2030 compared to 2000, although by only 1% in 2080 compared to 2000.
- To achieve the same level of per cow performance in 2080 as 2000, per cow intakes needed to increase to achieve the same level of energy intake. This also resulted in increased cow BCS at drying off.
- More supplements were harvested in spring, with these additional supplements fed to dry cows to ensure they reached the same BCS at calving in 2030 and 2080 as in 2000.

Effects of these adaptations:

- Milk solids per cow and per hectare increased when comparing both 2030 and 2080 with 2000. This was linked to the increase in lactation length, increased summer feeding levels and greater cow numbers in 2030. In 2080 compared to 2030, the increase in milk solids per cow and per hectare was mainly linked to an increase in lactation length (+5 days) and increased summer feeding levels.
- Profitability compared to 2000 levels increased in both 2030 and 2080, although the increase in profitability per year decreased when comparing 2030–2080 with 2000–2030.

The system modelling identified the challenges of increased temperatures and rainfall for a Manawatu dairy farm. This was predicted to lead to increased pasture production and invasion of C4 grasses, resulting in a potential loss in production. The modelling identified the opportunities which exist to adapt to the higher production of lower quality feed through a range of farm management decisions (such as earlier calving and increased stocking rates). The modelling did not consider the impact of the increase in cow numbers on nutrient losses or intensity of GHG emissions, or evaluate the impact of pests, diseases or weeds. However, the results highlight potential management responses to the impacts of climate change and potentially turn a negative (lower quality pasture) into a positive (more production).

A wider view of adaptation to climate change

Response time scale

It has been suggested that a more flexible approach will be needed to meet water resource and other problems that may arise from climate change. Three types of adjustment which might occur (from Griffiths,1990) include:

1. Progressive adjustment under current management regimes
2. Changes in management criteria
3. Revamping the system, including major structural solutions.

In relation to drought, and the possibility of drought risk increasing in the future, a range of measures might be considered over time, which are consistent with these types of adjustment.

These could include:

Short-term (next 10–20 years) measures such as reviewing farm policies and plans, and identifying low-cost adjustments that could be made to existing drought mitigation measures. In many cases, the encouragement of sustainable land management practices, such as planting trees for improved catchment protection and water quality, will have flow-on benefits both in the short and long term.

Medium-term (next 20–50 years) measures such as developing new policies and plans to address effects of climate change on drought, as well as other regional effects on land and water resources that may be increasingly apparent. For example, there could be a need for increased monitoring and regulation of ground water use.

Long-term (next 50–100 years) measures are more difficult to specify, but could involve more stringent regulations and structural solutions. Importantly, if a process is established now, which considers effects of climate change in regional policies and plans, then mechanisms will be established for progressive adaptation to changing conditions in the future. Increasingly over time, such measures should be designed to address the long-term sustainability of regional resources.

Lessons from Eastern New Zealand on adaptation to climate change

Over the last 10 years the East Coast of the North Island has seen an increased number of droughts with three years of summer droughts occurring from mid 2006 until mid 2009. After working with farmers in this region, Gavin Kenny and the Hawkes Bay Regional Council have complied a summary of the key tools and strategies farmers are using to deal with what are perceived to be 'more dramatic weather events[1]. These tools and strategies are termed 'smart farming' and are designed to improve the resilience of farms, placing them in a better position to deal with the changes they see occurring. The table on pages 108–109 summarises the features of smart farming and adaptation and mitigation benefits associated with them. Most of these features require planning, time and enthusiasm to implement, especially considering economics will influence the speed with which change could be carried out.

1 'Adapting to Climate Change in Eastern New Zealand: A Farmer Perspective'. July 2005. Complied and written by Gavin Kenny. Published by Earthwise Consulting Ltd, Hawkes Bay. ISBN 0–473–10069–X

How ‘smart farming’ can effectively deal with climate change

‘Smart farming’ for resilience	Adaptation benefits	Mitigation benefits
Trees for multiple purposes.	• Shelter and shade benefits. • Stock fodder. • Erosion control. • Drought and flood resilience. • Biodiversity enhancement.	• Carbon storage. • Lower methane emissions from reduced feed demand and improved feed quality. • Reduced fuel use with a well developed on-farm timber resource for local milling.
Pasture • Mixed species. • Low input regimes. • Longer pasture covers. • Deferred grazing. • Deeper rooting plants. • Focus on pasture quality.	• Drought and flood resilience. • Improved animal health.	• Carbon storage in soil from greater root mass to a greater depth. • Lower methane emissions from improved feed quality.
Soil • Lower inputs/soil biology. • Clover and other legumes instead of N-fertiliser.	• Buffering against flood and drought through increased OM, soil porosity and soil health. • Improved animal health through improved pasture quality. • Reduced erosion loss with an integrated approach to soil management.	• Carbon storage with deeper rooting pasture and soil OM increases to a greater depth. • Reduced N_2O emissions. • Lower fossil fuel use and emissions with reduced demand for, and production of, N-fertiliser and other fertilisers. • Carbon storage rather than loss through effective erosion control.
Stock • Focus on quality rather than quantity. • Stock ratio and breed selection.	• Greater resilience through smarter grazing management. • Animal health improvements — more resilient animals.	• Reduced emissions through smarter grazing management and improved animal health.

