


An overview of CLIMATE CHANGE

and possible consequences for Gisborne District

Louise Savage



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Emergency Management Group

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Contents

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Disclaimer: Various opinions are contained in this report. The information has been compiled by considering the most up to date published climate change information available at the time, and interpreting this in a local context. Numerous people have provided comments and expertise, however the nature of climate change predictions is that they contain elements of uncertainty.

This paper sets out the most plausible consequences, in the opinions of the author and contributors, and will require updating as further information comes to hand.

Foreword

The Civil Defence and Emergency Management Group needs to be kept informed on the local effects of long-term climate change. The purpose of this paper is to inform the Group, and the wider public, of the range of considerations we must have for climate change and its interrelated consequences.

Planning and policy decisions are required to be founded on the avoidance or mitigation of adverse effects on the environment, while weighing up all the costs and benefits.

The Gisborne District Council is required, under the Resource Management Act 1991, to manage the resources of land, water and air, within the boundaries of our district, on behalf of all our residents.

We are now entering a new era of climate instability that will see changes to land, water and air, in fact all the components making up our natural environment. I prefer the phrase 'climate instability' to 'global warming'. The latter is a little misleading because we will experience weather and climate extremes that at times will appear to buck the trend of 'global warming'.

The Earth's climate system as a whole is becoming more energetic because greenhouse gases in the atmosphere are increasingly absorbing and re-emitting heat that would normally escape to space. This extra energy may drive the climate system faster: it is likely to be windier, stormier and more humid, while the global average temperature trends upwards.

There will still be warmer and cooler, wetter and drier months, seasons and years. Climate parameters trace a 'wobbly' line if illustrated on a graph. If we experience a wet, cold winter like the current one, people tend to scoff at predictions of global warming. Instead think: "climate instability" and "a more energetic climate system".

Is this really our problem?

Although we each contribute in a small way to climate change, these influences are overwhelmingly coming from outside the boundaries of our District: they are largely the consequences of human activities taking place elsewhere in the world.

New Zealand contributes only 0.2% of global greenhouse gas emissions, but we cannot expect major industrial emitters to take action if we are not making a contribution. In addition, there could be significant opportunities for New Zealand to come up with new energy-saving technologies that will benefit the world's environment and our country economically.

Change to a warmer, more energetic climate system is irrevocably set in motion. Therefore avoidance is no longer an option. That leaves mitigation as our only resort.

There is little doubt that climate change is going to increase hazards and adverse effects: flooding, coastal and soil erosion, drought, inundation, invasion of animal and plant pests. There are few, if any, silver linings to climate change.

There are many individuals in our community for whom livelihood or business depends upon a benign climate, who are environmentalists, or simply concerned citizens. There are risks to human and animal health. We all want to know what is really going on. Many reports about climate change in the media have been confusing or even contradictory.

There are also of course some still in 'climate change denial', even though the evidence for climate instability seems to me compelling.

Many organisations including NIWA, the New Zealand Climate Change Office, Ministry for the Environment, Ministry of Health, universities, Crop and Food Research, the Department of Conservation, Landcare Research, Hort Research, MAF, Councils, and Civil Defence are continuing with research and in some cases modelling climate change effects.

Government's policy package to address climate change is at Select Committee stage; therefore the information contained in this report will need to be updated on a regular basis.

What's Kyoto all about?

Whatever the good *intentions* are, mention of *Kyoto* seems to cause many people's eyes to glaze over. At first it seemed like a boon for New Zealand, with a certain financial windfall. But the public has become cynical about *Kyoto*, perceiving the paperwork and jobs it has spawned as an 'environmental gravy train' for promoters of climate change. Even worse, it now seems certain there will be a big tax bill at the end of all the calculations. Many people think, "We can't afford to be part of this".

Kyoto, in a nutshell, states that ratifying nations, including New Zealand, agree to stabilise greenhouse gas emissions at or below 1990 levels. All the ensuing discussions have focused on how this might be achieved.

There is one glaringly big problem: since 1990 the world's population has increased by 27%, or a staggering 1.4 *billion* people. That is similar to adding another country as populous as China to the world since 1990. There are now 6.6 billion people on Earth, and energy consumption for most people would have increased since 1990.

At the same time, people in every country, and especially the "developing countries" aspire to the affluent lifestyle the people of industrialised and "western" countries have enjoyed for decades.

Ever-greater numbers of people own motor vehicles, drive on sealed roads (the tar used in construction is derived from oil), consume farmed meat and purchase disposable, non-repairable goods. Reducing emissions to pre-1990 level is, barring sweeping changes to technology and people's mind-set, an impossibility.

It is highly unlikely that most people in New Zealand (or any other wealthy country) would accept a lower standard of living, consuming less energy and making do with fewer material possessions, in order to allow people of developing countries to enjoy a corresponding increase in standard of living. Where does that leave Kyoto?

Are we fighting a losing battle?

The promoted solution is to increase stores of carbon dioxide (in vegetation, specifically forest). The net carbon dioxide 'permanently' removed from the climate system equates to that not re-emitted through the forest being cut down, destroyed by fire or natural disaster, consumed by insects, browsing animals or rotted through microbial action. Even if the timber produced is used to build a house, the sequestered carbon will eventually re-enter the atmosphere.

In addition, there is limited land suitable for afforestation. What happens when every available, fertile tract of land, not needed for food production, is covered in mature forest? If humans have not solved their dependency on fossil fuels, or numbers of people on the Earth have not drastically reduced, we are back to where we started.

Sequestering carbon in woody biomass will merely buy us some time. On the positive side, there will be enormous benefits for soil and water conservation and biodiversity if afforestation gathers pace, and occurs in the right place.

What is actually happening is that *some* countries are attempting to reduce emissions; *some* are looking at new technologies to supply non-polluting power, while other countries are only talking about what needs to be done but have no plans in place to actually do anything yet. Indeed, some people, in total climate-change-denial, are urging their governments to do nothing, that it is all an expensive mistake and will blow over eventually. Some people even seem to have the attitude that if all the resources are running out, "I better be quick to secure my share for me".

There are no countries whatsoever with policies to reduce numbers of people, vehicles and farm animals. In fact, many countries have policies to actively increase their populations, through immigration, increasing the birth rate, or both.

A fundamental question it seems everyone is avoiding is: just how many humans on Earth should there be for a sustainable future?

Will natural feedback mechanisms act to remove carbon permanently from the atmosphere and return the Earth to a comfortable temperature for some forms of life. Can the oceans absorb all the excess carbon dioxide? Will the present mass-extinction of species continue unabated?

Current research suggests some of the Earth's natural climate-regulating mechanisms may even act to exacerbate atmospheric warming, once warming is underway. Is it possible we are inexorably heading towards a climate that may not favour humans?

Forces much larger than Kyoto are at work, and we may be powerless to do anything. However, I believe we should certainly try.

Louise Savage

Summary

Are the global-warming models believable?

The ‘hard evidence’ for global warming comes from *measured* increases in the concentration of CO_2 (and other greenhouse gases) in the atmosphere, *measured* sea-level rise, and *measured* increases in global-average temperatures. We can compare current trends with historic and/or ‘fossil’ evidence for each of these parameters.

All the other effects of climate change are the consequences of these three observed changes, and include:

- Reduction in diurnal (day and night) and seasonal temperature variation;
- Decreased frost risk and increased chance of very high daily maximums;
- Reduced annual average precipitation, with drought risk extending into autumn and spring;
- Increased possibility of very heavy rainfall events;
- Coastal erosion and inundation;
- Increased strength of westerly winds.

There may be other changes, as yet poorly quantified, for instance to cyclonic storm frequency, ocean currents and wave heights.

Changes to the coastline

The residents of Gisborne value the coast and beaches, and people probably are concerned about sea-level effects.

Sea-level rise has been quantified locally, and is likely to result in more coastal floods. Storm surges will reach further inland. However, rising sea level will not significantly alter the impact of tsunami.

We will lose land, and some sandy beaches may be threatened, but people will probably still want to live on, and develop the coast, despite the increasing risks

‘Treatment options’ will depend on what is practical, affordable and possible at a given location, and some dwellings and infrastructure will ultimately have to be shifted.