'Smart farming' for resilience	**Adaptation benefits**	**Mitigation benefits**
Water • Storage. • Efficient reticulation and use. • Soil biology management. • Riparian protection.	• More efficient and effective water use. • Greater resilience.	• Improved carbon storage and reduced emissions from greater moisture retention. • Lower emissions from a healthier, less water-stressed farm system.
Whole farm • An integrated sustainable management programme.	• Long-term resilience. • Off-farm benefits (for example, catchment protection, biodiversity corridors.	• Efficient capture, storage and cycling of solar energy, carbon and water. • Reduced emissions.

From Factsheet 4: Farm Resilience for the Future — Hawkes Bay Regional Council
(www.hbrc.govt.nz)

The case study on pages 113–116 provides examples of some of these tools and strategies that have been implemented at farm level on the East Coast of the North Island. This document is also available from the Hawkes Bay Regional Council.

CASE STUDY

"Climate change means to me the change in how our rainfall is spread across the year and in the way that it occurs now. That's as a farm view, and as a world view climate change means 'Mans greed'."

Williams Hill, Puketitiri

The Farm

- 1297 ha in total of which 780 ha is effective. The bulk of the remainder is a 442 ha pine forestry block, which is a 60:40 joint venture planted in 1995.
- Altitude ranges from 396m to 823m, but most of the farm is around 457m.
- Sheep and beef operation, with about 7200 stock units before 2007, down to about 5200 by 2009.

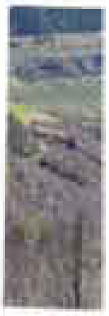
Adapting to climate change is about finding your niche

"We've been farming like this for a while and are just adapting. It's adapt or die really because the other choice is for the whole farm to be pines, or manuka. I'm open to anything. I said to the seed guy open your books and tell me what you've got. I'll try anything."

Tim Dinneen has had a tough time over the last few years but is optimistic and determined about the future. The Williams Hill farm at Puketitiri is owned by a family trust and leased by Tim and his wife.

At first glance it would be easy to say the farm should be shut up and planted in trees. That has happened with some of the harder country on the farm. A closer look reveals a range of land classes that, if managed well, provide plenty of opportunities. Tim believes that they just need to find their niche. The ideal is to have every hectare of the farm doing something, with protection from the sun and wind and making things as productive as possible. There are options going forward even if it becomes warmer and drier in the future.



Climate

"November is the big growing month up here, if you don't get a good November that's it you're out."

"Traditionally with these sorts of farms you'd outgrow your stock numbers in the spring and everything would go rank then you'd spend all summer cleaning it up and then autumn arrives. You could handle a dry February/March because you'd have standing feed."

They have a unique microclimate in their area, which extends along the foothills of the western ranges from Tarawera Station down to the Waitara river. Rainfall averages 1160mm, from records going back to 1982. Until the latest (2009/2010) summer what they've experienced in the last few years is that all of the rain is now coming in the winter months. And they've been getting dry Novembers. With the ash and pumice soils they need fairly frequent spring rains.

Winters are getting warmer and easier. Winter used to begin about April/May but it's now the end of May when winter kicks in (with the exception of 2009). A dry winter is good in this area. Huge snow falls can still happen. It's not as constant but heavier when it comes.

Climate risks

"It seems to be that when you get something now it's worse than it was, it's never Joe average any more. You either get no rain or you get heaps of rain."

"It seems to be that when you get something now it's worse than it was,..."

Rainfall variability provides the biggest climate risk. In recent years the main challenge has been the dry springs. In general they're getting more severe events. This includes drought, the shift to more rainfall in winter, and short-sharp bursts of rainfall in summer.

Stock policy

Stock numbers have been significantly reduced with three consecutive droughts since 2006/07. Pre-drought they had 3500 ewes, 900 hoggets, 80 rams, 220 cows with all progeny kept until 2 – 2.5 yr old, and 50 Friesian bulls. Post drought numbers have dropped down to 3200 ewes, 950 hoggets, 80 rams, 65 cows and 118 R1's. A consultant review showed that the sheep were twice as profitable as the cattle. One reason was that the cattle were spending too long in winter at just maintenance.

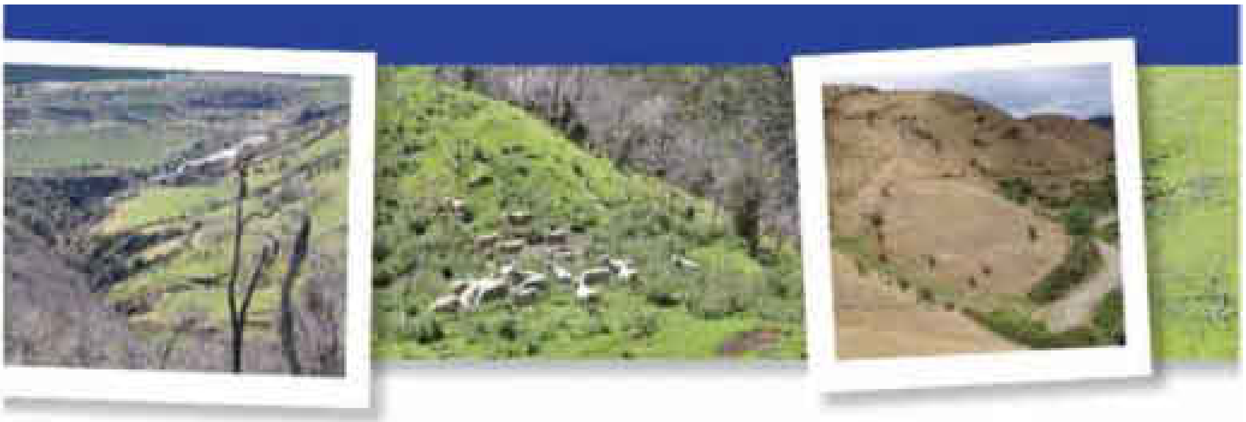
Pasture and feed management

"We've all been told at the monitor farms to keep your grass down, but when you have higher grass it has a shading effect on the soil, so you don't dry out as fast."

The main grass species are currently natives, rye, a bit of cocksfoot, and still some sub-clover after 50 years.

With the consecutive droughts they've been losing 500kg DM a year because the grass is too low all the time (1000kg's DM). He's now setting target lengths of about 1800 by the end of November.

With the droughts they quickly used their feed store. In the first drought they had two years of hay and silage stored, because they farm for a drought. This was used up and they also bought in ten tonne of palm kernel. In 2007/08 they managed to cut 300 bales of hay. In 2008/09 they were down to one paddock. They have been getting winter feed in just to maintain cattle. In retrospect they would have been better off financially by ditching the cows and selling the store feed.



Looking at options going forward

"This is steep hill country and so monitor farm information is harder to apply. It won't work splitting this farm up into 2ha paddocks. You have to have a system that works here."

"...You have to have a system that works here."

The options are limited. An intensive bull unit might be possible on the easier country, but not on the steeper stuff. The farm could all be put in pines and the carbon credits sold. Tim's view is that this land needs to be managed with different solutions for different land classes.

Soils

P levels are reasonable for steep hill country, 36 on the home block, 18 on the Williams Hill block and 10 out the back. The pH levels on the same blocks are 5.6, 5.8 and 5.9. Tim doesn't believe the old thought that you don't put lime on unless pH drops to 5.5. The fertiliser regime is being changed to a more lime based system.

Stock policy

The aim is for about 25 percent of stock units to be trading. Higher pasture covers will be kept through the summer, with all trading cattle quit before winter. Instead of wintering 7500 stock units they'll only be wintering about 4500-5000 stock units.

Pasture

"We need to start growing some of these grasses that are grown in other parts of the world that would thrive in this sort of climate and then stock our farms accordingly. When you ask seed merchants for something that will work here you just get a blank stare."

"When at Massey I never learnt anything other than getting an aeroplane to fly around and do an oversow. We need methods developed for renewing pasture in the hills, including more work on other species that will grow in this climate."

The focus with pasture is going to be more on residuals. With longer covers the emphasis will be on growing clovers, the clovers will then grow grass. Tim thinks that grass species need to change. There are plenty of other grass species around the world. New Zealand has trialled different species in the past (40-50 years ago), but that's all gone now.

Water

There are springs all over the farm. Stock water is provided through dams. Intensification of some of the easier country is an option for the future with possibilities for reticulated water to smaller paddocks and irrigation. However, the investment costs and effects on the whole farm operation have to be weighed up against the benefits.

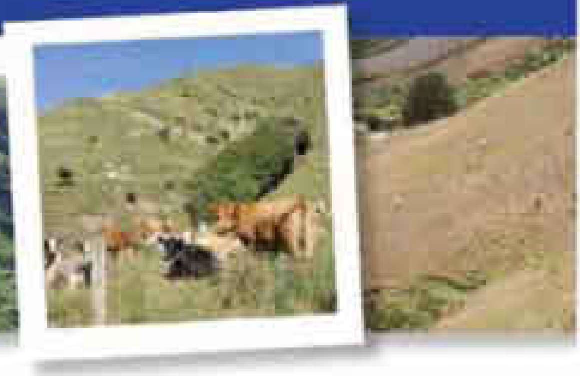
Two-tier farming

Tim is looking at doing a two-tier farming trial on a block with flats and two terrace rises. The plan is to plant the terraces in pines and then plant the flats out in tree lucerne and undersow that with clover and grass. The tree lucerne will a) be feeding nitrogen to the soil, b) provide a source of stock feed and c) provide

a microclimate for the grass underneath. If the two-tier system works well then Tim would try to replicate it across the whole farm.

Stock fodder

Crops such as swedes and kale don't work any more because they don't handle the long dry, nor big heat events. Tim is going to trial 100m strips of the different crops he wants to evaluate, including pumpkins, fodder beet, blue lupins, and lucerne.



Erosion and flood control

The idea is to start space planting poplars at final spacings down all the guts of the farm. For the past seven years they've been fencing off and planting pines along the river frontage. This has been done in partnership with the regional council with about 20ha planted and another 24ha this year.

Culverts

They've had some large culverts wiped out twice with big rainfall events. Tim wants to use geo-cloth to trap the fines. He is going to do all crossings with that from now on.

Eco-tourism

Tim has guided a few people hunting. A company is already bringing people in by helicopter for fishing. It could be an awesome safari farm, but it would require an investor to implement and market it.

Resources/support

"I'm a great believer that the only way you learn is doing it. You've got to see the results."

The main constraint is the lack of reliable knowledge and advice. Tim feels that there is a lot of misinformation out there, from seed companies, fertiliser companies, and others, all wanting to sell their products. He would like to see some of the ideas he is looking at taken up by different people and trialled. He doesn't want information so much as testing of ideas.