River mouths may be inundated, and rivers could alter their course close to the mouth,

Effects of climate change on indigenous biodiversity

Indigenous biodiversity is already under pressure. Effects of climate change will exacerbate the problems that already exist. Drought, pests, weeds and fire will be the biggest threats.

Species would, in the natural setting, alter the boundaries of their natural distribution in response to climate change. In a modified environment this may not be possible.

We can examine changes that have occurred in the past from fossil and pollen records, but the magnitude of human-induced climate change will be bigger than ever seen in the past. In fact, changes may be too fast for some species to adapt, and the mix of indigenous species present could be drastically altered.

Locally we could lose some species. Especially vulnerable are weka, kiwi, aquatic species, some forest trees, alpine plants and alpine animals.

Climate change impacts for agriculture and horticulture

The effects of climate change look to be disadvantageous for farming, horticulture and cropping, all things considered.

An increase in the frequency of climate extremes will be more significant for farmers and growers than incremental change.

Some crops might no longer be economic in Gisborne District, and a warmer climate will favour the spread of invasive sub-tropical grasses and numerous other plant and insect pests from the north.

Drought risk will intensify for all areas that are currently drought prone, while the expected increase in intense rainfall events will mean much valuable precipitation is lost as runoff, and soil erosion will be exacerbated.

There will be increasing pressure on water resources, for both stock and irrigation, but at this stage it is unclear precisely what the effects will be on the groundwater aquifers. The Council will need to be careful with allocation of water permits, and many if not most of the rivers and streams of the district will have minimum flows set in the future.

Ultimately, downstream users will be competing with those upstream for water resources

Irrigation of pasture may become popular in some areas where it is practical to do so.

Agriculture is responsible for around 55% of New Zealand's greenhouse gas emissions, and yet mitigation options are limited. Animal vaccines and feed additives, as a means of reducing emissions, are years away.

At the moment, practical options include retirement of marginal land for the creation of carbon sinks, and planting more trees in general.

Pest insects are directly favoured by a warmer climate and we can expect greater numbers of those already present, and numerous new invasions in the future. We may need to use significantly more chemical insecticides, and possibly new types.

Animal health effects are already noticed and Gisborne's climate is likely to become increasingly marginal for sheep. Heat stress on animals may be severe with an increase in the frequency of very hot summer days. Animal diseases are likely to increase in prevalence across the whole range: parasites, flystrike, fungal and bacterial diseases.

Farmers will need to consider provision of shade trees, more water storage, and possibly alternative forage trees and crops.

Soil conservation measures will become more critical in view of an expected increase in intense rainfall events.

Warmer temperatures could be advantageous for arable crops, however moisture availability may be critical, temperatures may get too high, and increased cloud cover would delay crop maturity.

Perennial crops with chilling requirements (eg kiwifruit) will ultimately become uneconomic in Gisborne District.

The season for apples could theoretically be advanced, however very hot temperatures or increased cloud cover may be deleterious.

Wine grapes may benefit from warmer conditions, however fungal and insect pests will increase.

Rural fires

The risk of fire and catastrophic loss of vegetation cover becomes ever more likely as the climate warms. A warmer, windier and drier climate will mean a greater number of larger, more intensely burning fires. Fires will be more dangerous and take much longer to put out.

If water is not readily available due to low river flows and dams drying out, more labour intensive and invasive methods of fire fighting may need to be employed, for instance the use of bulldozers.

The role of forests in mitigation of climate change

The government has clearly signalled its intention to retain carbon credits accruing to plantation forest, in order to avoid distortions in the timber market.

While plantation forests do absorb carbon, the sequestered carbon is ultimately released when the forest is pruned, thinned and harvested. Even timber used in a ‘permanent’ structure will ultimately be released.

On the other hand, permanent forest sinks will sequester carbon and help New Zealand meet Kyoto commitments. This will require land use change, and the incentive for landowners will probably come from allocating tradable carbon units.

Legislation to enable the Permanent Forest Sinks Initiative (PFSI) is at select committee stage, and is intended to be in force in advance of the first commitment period of Kyoto (by 2008). The PFSI could enable land that is unsustainable for farming to generate an income by facilitating regeneration to indigenous vegetation.

There is up to 120,000 hectares of ‘marginal land’ within Gisborne District, including multiple-owned Maori land, which may be suitable for ‘carbon-farming’. How much land, and which classes, is converted from farming to trees for the purpose of ‘carbon-farming’ may depend upon the price set for a tonne of CO_2: \$15 is said to be the likely value at the commencement of carbon trading.

There may be opportunities to create forested areas utilising ECFP funding for reversion, and these areas could become permanent forest sinks, if protected by a QEII covenant or Nga Whenua Rahui. Another possibility may be to plant pines as a nursery crop, but then facilitate a change to other species.

EBEX21® is a voluntary programme, designed by Landcare Research, that will match landowners with land available for revegetation, with businesses wishing to offset carbon emissions. Several businesses have taken up the scheme, but emitters are at present outnumbered by offers of suitable land.

There is uncertainty about what will happen after the First Commitment Period of Kyoto (2012). This could be a major stumbling block for landowners and may hinder uptake of afforestation projects.

Ocean & currents

The Subtropical Front is an important area for plankton and fish stocks. A significant proportion of New Zealand's fish stocks come from the area of ocean close to the Subtropical Front. Present climatic conditions enhance the productivity of the front, to New Zealand's benefit.

Phytoplankton are crucial to regulation of global climate. They represent a major carbon sink, through absorption of CO_2 from the atmosphere. Scientists now have the remote-sensing technology to photograph distribution and abundance of phytoplankton blooms.

El Niño and La Niña weather patterns affect both phytoplankton and fish abundance; Climate change may intensify El Niño and La Niña weather patterns. The intensity of mid-latitude storms affecting New Zealand may also increase.

If westerly winds increase, the Antarctic Circumpolar Current would be strengthened, further isolating waters on Campbell Plateau and increasing the inflow of cold water to Chatham Rise. This may modify the Subtropical Front and associated cloud cover.

Stronger westerlies could also enhance the influx of warm subtropical waters to New Zealand shores, although this effect may offset locally by wind-induced upwelling of cooler subsurface waters.

Effects of climate change on human health

Climate influences health both directly (heat stress and the consequences of natural disasters), and indirectly (the resulting burden of disease due to disrupted agriculture, food supply and water quality).

Secure and clean drinking water supplies are probably the most significant concern for Gisborne District, because in many rural areas and settlements they are already inadequate.

Skin cancer may continue to increase, unless offset by changes in behaviour.

There may be more civil emergencies such as floods and storms.

There could be more dust and allergens in the air, but less winter smoke.

Incidence of food poisoning will increase as the climate warms.

Algal blooms and shellfish poisoning may become more frequent.

New insect disease-vectors may become established in Gisborne District, and we wont be able to control or eradicate exotic insects indefinitely.

Land-use changes, particularly from farming to forestry, would increase exposure to occupational hazards.

Hardship, due to prolonged drought or severe storm damage, may have consequences for the physical and mental health of our citizens.

Influence of climate change on tourism

Gisborne's climate, sandy beaches, surf and outdoor lifestyle are the major drawcards bringing tourists to our region. Future decisions may allow the sea to claim low-lying coastal land in order to conserve sandy beaches.

A warmer climate may extend the peak visitor season, however the cost of transportation (fuel) will be a major influence. Overseas visitor numbers will be reduced, but domestic visitors may increase.

When it rains or is windy enough to make the beach unpleasant, the focus for visitors here for the sea and sun tends to shift towards cultural and heritage activities (food, wine, the museum, cultural tours).

Increased wind days, and coastal erosion may combine to further reduce opportunities for camping.

Projects to reduce emissions

The Projects to Reduce Emissions (PRE) programme is a Government initiative to encourage reductions in emissions of greenhouse gases by awarding carbon credits for reductions made in CO_2 emissions that are above and beyond business-as-usual.

The extra funds generated are expected to bring forward projects that would have otherwise been uneconomic.

Potential projects in Gisborne may include reducing fuel consumption by 2 to 3.3%, perhaps by increasing use of the railway line south and by voluntary reductions in use of private cars.

Bio-ethanol is unlikely to be used extensively as a transport fuel in the near future as it is too expensive.

The proposed Mokairau wind farm is on hold indefinitely. Mokairau may not be consistently windy enough and the current focus is on 'prospecting' for alternative sites.