Future thoughts

"The climate thing seems to be getting more and more severe."

"The national ewe flock is all pushed back into the hills. If they want to keep the industry going then they need to look at what can be done on the hills. There is a need to be revisiting things."

There needs to be more emphasis on making hill country farming more sustainable. They've been pretty neglected. New Zealand's east coast is very significant to our economy.

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Further reading

A series of useful Factsheets have been produced from the work in Eastern New Zealand. These provide an excellent resource of farmer perspectives on some on-farm strategies to adapt to climate change. They include:

Factsheet 1: Climate Change

Factsheet 2: Grazing Management

Factsheet 3: Water, Infrastructure and Trees

Factsheet 4: Farm Resilience for the Future.

These Factsheets are available from:
Hawkes Bay Regional Council
06 835 9200
www.hbrc.govt.nz

Adapting to a changing climate: Case Study 1 — 'Dryland farming: A Marlborough family's journey'. This tells the story of Avery family who made systematic changes to his farm to cope with repeated droughts. This is one in a series of case studies called Adapting to a changing climate that can be found at **www.maf.govt.nz/climate change**. Published by Ministry of Agriculture and Forestry PO Box 2526, Wellington 6140. Freephone: 0800 008 333

The ETS, farms and forestry

This section covers:

- ETS legislation
- Impact of the ETS on agriculture
- The costs of the ETS to farms
- How forestry might be used to offset emissions liabilities
- Potential impact from the price of carbon to farm ETS costs
- Comparison of ETS components with the concept of carbon footprinting.

This section describes how the ETS will add cost to a farm enterprise and a potential strategy to reduce the impact of those costs in the medium term.

Planting a new forest will not necessarily reduce or 'mitigate' GHG emissions from livestock. It will improve the farm carbon balance and potentially reduce the costs of the ETS. Forestry will offset GHG emissions in the short to medium term (30–50 years).

Tutor notes

Suggested activities:

- Discuss the timelines as various sectors of the economy enter the New Zealand ETS.
- Explain how the cost of the ETS will impact on a farm over the next 10 years.
- Examine how forestry may offset future emissions liabilities from agriculture.
- Contrast the ETS with carbon footprinting in terms of what emissions liabilities are accounted for and how those liabilities will translate to costs or benefits at farm level.

New Zealand legislation

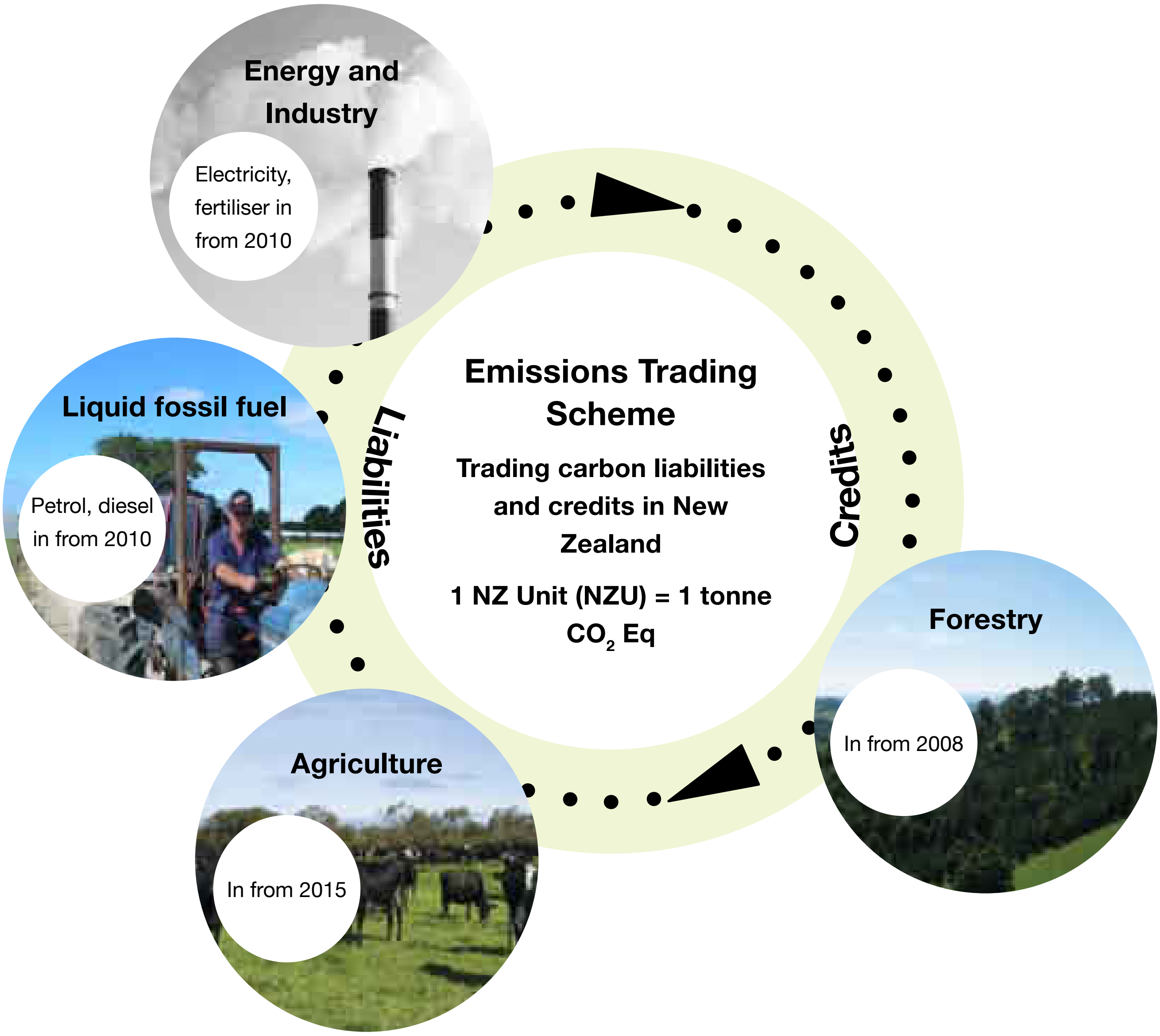
Legislation and initiatives have been introduced by the New Zealand Government to address climate change and meet responsibilities as signatories of the Kyoto Protocol. Three programs provide opportunities and responsibilities to the agricultural industry:

- The ETS
- Permanent Forest Sink Initiative
- The Afforestation Grant Scheme.

ETS — This initiative was established through legislation introduced by government in late 2008. It has since been reviewed with amendments passing into law late in 2009 with further regulations passed in 2010. Under the ETS, agriculture, along with other industries, will be required to purchase carbon credits to offset carbon liabilities. Activities such as forestry generate carbon credits which can be entered into the ETS and used to offset emissions, or traded for cash. There is no restriction on forest species or harvesting regime. However, harvested wood is treated as a carbon liability which has to be paid back, but only up to the level of credits claimed. Therefore forest owners need to consider how credits and liabilities are managed through the forest cycle.

Forestry has been in the ETS since January 2008, with carbon credits available for forests planted after 1990 on land that previously was not forest land. These are known as Kyoto compliant or post-1989 forests. Also forests which existed before 1990 which have been harvested after 2007 will be liable for deforestation penalties unless they are replanted. Existing post-1989 forests can be registered under the ETS for the 2008–2012 commitment period. Returns to claim carbon credits can be filed annually by March 31.

The diagram on page 120 shows when various sectors are due to enter the ETS and the flow of carbon credits (NZUs).



Source: Infosheet 4 (**www.carbonfarming.org.nz/articles**)

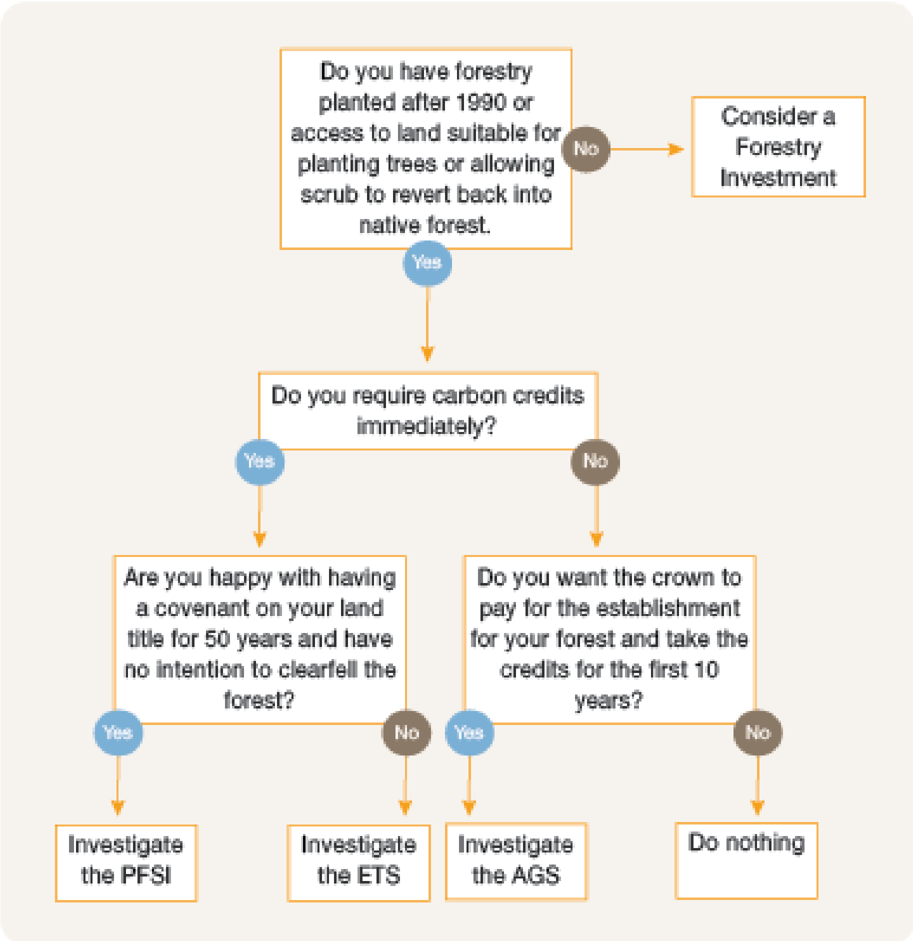
Permanent Forest Sink Initiative (PFSI) — This program is targeted towards new forests that will not be clearfelled in the future. This will suit natural reversion of scrub back into native forest and the establishment of high value species which lend themselves to selective harvesting. A forest area can be entered into the PFSI and carbon credits received and used to offset other activities, or traded for cash.