It is unlikely a wind farm development would go ahead locally in the absence of PRE.

Chapter 1: Are the global-warming models believable?

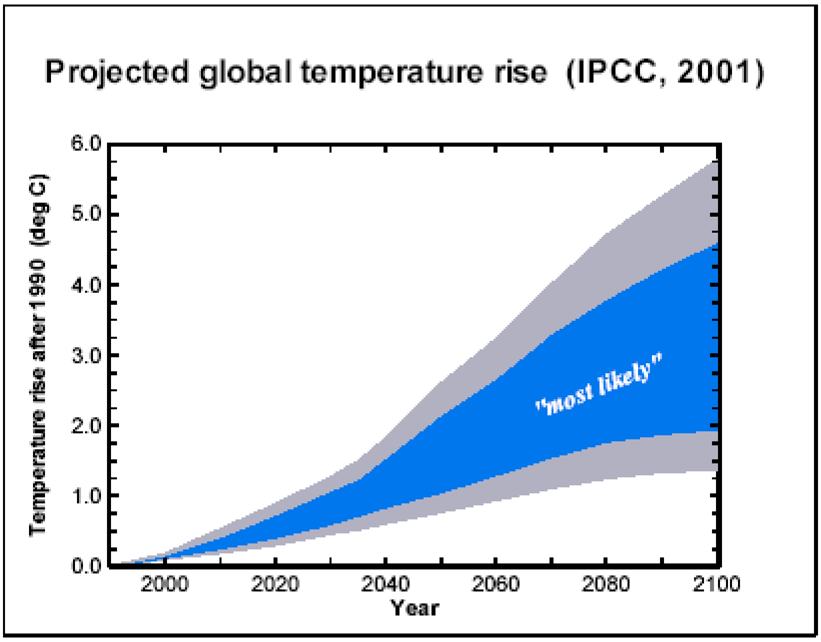
Key points from this section:

- Temperatures will increase, with most pronounced increase occurring in the winter and at night, leading to:
- Decreased frost risk and increased chance of very high daily maximums;
- Reduced annual average precipitation, with drought risk extending into autumn and spring;
- Increased possibility of very heavy rainfall events;
- Sea level rise with associated coastal erosion and inundation;
- Increased strength of westerly winds.
- There may be other changes, as yet poorly quantified, for instance to cyclonic storm frequency, ocean currents and wave heights.

New Zealand is now close to being as warm as it has ever been over the past 100,000 years, and during the next 100 years the climate is likely to shift outside of the range it has occupied for the last two million years.

No one can predict precisely what Gisborne's future climate will be. Climate modelling is not an exact science. Current models have a sensitivity of around 50%, and it is impossible to accurately quantify future atmospheric concentrations of greenhouse gases: emissions will reflect social and economic development in various countries of the world, and the efforts of some countries to stabilise emissions and create more carbon sinks. But whatever the rest of the world does, it will affect us, down here in the south Pacific.

This does not mean predictions are guesses, rather that there is a plausible range of global climate scenarios on a spectrum from 'best case' (+1.4^{o} this century) to 'worst case' (+5.8^{o} this century).



Above: IPCC (Intergovernmental Panel on Climate Change) climate model predictions for global mean air temperature. The "most likely" zone shows the range of the average of seven ocean-climate model simulations for each of 35 socio-economic emission scenarios. The grey-shaded zones show the ranges of all seven models for all 35 scenarios.
Source: New Zealand Climate Change Office.

Climate change in New Zealand will be ameliorated by the vast expanse of sea around us. We will be subjected to less warming than the continents. New Zealand is likely to warm by 0.7^{o} for every degree of average global warming. Our climate has already warmed measurably. In general, warming has been more marked in winter then in summer and at night rather than during the day, decreasing the seasonal and diurnal temperature range.

Precipitation will change by around 10% for every degree of global warming, and will steepen the current gradients (wetter to the west of the axial ranges, and drier to the east).

Global models are able to predict trends in broad climate patterns across the Pacific. These were "downscaled" by NIWA to produce more localised predictions by applying a statistical technique to account for the influence of New Zealand's complex topography. These data were used to assess in particular drought risk, because of the importance of drought for agriculture and water resources.

NIWA has investigated four climate change scenarios by combining two different regional patterns produced by two climate models. The two global temperature projections selected span the central portion, but not the full range of possible temperature changes developed by the IPCC (Intergovernmental Panel on Climate Change) in 2001. It is therefore possible that the effects we will observe could be more severe, or milder, than the models predict.

Are El Niño and La Niña phases linked to global warming?

Recent analysis suggests that rising global temperatures may be linked to stronger and more frequent El Niño episodes. In the past twenty years, there have been significantly more El Niño episodes than in the 20 years before that. El Niños are characterised by enhanced westerly winds, with a high risk of drought on the east coast of both islands. Conversely, La Niña episodes are characterised by more northerly and easterly winds: the southern part of the South Island is prone to drier than normal conditions while temperatures are above average in the north and west of the North Island.

The Interdecadal Pacific Oscillation (IPO)

The IPO causes shifts in the climate every one to three decades. Although strongest in the north Pacific (centred near the dateline at 40°N), it appears to have an effect in the New Zealand region.

The IPO has positive (warm) phases associated with an increase in El Niños, and negative (cool) phases, showing an increase in La Niñas.

Three phases of the IPO have been identified during the 20th Century: a positive phase (1922–44), a negative phase (1946–77) and another positive phase (1978–98). Since 1999 the IPO appears to have reversed again, to become negative.

There is therefore the potential for some years to be moister and cooler than average on the East Coast over the next 20-30 years.

Predicted seasonal temperature change

Temperature predictions for Gisborne District, set out in the table (over), were calculated by NIWA based on the full range of IPCC greenhouse gas emission scenarios and using a range of different global climate models[1].

1.Projections given in official reports from the New Zealand Climate Change Office are typically given for the 2030s and 2080s compared with the 1990s.

	Summer	Autumn	Winter	Spring	Annual
1990-2030s	+0.0° to +1.3°	+0.1° to +1.3°	+0.4° to +1.6°	+0.2° to +1.3°	+0.2° to +1.4°
1990-2080s	+0.4° to +3.9°	+0.5° to +3.8°	+0.8° to +4.1°	+0.6° to +3.4°	+0.6° to +3.8°

Above: Predicted seasonal temperature change for Gisborne District

Predicted changes in precipitation for Gisborne

There are variations in projected rainfall in different localities throughout the district, as would be expected, due to topography. There is a great deal of variability between climate models, however all predict that Gisborne District will become drier, and that the changes will be more pronounced in autumn and spring.

	Summer	Autumn	Winter	Spring	Annual
2030s	-20 to +7	-29 to +2	-14 to +10	-27 to +11	-17 to 0
2080s	-21 to +19	-54 to +12	-32 to +23	-60 to -6	-31 to +4

Above: Predicted changes (in %) in annual and seasonal precipitation for Gisborne

Heavy rainfall events

A warmer atmosphere can hold around 8% more moisture for every 1° increase in temperature. There is therefore potential for more frequent, intense rainfall events, but the changes are very difficult to quantify.

One earlier study (by Whetton *et al,* 1996[2]) suggested no change, through to a halving of the return period for heavy rainfall events by 2030 (in other words, downpours of a given magnitude could be twice as frequent). By 2070 the same study predicts no change through to a fourfold reduction in the return period for heavy rainfall (equating to downpours being four times as frequent).

A more recent simulation (Semenov and Bengtsson, 2002[3]) confirmed predictions of an increase in heavy rainfall events. When used to predict rainfall returns for Auckland, a rainfall event with a return period of 50 years could be expected to have a return period of less than 10 years by 2100, under a worst-case climate scenario. No predictions for Gisborne were given in that study.

When projected increases in wind speed are overlain with temperature predictions there is an additive effect on the amount of rainfall.

Wind patterns

For mid-range temperature projections, the annual mean westerly wind component across New Zealand is expected to increase by 60% by the 2080s. Projected changes in the north-south wind component are not clear.

Intense low-pressure weather systems may become more frequent as the climate warms, so there could be an increase in severe winds.