Afforestation Grant Scheme (AGS) — Provides an opportunity to obtain a grant to establish a new forest on unforested land whereby the government retains the carbon rights for the first 10 years. After this period there are no obligations on the landowner regarding the forest and he or she can enter either the ETS or PFSI to claim subsequent credits. This scheme has been very successful but has also received a funding cut and is unlikely to be available in the future.

More information on each of these schemes can be found at:
www.maf.govt.nz/sustainableforestry/

The diagram below shows a basic guide a farmer might use to decide what (if any) forestry programme might suit or be required to claim carbon credits.

Which program might apply to me?



Source: Infosheet 4 **(www.carbonfarming.org.nz/articles)**

What does this mean for agriculture?

The energy and industrial sectors entered the ETS from July 1 2010. This brought an approximate 4 cents/litre rise in fuel and 5% rise in electricity prices, which accounts for half the carbon emissions. This level of price increase will remain until the end of 2012 after which time these price increases will increases will double as full emissions liability becomes due (for example, 8c/litre and 10% respectively). From 2015, agriculture will enter the ETS and be asked to pay for a portion of emissions from livestock.

Just how all this works is best described using a case study. The example below describes a balance of carbon liabilities and credits for the dairy farm described on page 38 (Topic 2). The potential impacts of becoming carbon neutral are discussed, along with the possible use of forestry to offset all on-farm emissions. This example is based on Infosheet 9 (**www.carbonfarming.org.nz/articles**).

See **www.carbonfarming.org.nz/articles.html** for examples of other farm types (including sheep, beef and arable).

Dairy farm example (repeated from Topic 2)

Remember that livestock are the source of 86% of emissions from the case study farm (1606 of the total 1876 farm emissions). The Carbon Farming Group calculator was used to prepare this table — **www.carbonfarming.org.nz**

Annual GHG emissions from a 535 cow dairy farm

GHG source (annual emissions)		Emissions factor	Tonnes CO_2 (NZU)
Petrol	1,500 litres	0.00234[1]	4
Diesel	11,000 litres	0.00268[1]	29
Electricity	62,240 kWh	0.00023[1]	14
Nitrogen	39 tonnes	5.72[2]	223
Milk solids	210 tonnes	6.14[2]	1290
Cull cows	80 head	1.98[2]	158
Carcass weight (cull cows)	20 tonne	7.9[2]	158
	Total		**1876**

[1] From New Zealand Greenhouse Gas Inventory (unit of measure x factor = tonnes CO_2/unit of measure) **www.mfe.govt.nz**

[2] From Regulations for Agriculture in the NZ ETS. This can be found at: **www.maf.govt.nz/climatechange/agriculture/EmissionsFactors_AgETS.pdf**. Note that two calculations are required for sales of livestock to meat processors, number of head killed x factor and carcass weight of livestock x factor.

To work out the full cost of GHG emissions, multiply the quantity of emissions as tonnes CO_2 Eq by the cost of a New Zealand Unit (NZU). For example the total annual GHG emissions cost of the cull cows is 80 head x the factor (1.98) plus 20 tonnes meat (80 x 250 kg/head) x the factor (7.9). This equals 316 NZUs. Multiply this by the cost of an NZU, say $25. The total cost is $7900. This equals 39.9c/kg meat. Similarly for milk solids the total cost is 210 tonnes x the factor (6.14) x $25/ NZU = $32,250 or 15.4c/kg milk solids.

Impact of ETS on-farm

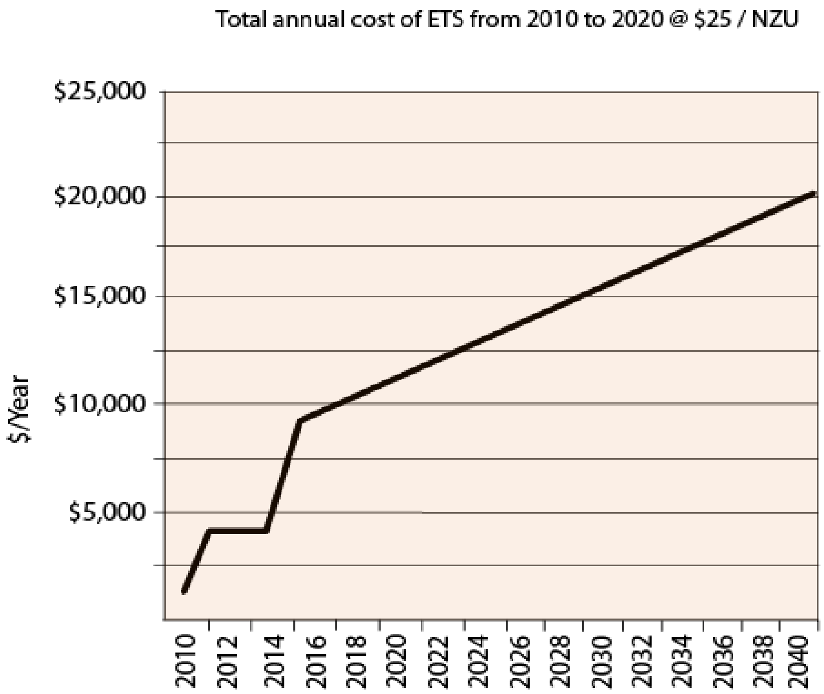
When agriculture enters the ETS from 2015, initially there will be a 90% free allocation of credits which means that farmers will be liable for 10% of their livestock emissions (energy and fertiliser will be paid separately). This amounts to 161 NZUs in 2015 for this farm (4c/kg meat and 1.5c/kg milk solids). Agricultural processors will pay this on behalf of individual farmers as a levy per kg of produce. This includes meat and milk processors, fertiliser manufacturers and importers, egg producers and live animal exporters. The free allocation for agriculture (livestock emissions) will reduce by 1.3% per year from 2016 onwards. The table below shows how the various sectors enter the ETS and the gradual ramp up in portion of emissions liabilities this example farm will have to pay for. It is expected that additional processing costs associated with the ETS will be passed on to farms. For dairy farms this may amount to 1.8c/kgMS /year in 2011 and 2012 and will double to 3.6c/kgMS/year