2 & 3: in Wratt *et al*, 2004

Ex-tropical cyclones and mid-latitude storms

There are big uncertainties with predicting cyclonic storm frequency. Current knowledge[4] suggests ex-tropical cyclones may be slightly less likely to reach New Zealand as the climate warms, but that their impact may be greater when they do.

The intensity and frequency of mid-latitude storms may increase for New Zealand, but the level of confidence in this prediction is low.

Ocean currents and wave patterns

Climate and atmospheric models do not contain enough detail to quantify current and wave patterns around New Zealand.

The predicted increase in the westerly wind flow across the country, and especially in the Southern Ocean could accelerate the cold Antarctic Circumpolar Current. This may enhance isolation of cold waters on the Campbell Plateau, increase the inflow of cold water to the Chatham Rise, and alter cloud cover.

Increased westerly winds could also enhance upwelling of cold bottom water along the New Zealand coast, particularly on the West Coast of the South Island and the northeast coast of the North Island.

Increased westerlies may increase the frequency of heavy swells on those exposed coasts, exacerbating the effect of rising sea levels.

Changes in the atmospheric concentration of carbon dioxide

Globally, the increasing concentration of CO_2 in the atmosphere caused by the burning of fossil fuels is thought to be the predominant cause of global warming.

In 1750, CO_2 was at 280 ppm (parts per million) in the atmosphere. Currently, CO_2 comprises 366 ppm.

There are many uncertainties in the feedback mechanisms and biological responses to increased CO_2 concentration, however the scenarios considered by IPCC give CO_2 concentrations of 490 to 1260 ppm by year 2100.

Greenhouse gas	Main sources	Current concentration	Change expected by 2100
Carbon dioxide (CO_2)	Burning of fossil fuels	366 ppm	+170 to +600 ppm
Methane (CH_4)	Ruminant animals, landfills	1760 ppb	-190 to + 1970 ppb
Nitrous oxide (N_2O)	Fertiliser, animal excretions, crop residues	316 ppb	-12% to + 62%
Tropospheric ozone (O_3)	Natural source is downward flux from O_3-rich stratosphere. Anthropogenic source is photochemical production from precursor gases	Variable	Wide range

4: The IPCC Third Assessment Report

In Gisborne District, and New Zealand as a whole, emissions of enteric methane from ruminant animals and nitrous oxide (from fertiliser application and excreted by animals) are the more significant greenhouse gases.

Projected concentrations of greenhouse gases vary considerably across the climate scenarios. Plausible ranges of concentrations of the most important gases are set out in the table on the previous page.

Interestingly, "natural aerosols" such as sea salt and dust are also expected to increase as a result of increased evaporation, stronger winds and more drought-prone conditions.

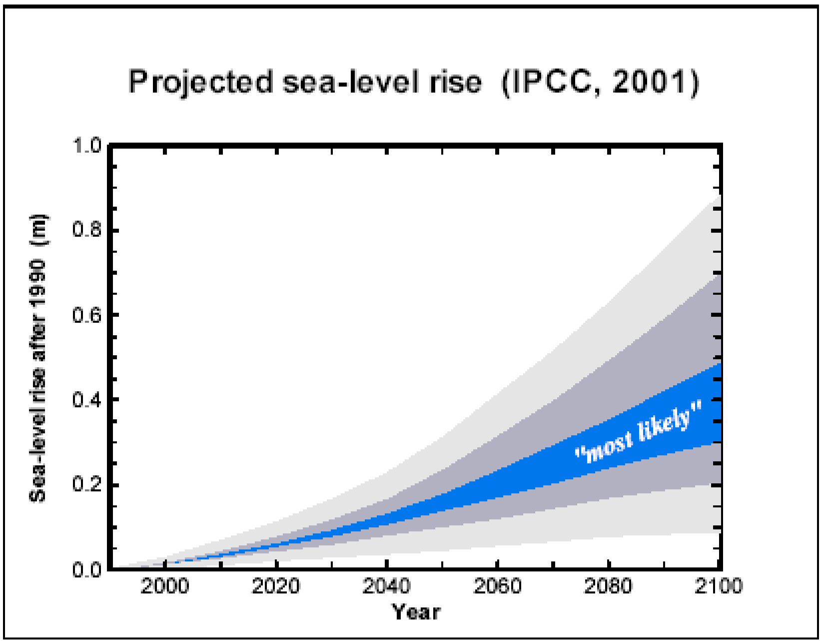
Chapter 2: Changes to the coastline

Key points from this section:

- Sea level rise is a reality – it has already been quantified locally;
- There are likely to be more coastal floods, and storm surges will reach further inland;
- We will lose land, and some sandy beaches may be threatened;
- People will still want to live on, and develop the coast, but it will become increasingly risky;
- 'Treatment options' will depend on what is practical, affordable and possible at a given location;
- Some coastal structures are currently only 1 – 2 metres above sea-level;
- Some dwellings and infrastructure will ultimately have to be shifted;
- River mouths may be inundated, and rivers could alter their course close to the mouth;
- The Coast and beaches are valued by the residents of Gisborne, and people will be concerned about sea-level effects;
- Rising sea-level will not significantly alter the impact of tsunami..

Sea level rise

The sea will ultimately inundate coastal wetlands and lowlands and exacerbate flooding, accelerate coastal erosion, threaten structures, raise water tables, and increase the salinity of rivers, bays and aquifers. The mechanism for this is believed to be the combined effect of thermal expansion of the ocean and melting of glaciers and terrestrial ice caps. It is happening now; there is no silver lining to sea level rise; we need to be aware and prepare.



Above: IPCC climate-model projections up to 2100 for global mean sea-level rise. The "most likely" zone shows the range of the <u>average</u> of seven ocean-climate model simulations for each of 35 socio-economic/emission scenarios. The dark grey-shaded region shows the range of <u>all</u> seven models for all 35 scenarios. The outer, light-shaded zone shows the range for all models and scenarios including uncertainty in ice-land changes, permafrost changes (thawing) and sediment deposition, but excluding changes in the Antarctic ice sheet. Source: New Zealand Climate Change Office.

Changes measured locally

Sea level was measured very accurately at Gisborne Harbour by the Lands and Survey Department in 1926, and again in 1990 by DOSLI[5] (Department of Survey and Land Information). Measuring seal level is a complicated (and expensive) exercise, with frequent measurements required over a period of twelve to eighteen months.

Observed net sea level rise over this period averaged 2.3mm per annum.

Compared with a national average annual sea level rise of around 1.7mm, this appears to indicate land subsidence of around 0.6mm per year at Gisborne Harbour. There is thought to be a geological 'tilting' effect occurring along the East Coast, with subsidence occurring fastest at Muriwai, and uplift of 4mm per year at the East Cape Peninsula.

This net sea level rise of 2.3mm per annum equates to 11.5cm for the past 50 years. This has had a significant effect on the coastline and on low-lying coastal land. It is likely the rate of sea level rise will accelerate; 11.5cm is the absolute minimum that will occur over the next 50 years. Climate change models predict the rise will be 30 to 50cm.

Seismic events (earthquakes) may result in rapid uplift (or downward movement) that alters relative sea level in localised areas, either exacerbating or mitigating sea level rise. These changes are of course impossible to quantify.

An increase in the risk of coastal flooding

Coastal areas will become more vulnerable to flooding for five reasons: 1. A higher sea level provides a higher base for storm surges to build upon, for instance a one-metre rise in sea level would enable a "one-in-15-year" storm to inundate many areas that today would only be flooded by a "one-in-100-year" storm. 2. The Waipaoa River will 'back up' to a greater extent during rain storms. 3. Beach erosion will make some areas of the coast more vulnerable to storm waves.
4. Higher water levels will increase flooding due to rainstorms by reducing coastal drainage. 5. A rise in sea level will raise water tables.

Storm surges

A storm surge is water that is pushed against the shore by the force of the winds swirling around a storm. This advancing surge combines with the normal high tide to increase the mean water level by a metre above the expected high tide (or possibly higher).

Wind-generated waves are superimposed on top of the storm surge. The total rise in water level could be 3 metres (or more), and may overtop dunes, causing severe damage to the foreshore and flooding coastal areas.

Much of Gisborne (including Wainui, and the airport) is currently below 4 to 5 m above sea level, so the possibility of inundation as a result of storm surge should be considered in light of the possibility of more frequent and intense cyclonic storms in the Pacific.