Annual cost of ETS to a 535 cow dairy farm[1] until 2020 ($25/NZU)

Year	Energy (NZU)	Fertiliser Nitrogen (NZU)	Liquid Fuel (NZU)	Agriculture (NZU)	Liabilities (NZU)	Total
2010	4	0	8	0	12	$300
2011	7	0	17	0	24	$600
2012	7	0	17	0	24	$600
2013	14	0	33	0	47	$1,175
2014	14	0	33	0	47	$1,175
2015	14	22[2]	33	161[2]	230	$5,750
2016	14	25	33	179	251	$6,275
2017	14	27	33	198	272	$6,800
2018	14	30	33	216	293	$7,325
2019	14	33	33	234	314	$7,850
2020	14	35	33	252	314	$8,350

[1] On-farm emissions only based on 210,000kg milk solids and 80 cull cows with 250 carcass weight.

[2] The gradual increase from 10% liability for agriculture is factored in for livestock and nitrogen fertiliser.



Reporting requirements

Emissions reporting requirements for agriculture were released in October 2010. They are:

- Agriculture will be able to carry out voluntary reporting from 2011
- Reporting will be mandatory from 2012
- Emissions costs will have to be paid from 2015 onwards.

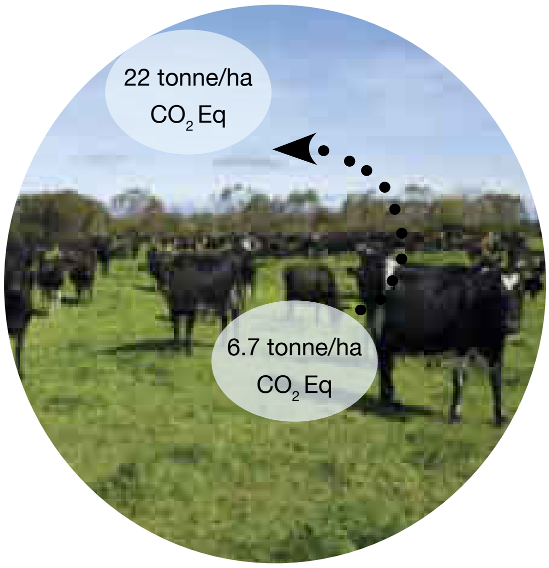
To obtain the latest information on reporting go to **www.maf.govt.nz/climatechange/agriculture**

Carbon price effects

At the moment carbon liabilities for agricultural livestock will be paid for by the processor from 2015. Changes in the carbon price will have a direct impact on final costs of any scheme. The market price for carbon is very uncertain and will continuously vary like other commodity prices. However, post-1989 forests provide credits at farm and national levels. Access to these credits reduces exposure to future increases in carbon price, significantly reducing business risk. This will add carbon to the range of products considered by forest managers.

Off-setting liabilities using forestry

Forestry offers farmers an opportunity to gain carbon credits which could be used to off-set emissions from farming activities — but how might this work? It requires an understanding of some basics of forestry and carbon management. As forestry offers potential to offset emissions it could be used as part of a strategy to respond to the GHG emissions liabilities expected for agriculture.



In order for a forest owner to receive credits for the carbon stored in their forests certain conditions must be met. Forests need to capable of growing to 5m in height, cover over 1 hectare, be over 30m wide and have 30% land cover. They can have be any species except trees grown for fruit or nuts and can have any harvesting regime.

Forestry and carbon accumulation

Trees use the sun's energy to convert CO_2 into organic compounds using photosynthesis and store carbon for between 70–500 years. Carbon, along with hydrogen and oxygen, is stored in the stem wood of a tree. At harvest when a log is removed, approximately one tonne of CO_2 Eq is also removed in a cubic metre of stem wood. There is about 2.5 tonnes of CO_2 Eq in a 30 year-old pine tree. It is worth remembering that CO_2 Eq do not equal tonnes of carbon. CO_2 is 27% carbon and 73% oxygen. So a log of pine stem wood has about 270kg of carbon.

The quantity stored by a tree and the length of time before a maximum is reached depends on the species and where it is growing. You will find that most descriptions of carbon accumulation by forests in New Zealand relate to pinus radiata or radiata pine trees. That is because a lot is known about this species as it has been grown widely, studied and measured since before 1900. Enough is known in fact that growth rates can be predicted or 'modelled' by region. In this way the quantity of carbon accumulated (or carbon credits) can be calculated from pre-determined growth rates. This information is available as 'look-up tables' from MAF to determine the quantity of carbon which can be claimed for a forest of radiata pine planted after 1989 on land not previously planted. The tables go up to 50 years of age and the information shows growth rates for different regions. For example, Gisborne has the best radiata pine growth in the country while Canterbury and West Coast have the lowest.