The rivers within the city bounds can dramatically back-up when high tide coincides with a large storm surge. If the above effect occurs when river flows are high, the risk of inundation of urban areas dramatically increases.

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5. "Report on Height Datums and Tide Gauges, Gisborne City", Alan Radcliffe, 1993.

Coastal erosion

Erosion scenarios for Gisborne coastal areas include:

1. Shoreline retreat and lateral loss of land: This is the likely consequence for our open-coast sandy beaches. Sandy beaches would still exist where retreat is allowed to happen naturally, without placement of protection works. Shoreline retreat may not occur, or may occur only slowly, on sections of coastline close to the mouths of our sediment-rich rivers.
2. Loss of beach volume: Sand may be lost offshore (or along the shore) due to changes in currents, due to erosion of headlands formerly protecting the beach, or due to reduction in sand source. The problem is exacerbated by construction of sea walls, forcing the sea to cut downward, rather than allowing sediment to be taken from the dunes.
3. Cliff erosion: The process of cliff erosion includes frittering (small pieces shattering off), undermining and slumping (for instance at Tatapouri). Where the base of a cliff is protected by a significant boulder bank or beach, the cliff will be buffered, possibly for years to decades, against erosion at the base.

The Waipaoa River mouth

As sea levels rise, the mouth of the Waipaoa River will be slowly drowned as the tidal prism[6] intrudes further and further upstream. There is plenty of freeboard in the Waipaoa Flood Control Scheme at the lower end, so capacity to hold the water is not an immediate concern.

Salt water extends inland as far as Matawhero Bridge at high tide. At the present rate of sea-level rise, salt water would not reach the Bushmere Road water intake for several hundred years, assuming river-bed levels remained constant. However, it is probable the rate of sea-level rise will accelerate, and the river bed will certainly alter over time.

Changes in rainfall patterns and possible increase in storm intensities may have an impact on sediment budgets. There could be more frequent large doses of sediment entering the sea. Turbidity in Poverty Bay is already high, and there is little benthic (bottom-dwelling) sea life.

There may be changes at the Waipaoa river mouth, with sediment bars building after storms. This could exacerbate back-up of water in the lower reaches of the flood control scheme.

Log and debris clean-ups of our town beaches may be needed more frequently.

Coastal structures and assets at risk

At-risk structures include all (natural) fore-dunes on erosion-prone stretches of coast, and the existing gabions and protection works at Wainui Beach.

The far end of Kaiti Beach Road has already been closed at the far end, due to being undermined by the sea. This will get worse and more of the road will need to be closed in the near future.

The Waima Road from the township of Tokomaru Bay to the old freezing works is also under threat from the sea, as is the East Cape Road. State highway 35 at Tatapouri is already being undermined, and together with the road at Pouawa will be increasingly threatened by the sea. Also threatened will be the building and boat ramp belonging to the Tatapouri Fishing Club.

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6. Tidal prism is the volume of sea water that flows in on each incoming tide.

Wetlands

Estuaries will migrate inland as sea level rises, transforming surrounding land into salt marsh, and the tidal area of the estuary may increase in area. Adjacent farmland worth up to $30,000/ha (in today's money) will be progressively lost.

Warmer winter temperatures may allow the establishment of mangroves in the estuarine areas of Eastland, if sea currents are conducive to their spread. The present southern limit for mangroves is Ohiwa Harbour[7].

Warmer sea-water and estuary temperatures may create more favourable conditions for toxic algal blooms, with significant impact on kaimoana, and explosive growth of invasive introduced species such as sea squirt and *Undaria*. There are certain to be others that find their way here on ocean currents, or which are transported on the hulls of ships and in ballast water.

Tsunami

Poverty Bay and the East Coast are vulnerable to tsunami, however global warming will not increase the risks of tsunami occurring: They are generated by geological events such as earthquakes, underwater landslides and volcanic eruptions.

The influence of 'baseline' sea level on how far tsunami may extend inland is inconsequential compared with the power and volume of water contained in these surges.

Pressure on coastal land

Climate change may alter any or all the physical forces that combine to shape the coastline - winds, currents, waves, storms, sediment supply and sea temperature. The situation is complex and there are no predictive models at present to take account of all these factors.

For the areas of our coastline that have historically been eroding or retreating, climate change will certainly exacerbate these trends.

However prices continue to escalate, and the desire to develop and occupy the coast has not diminished in the wake of the Asian tsunamis, the recent severe storms in the USA and Australia, nor in light of the Council's 2001 Coastal Hazards Report.

Wainui residents are already facing up to accelerating coastal erosion. Many residents took part in the process of drafting the "Wainui Beach Management Strategy" (2003).

Beach protection works should be considered short- to medium-term solutions, and may last for decades. There is pressure from property owners for protection works in some places because of the large investment in real estate.

The problem with barrier-type protection works is that the natural intertidal zone is squeezed out of existence between the sea wall and the waves. On a natural coastline, this zone is able to absorb the energy of tides and storms by shifting sediment around. High-energy waves hitting a sea wall can undercut or outflank the wall and strip sand off the beach. We have already seen this happen at the south end of Wainui Beach. Long-term, protection works are probably futile when we know sea level is rising. Managed retreat is the most cost-effective option long-term.

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7. Refer to page 17 of this report for discussion on distribution of mangroves

How can we respond to sea level rise?

There are just three possibilities:

1. Retreat. This means giving up threatened land by moving away from the coastline, or by preventing future developments along vulnerable coastlines. The sea will progressively reshape the coastline. This is what will occur along large open tracts of our coastline, where the adjacent land is used mainly for agriculture.

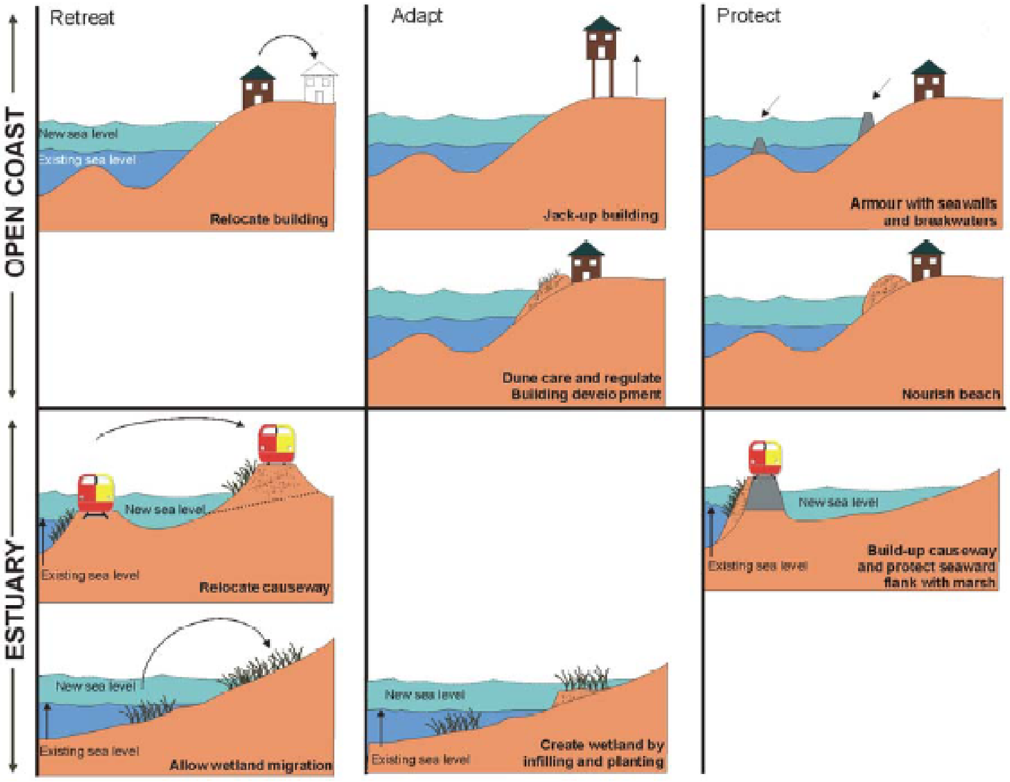
By allowing coastlines and estuaries to migrate naturally inland, the natural ecosystems will readjust. Sources of kaimoana may be maintained. Allowing the beach to retreat on sandy shores will maintain a useable beach – very important to our lifestyle in Gisborne District. Land-owners will be the losers.

For coastal communities already experiencing erosion, retreat will ultimately be the only long-term option. For any new development near the coastline, a wide buffer will be desirable, and/or buildings will need to be removable.

Managed retreat is being tried at 40 localities around the British coastline where subsidence has been occurring for some time. Coastal erosion will be allowed to follow its natural course.

2. Adapt. The land continues to be used, but with adaptive responses such as elevation of existing buildings, raising existing stopbanks, roads or railway lines, modification of drainage (maybe pumping stations) and land-use change. Enhancement of natural defences may include dune care initiatives, and the creation and planting of intertidal zones and marshland.

3. Defence. This includes ‘hard’ options such as sea walls, or more environmentally acceptable ‘soft’ options such as nourishing the beach by adding similar sized sediment to the beach. The latter is very expensive, but has been done at Mission Bay in Auckland, and at Westshore in Napier.



Above: Response options to sea-level rise for open coasts and estuaries.
Source: New Zealand Climate Change Office, graphics by K MacLeod.

Hard protection works result in loss of character of the beach and ultimately loss of the beach. They are not a practical measure for vast tracts of New Zealand. In South Carolina, USA, hard structures are now prohibited even in urbanised areas, in recognition of the importance of beaches to the wider community.

Accreting sections of the coast

Some areas of our coastline are currently accreting, or building out to sea. These areas coincide with the mouths of major rivers and the adjacent beaches, due to the sediment delivered by those rivers. Accretion is likely to continue under moderate climate change scenarios, but the rate of accretion may change, depending on how rainfall and storm frequency affect sediment supply.

On the accreting beaches, there may initially be inundation, but eventually enough material will be deposited offshore to re-establish the beach profile at a higher elevation.

The Waipaoa River carries a very high sediment load in times of flood and will probably continue to supply sediment to the City and Poverty Bay beaches (free of charge!) for the foreseeable future.

The Waiapu River has created extensive gravel beaches on either side of the mouth.

Goodbye to Our Beaches on the Bay

The following article is reproduced from The Washington Post. The message is certainly pertinent to us:

Sunday, May 18 1997; Page C08
The Washington Post

Maryland is giving away the beaches of Chesapeake Bay, and the recipients are destroying them.

Since colonial times, the public has owned all of the shore in Maryland below the high-water mark. While there is ready access to ocean beaches, it is difficult to get to beaches along Chesapeake Bay. In other states, such as New Jersey, new subdivisions must include a path to the water, but in Maryland, bayfront development prevents the public from reaching the beach. The essence of the state's policy is: If you want to visit your beaches, buy a boat.

If you have a boat, you can land along any beach at low tide and take a walk along the shore -- for now. But soon, even boaters will be excluded from these beaches as the process of giving away the shore continues. Here is how it works:

The level of the sea is rising about an inch every decade, which causes most wetlands and beaches to erode a few feet per year. Homeowners losing parts of their yards are building various types of sea walls (usually piles of rocks called "revetments") to stop the erosion. The shore erodes up to the sea wall, and presto: no beach and no marsh. And because no land separates wall from water, the publicly owned part of the shore is eliminated. It is now a private waterfront.

Since 1980, more than 300 miles of shoreline essentially have been donated to private property owners. And that rate will almost certainly increase. Global warming, which has already raised the sea a few inches, is expected to raise water levels another foot in the next 50 years.

Because these sea walls are on public property, the state could require the homeowners to let the public walk along the shore above the sea wall. Without the walls, that land would belong to the public anyway, because the beaches and the state property lines would have moved inland.

Many states go farther than that: Maine and Rhode Island protect their dunes and marshes by prohibiting sea walls. Mississippi pumps sand to protect its bay beaches, and many states require homes to be moved back as shores erode. Maryland may be unique: Its Tidal Wetlands Act gives people the right to erect sea walls that eliminate wetlands and beaches.

Losing our natural shorelines is bad news for life in Chesapeake Bay. Terrapins cannot climb the walls, so they will be unable to lay their eggs. Estuarine beaches are habitat for endangered species such as the tiger beetle and the least tern. Many species of birds and fish depend on the marsh for habitat and food.

And people like beaches too. Next weekend, thousands of people will head to the ocean beaches. But for the first half of this century, everyone went to bay beaches such as Chesapeake Beach. What happens if we decide that we want our bay beaches back?

Protecting the shores of Chesapeake Bay would not require Draconian measures to prevent people from using their own property. We already own the shore. We just need a plan for holding on to our own property, and for making it easier to get there.

-- *Jim Titus*

Chapter 3:Effects of climate change on indigenous biodiversity

Key points from this section:

- Indigenous biodiversity is already under pressure. Effects of climate change will exacerbate the problems that already exist;
- Species would, in the natural setting, alter the boundaries of their natural distribution in response to climate change. In a modified environment this may not be possible;
- We can expect the magnitude of the changes to be bigger than ever seen in the past;
- Changes may be too fast for some species to adapt – changes in the mix of species present could be sudden;
- Drought, pests and weeds and fire will be the biggest threats;
- Locally we could lose some species. Especially vulnerable are weka, kiwi, aquatic species, some forest trees, alpine plants and alpine animals.

Changes complex to predict

Pollen, fossil and tree-ring records reveal that fluctuations in temperature and rainfall have, in the past, been accompanied by significant changes in flora. This time the situation is compounded by a potential increase in the incidence of extreme weather events and the invasion or expansion of pest, weed and disease-causing organisms.

The effects of climate change on indigenous biodiversity are probably the most complex to try to predict. And yet we should be very concerned about stewardship of our natural heritage: so-called 'ecosystem services' provided by indigenous biodiversity are estimated at half the current national GDP.

People tend to focus on a small number of "icon" species threatened with extinction, and on the preservation of near-pristine areas (such as national parks). It may be time for some priorities to shift, and indigenous species will need to "come out" of our reserve areas and be integrated into our working and modified environments.

Climate change impacts

The most pressing and severe threats to indigenous biodiversity are not directly related to climate. Biodiversity managers are already snowed under with problems of predation, pests, weeds and habitat loss. Climate change will exacerbate these problems.

Matt McGlone in his comprehensive 2001 paper identified several classes of climate change impacts: 1) alteration in latitudinal and altitudinal biogeographical boundaries (for instance, as the climate warms, species may migrate southwards and to higher ground; 2) direct effects of extreme weather events; 3) changes to productivity and nutrient cycling within natural ecosystems; 4) disruption to freshwater ecosystems due to reduced stream flows and warmer water temperatures; 5) establishment of more invasive and damaging pests and weeds, including the expansion southwards of exotic organisms already present.

Climate change will impact most on natural areas already under pressure, such as small fragments of habitat, and freshwater streams in modified environments such as farmland. There could be boom-and-bust fluctuations in numbers of animal pests should food supplies become more abundant.

However, the possibility of government initiatives to encourage the creation of forests as "carbon sinks" (indigenous, exotic or mixed, may have large benefits for natural biodiversity. Thus there are potentially some opportunities for biodiversity conservation.

Timeframes – the long-term view

When considering biodiversity, long time frames must be considered: around 500 years encompasses the lifespan of the longer-lived forest trees species. Researchers in every other area of climate change are focusing on a timescale of only 0 to 100 years (and governments in multiples of only three years).

The majority of our indigenous species are genetically adapted to cooler conditions than prevail now, as a result of the preceding 2.5 million-year-long Pleistocene period, during most of which temperatures were 2^o to 6^o cooler than at present.

It might be expected from examining past temperature curves, and their distinct periodicity, that the Earth would have reached the peak of the current interglacial and would in fact be on a cooling trajectory. Glacials and interglacials are initiated by orbital parameters, a very small variation in solar radiation producing large climate changes.

Instead, the enhanced greenhouse effect of industrial gases, combined with deforestation, is producing an unprecedented and very fast perturbation in the climate system. Indigenous species will now have to adapt very quickly to conditions that may be warmer by as much as 3.5^o to 8^o for a protracted period.

Atmospheric carbon dioxide is the major raw material for the structural component of plants and under laboratory conditions is found to encourage growth. In reality soil moisture is the major limitation east of the axial ranges.