Alternative species to radiata pine such as douglas fir, macrocarpa, eucalyptus and native species also have look-up tables but these are generalised over the whole of New Zealand and provide more conservative estimates of tree growth. This system allows carbon credits from forestry to be accounted for and allocated to forest owners. These NZUs equate to CO_2 Eq which is approximately one cubic metre of pine stem wood. NZUs can be sold to businesses with emissions liabilities in New Zealand and used to pay for the additional cost of GHG emissions. There is scope to conservatively manage sales of carbon credits through the life of the forest so that sufficient credits are retained to balance forest harvest and livestock emissions.

Carbon forest management

Should a farmer be interested in planting a new forest for the purposes of gaining carbon credits and the other benefits of growing trees (listed below) he or she should learn more about managing forests for carbon and timber. Information is available at **www.carbonfarming.org.nz/articles.html.** Look for Infosheet 12 and 14 on forest carbon management, risks and liabilities.

Other benefits of incorporating forestry for carbon management

While on-farm planting of trees can reduce exposure to external carbon costs imposed by markets or governments, it can also form part of a sustainable land management strategy with positive environmental and economic outcomes. Farming operations which integrate forestry can become more resilient to climatic and market changes. In some farming situations the incorporation of forests into the farming business (either on or off-farm) may offer resilience to climatic events. For example, through soil stabilisation, waterway protection or emergency stock fodder from poplars during drought. Income from forest harvest can provide resilience to fluctuations in prices of other farm commodities. The timing of harvest is flexible so forests can be retained when income from other commodities is good, and then harvested in a year of poor returns from other commodities. Retiring less productive areas of the farm to forestry can improve overall profitability as inputs are focused on the more productive features. Additional benefits from tree planting include:

- Provision of shelter for stock
- Increasing on-farm biodiversity
- Improvement of the amenity or aesthetic values of a property.

Relationships with regional councils are also likely to be improved in recognition of improved on-farm environmental performance.

Using forestry credits to offset liabilities from agricultural emissions

There is little that can be done immediately to reduce livestock emissions without reducing stock numbers. In this example we have assumed that emissions will remain constant in the short term, and so carbon credits are required to offset emissions. The rate of carbon accumulation (or 'sequestration') varies with species, climate, age and management regime. For the case study discussed on page 120, we have conservatively estimated that by the year 2040, 400 tons of carbon will be accumulated and stored in a hectare of radiata pine forest. This forest is assumed to be planted and harvested on a continual basis ie, harvest rate is equal to growth rate. We calculate that total emissions liabilities for the example dairy farm from 2010–2040 will be 12,412 NZUs.

31 hectares of new forestry would be required to offset this amount. The table below shows:

- The total cost of emissions liabilities to the farm
- The effect of carbon price
- The impact forestry could have on addressing those costs.

Effect of carbon price and forestry on cost of ETS to a typical dairy farm

Carbon (NZU) price	Total cost to 2040 No forestry	Total cost to 2040 With 31ha forestry
$25	$310,300	Cost of forest
$50	$620,600	Cost of forest

At $25/NZU the total cost to the farm for emission liabilities between 2010 and 2040 will be $310,300, or about $10,340 per year. Double this if the price rises to $50/NZU. However, if 31ha of new forest is established then the cost of liabilities under the ETS will not exceed the costs of establishment and maintenance which will be considerably less (approximately $71,000). The addition of forestry as an offset against emissions could play an important role in reducing the cost of the ETS to the farm by protecting the business from the risk of future increases in the price of carbon.

But I don't have land for trees?

For farms without suitable land, new forests could be established on less productive land purchased in partnership with other livestock owners. Joint ventures could be developed whereby a forestry right is granted against the title of the land by a landowner to another person to establish, maintain and harvest a crop of trees.

How does the ETS differ from carbon footprinting?

GHG emissions from the farm are calculated for two main reasons:

- The ETS
- Carbon footprinting.

The principles are the same for both but the accounting and reporting requirements for carbon footprinting are more complex than the ETS.

Calculations required for the New Zealand ETS focus on annual GHG emissions and can be calculated from the inputs to the farm, including energy (electricity and liquid fuels), nitrogen fertiliser applied and the numbers multiplied by the emissions per animal. This is presented in the annual GHG inventory produced by the Ministry for the Environment. These calculations will determine the costs to agriculture in 2015 for emissions liabilities from livestock.

GHG or carbon footprinting is a way of measuring and quantifying GHG emissions for marketing and consumer information purposes. These assessment processes measure the emissions from the 'paddock to the plate', or the lifecycle analysis of a product. This describes to the consumer what quantity of GHG emissions went into producing, transporting, storing and consuming the product. On the farm GHG emissions for carbon footprinting must account for:

- The energy content of agrichemicals and fertiliser used
- Emissions from earthworks

- Emissions produced by contractors used on the property
- Lifecycle emissions from tools used, such as machinery.

In contrast with the ETS there are no credits for new forest plantings but as with the ETS, there are liabilities associated with changing land-use from forestry to agriculture.

At present carbon footprint has no penalties or added value associated with it. An efficient carbon footprinting may be important for access to overseas markets in the future and so these principles are important to understand. The picture (right) shows labels on products in our overseas markets which indicate their carbon footprint.

Carbon footprint label on food products

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