The expected increase in drought-proneness for Gisborne District could even cause profound and sudden changes in vegetation type and the mix of species present. Some habitats may be lost or permanently changed.

Alpine species will become stranded in ever-smaller, isolated areas, and may be lost from some alpine areas. Much of the lowland area of the North Island is expected become a subtropical climate zone.

In order to maintain evolutionary potential for a broad range of species, conservation dollars may have to be refocused, to ensure the biodiversity of species that may be able to contribute to evolution over the long term. These species are likely to include those capable of existing within a human-disturbed or managed landscape.

It is desirable to work towards the creation of large, extensive and *connected* natural areas, where a full range of natural processes can take place.

Forest species

Our natural forests are dominated by long-lived perennial species, and these trees have no scope for fast adaptation in the face of rapid changes in climatic conditions. The most damaging impacts of climate change will result from interaction of climate extremes with the various stressors that already exist.

Kauri, for instance, is a warm-adapted species and has high rates of photosynthesis in warm conditions. On the face of it, we might expect kauri to extend its range southwards into Gisborne District as the climate warms. In fact they are unlikely to do so due to their day-length and soil requirements, and under a 4^{o} warmer climate, their current range is in fact predicted to decline.
If species become stranded in a climatic zone that becomes unfavourable, they may become extinct.

In the northern hemisphere there is fossil evidence of major latitudinal retreat and advance of biota in response to glacial and interglacial stages. This is not so obvious in New Zealand, rather, populations of indigenous plants seem to have sufficient genetic diversity to expand and contract within regions (McGlone *et al*. 2001). Therefore it seems our biota are genetically highly variable, able to survive over a wide range and have adaptations to specific sites.

Department of Conservation scientist Dr. Chris Ward describes the potential changes in flora as a "sorting" of species: some with readily dispersible seeds will be able to alter their range in spite of fragmentation of habitat. Some will not be able to disperse across extensive intervening areas of pastoral farmland

Humans may be able to facilitate the expansion of ranges southwards for indigenous species that cannot do it for themselves. Southern variants may ultimately be superseded or out-competed by species from the north. Species or sub-species already restricted to the extreme southern limits of their tolerance may face extinction because there is nowhere else to go. Southern variants could possibly hybridise with subspecies from further north.

Disturbance is another determinant of forest structure, and the possibility of more frequent, intense storm events causing soil erosion or trees to be blown over, could completely alter the vegetation at localised sites.

Prolonged drought could devastate forest trees, especially in the mountainous areas of our region, accustomed to higher, more frequent rainfall distributions.

The risk of fire, and catastrophic loss of forest, becomes ever more likely as the climate becomes drier, hotter and windier.

Is Gray's Bush vulnerable to climate change?

Gray's Bush is a small but significant remnant of lowland primary forest that dates back to the deposition of the alluvial surface on which it is situated - over 500 years.

Members of the public visiting Gray's Bush often notice a lack of regenerating kahikatea, and wonder whether kahikatea will "die out" in the reserve.

The observation is correct: There are tiny seedlings of kahikatea in the understorey of Gray's Bush, but a noticeable lack of larger saplings. Why are they not surviving?

Kahikatea are in fact a colonising species, requiring full sun and damp fertile soil. Kahikatea seedlings can germinate in shaded conditions, but would not survive long. This fact is borne out by the fact that kahikatea are often found colonising damp hollows in open, erosion-prone hill country, where site fertility is high and the soil of neutral pH.

The mature Gray's Bush kahikatea represent the ultimate survivors out of many seedlings that initially colonised the site after the fresh sediment was deposited. They would have "thinned" themselves naturally, a process continuing to this day. It is therefore perfectly natural for the species mix to change over time; this is not a climate-change effect. It does mean that if people want to retain kahikatea forest, then we will have to allow for new ones.

There is low species diversity in the understorey of Gray's Bush, reflecting its history of complete decimation by browsing stock up to the 1920s. It was not until the 50s when a proper stock-proof fence was erected that there was any chance for regeneration to occur. The species in the understorey we see today are therefore those having readily dispersed seed.

There are however a number of species in Gray's Bush that are close to their limits of distribution, and these may be severely affected by climate change. Several have low tolerance to very low humidity and vapour pressure deficit. Hot, dry north-westerlies place extreme pressure on these species and can cause wilting and death, even if there is still some moisture in the root zone. These plants simply cannot take up moisture fast enough to replace that lost through evapotranspiration.

Kawakawa and kohekohe are close to their inland limit at Gray's Bush. They are amongst those species limited by humidity and cannot endure desiccation. Kohekohe is not found in most of Hawke's Bay where the climate is only slightly hotter and droughtier than Gisborne.

Tree fuchsia, nikau and kamahi can similarly not tolerate extremely low humidity. Kamahi, in fact a southern species, is more abundant at higher-altitude sites in this district due to its soil-moisture requirement.

There are only around a few dozen mature nikau that survived last century's grazing in Gray's Bush, but they have produced thousands of young trees, despite the generation gap.

Streams and wetlands

In Gisborne District there are 9 indigenous fish species (out of 36 nationally) and 2 exotic (of 16 found nationally). Some indigenous freshwater fish seem to be highly flexible in habitat and are found at wide-ranging altitudes and water temperatures, while others are more limited in habitat. Several species populate Gisborne District's silt-laden rivers, however the greatest diversity of species is found in clear-flowing streams.

Some fish and invertebrates show a definite preference for water below 16 to 18°C, and become vulnerable if shading vegetation is lost from stream banks, or if water flows drop to very low levels due to drought, or demand for irrigation water.

Around 25°C seems to be a critically warm temperature for much aquatic life in New Zealand. It is not unusual for fresh surface water to reach 25°C for periods during summer and several dramatic changes can occur. One noticeable effect is overgrowth of algae, often attributed to eutrophication. In fact, water above 25°C is lethal for significant algal grazers, freshwater snails *Potamopyrgus antipodarum*. In their absence algae grow on ungrazed.

The effect will be further exacerbated for streams over-enriched with nutrients, especially with the likely spread of exotic algae southwards[8], and the introduction of additional new pest algae.

8. Or, in the case of Didymo *(Didymosphenia geminata)*, from the South Island.

As well as keeping run-away algal growth in check, *Potamopyrgus* is an important food source for fish.

Ephemeral wetlands, especially in farmland, will be subjected to longer dry periods due to precipitation changes and the ensuing fall in the water table. Some wet areas may be lost if the watertable is permanently lowered. Some wetlands may be inundated by sediment if heavy but isolated rainstorms become the norm.

Constraints on electricity generation

Huntly Power Station diverts around 10% of the flow of the Waikato River for cooling purposes. A condition of the resource consent is that the mixing of warmed water back in to the main flow is not allowed to raise the temperature of the river to above 25^{o}C, in consideration of the requirements of aquatic life.

During the summer, the Waikato River is frequently 24^{o}C and therefore the power station is permitted to run at only low capacity. Occasionally the river reaches 25^{o}C and power generation is suspended for a period, usually several hours. This situation could become more common as the climate warms.

Huntly is required to provide a significant output of electricity (1,000 MW) and the increase in use of air conditioning has meant that electricity demand is very high, even during the summer months. This situation may impact on power supply for half of the North Island, including Gisborne.

Coastal estuaries

Coastal estuaries will experience marked boundary changes due to sea level rise.

Natural assemblages of estuarine plants could survive if the estuary is allowed to take over the surrounding land, to replace the area inundated. However if expansion of the estuary is constrained by barriers, dikes or stop banks, then marshland species will be squeezed out. Other problems for coastal wetlands include sedimentation, eutrophication and pollution by human activities within the catchment.

Frost-tender mangroves are present at Ohiwa Harbour, their natural southern limit. They had never established naturally in Gisborne District, probably due to the inshore current direction, which in the eastern Bay of Plenty is westward, away from East Cape. But around 1984 someone planted 6 mangroves in a straight row in Hauiti estuary on the southern side of Uawa River, Tolaga Bay. These have produced thousands of offspring throughout much of the estuary .

Mangrove seeds germinate while attached to the plant then fall off and float, so are readily dispersed. Mangrove propagules wash up on the city beaches and from time to time as far south as Napier. These are likely to have originated from Tolaga Bay.

For propagules that wash up in a suitable habitat, frost is likely to be the only limitation on their spread, and we would expect them to become naturalised further south as climate change progresses.

Dunes

Natural dune areas typically encompass discrete wetland microhabitats: the hollows between the dunes. They are subject to constant gradual change as natural dune systems erode, rebuild, stabilise and are reburied. The biota of such systems survives in the long term by being able to colonise suitable new areas as they arise.

Many plants of dune-hollows are threatened, and will become increasingly at risk as sea level rises. Dune ecosystems may also be destroyed by stabilisation of dunes with sand-binding plants such as introduced marram grass, lupins, wilding trees or plantation forest.

Alpine areas

Ranges of species adapted to alpine environments are likely to contract as the climate warms.

About 40% of plants found in the alpine zone are not obligate alpine species – they are also found below the tree line and in lower open areas. True, cold-specialised alpine plants tend to occur in high, extensive areas of open habitat. They often occupy specific habitats such as bogs, shingle slides, bluffs and rocky outcrops, features that will still persist in a warmer climate.

The situation may be more complex for alpine animals. One study of alpine grasshoppers showed the population would shrink and be displaced to higher altitudes and marginal habitats. Another study of alpine cockroaches revealed that decreased snow cover actually meant more freeze-thaw cycles making conditions more hostile.

The summits of Raukumara and Mt. Hikurangi comprise the northernmost extent of alpine vegetation in New Zealand. Hikurangi, due to a history of fires, has a lower-than-expected tree line.

Alpine species found on Raukumara and Hikurangi include giant buttercups (*Ranunculus* spp.), prickly wild Spaniards (*Aciphylla* spp.) and most significantly Hikurangi tutu (*Coriaria pottsiana*), which was first described from the grassy scree slope behind the tramping hut. It occurs at around a dozen sites in the mountain, all areas of disturbed ground below the natural tree line.

Despite warming recorded over the past century and the marked retreat of glaciers, the tree line has not measurably moved on the New Zealand mainland. The tree line is usually defined by silver or mountain beech. The seeds of these trees are heavy, tend to drop straight down, and therefore don’t disperse well uphill, which may account for a lag in migration of the tree line.

Mast fruiting in plants

Mast fruiting is an exaggerated inter-annual cycle of fruiting, and is common amongst indigenous plants. Mast fruiting is strongly correlated with climate, the precondition being warmer than average summer days, so we may expect it to become a more frequent occurrence as average temperatures rise.

An abundance of fruits and seeds can trigger serious pest outbreaks, particularly amongst rodents. Rats and mice have a direct effect on indigenous invertebrates, while themselves providing prey for stoats; stoats in turn predate bird life. On the other hand, the abundance of fruit can improve chick survival. The relationships are complex.

Continued loss of indigenous birds involved in pollination (such as bellbirds and tui) and dispersal of fruits and seeds (kereru) would reduce the ability of fruiting plants to disperse to new habitats, and therefore reduce the ability of flora to migrate or change their range in response to climate change.

Kiwi and weka

Dry soil is a major limitation for both North Island brown kiwi and North Island weka. While kiwi are generally considered to be our icon species, North Island weka are more severely threatened. Motu and the area to the north-west of Motu is the only area weka are found in the wild on the mainland of the North Island. Only twenty-five years ago they were common throughout Gisborne and the Poverty Bay flats. Now there are estimated to be around 2,000 birds left.

Both kiwi and weka rely on invertebrates in the soil as their major food supply. In times of drought, worms and soil insects are drastically reduced, or may migrate deeper into the soil to aestivate, where they are out of reach of the birds.

Role of climate in the decline of weka

Weka were once so common in Gisborne District as to be classed a nuisance by some people, particularly gardeners and horticulturists on the Poverty Bay Flats. Suddenly weka underwent a severe decline, noticed initially by staff of the (then) Wildlife Service as a reduction in the number of complaints. The decline of weka is a graphic illustration of how a change in climate can interact with other stressors to produce a catastrophic result.

It was the severe drought of 1982/83 that probably initiated the decline in numbers. Food supplies were severely reduced and some birds may have starved or failed to rear chicks.

Farmers responded to the drought by, naturally, making use of every bit of rough ground available to feed stock: road verges and drains, blackberry patches, hedges, and cattle were even let into bush reserves with the permission of the Commissioner of Crown Lands. Weka, although used to surviving in modified areas, lost all natural “cover” and any protection they may have had from cats, dogs and stoats.

At the same time as weka were struggling, a voracious new predator arrived on the scene. Prior to the 80s ferrets were not found in Gisborne District. Escapee (or released) ferrets from “fitch farms” allowed these pests to naturalise in the district, with further dire consequences for weka, kiwi and other bird species.

North Island weka had fortunately been established on several offshore islands prior to their decline on the mainland, almost by default. In the 50s and 60s a typical response by Wildlife Service staff to a weka complaint was to live-trap the offending birds. When they had several dozen they would be relocated elsewhere, including two offshore islands: Kawau and Rakitu (or Arid Island), east of Great Barrier, and Mokoia Island in Lake Rotorua. Now these island populations comprise a valuable repository of this severely threatened bird.

Exotic weeds

The rate of entry of alien plant species into New Zealand (in the time since European settlement) is approximately one species every two days. Amongst the 144 new species that enter per year there are likely to be 3 to 5 potential new weeds.

We now have approximately 10% of the world's flowering plants represented here, on a land area comprising less than 0.2% of the world's total area.

Invasive weeds are, by definition, aggressive colonisers. Climate change will favour weeds in every respect. Their impact is most severe where they impede or entirely prevent regeneration and natural succession of indigenous species.

Wild ginger, for example, has completely covered the forest floor, to the exclusion of indigenous seedlings and shrubs, in the Te Araroa area and many other locations in the northern half of the North Island. Wild ginger prefers a humid climate and regular rainfall so may not be so severely invasive in the drier parts of Gisborne District.

Buddleia is another aggressive weed well adapted to colonising active disturbed riverbeds and it prevents native species from doing so. Indigenous plants would colonise riverbeds and initiate a succession of species, however buddleia in a riverbed excludes natives. Even if knocked back by a flood it comes back again and again.

The situation on slip scars is fortunately different, where buddleia will initially colonise the bare soil, but ultimately be overtaken by native species.

We can expect a suite of new weed species to invade form the north. There are already many subtropical weeds present in Northland. They will inevitably march south.

Does it really matter if there are changes?

The way money is allocated or redirected within biodiversity conservation is influenced to a large extent by the public's views. Does it really matter if the northernmost extent of obligate alpine species is the Kaweka Ranges instead of Raukumara? Is the public really concerned that the mix of species in natural areas may change? For many people the answer may be no, not really. However, if climate change means losing species entirely, to most people that would matter a great deal.

A possible silver lining for biodiversity

The creation of carbon sinks and reservoirs, likely (though not yet certain) to be encouraged when legislation is drafted under New Zealand's Kyoto obligations, will have positive effects for indigenous biodiversity.

To be considered a sink a system must be absorbing more CO_2 than it is releasing, thereby storing carbon in the process of increasing its biomass. In a growing forest about half the dry weight of the wood comprises sequestered (stored) carbon, and in addition soils under forest have a much greater capacity to retain carbon.

Once a forest reaches maturity it becomes a carbon reservoir, because in a climax forest equilibrium is reached when decay releases about as much CO_2 as the volume being absorbed by the forest. Land-use change to forest therefore provides a temporary fix for the problem of continued emissions of greenhouse gases, and has huge, positive spin-offs for biodiversity, soil and water conservation.

The sites potentially of most value for biodiversity conservation (warm, moderate rainfall, high fertility sites) are of most value to agriculture, and it is likely to be marginal land (less fertile, wet, cool sites) that is selected for planting or regeneration.

Provided regeneration projects are planned carefully with consideration to the landscape, seed sources and connections with other indigenous areas, the contribution of regenerating areas to biodiversity will still be great.

Restored or newly created wetlands are another potential carbon sink, as they can accumulate carbon in the form of peat. Wetlands have not been seriously considered in the literature for their role in carbon sequestration, but it is thought they may sequester up to 2 tonnes of carbon per hectare. An anoxic wetland may however emit methane (an even more potent greenhouse gas than carbon dioxide). There is a need for further research into carbon sequestration in wetlands.

Possum browse – a threat to carbon sequestration

Significant carbon losses occur from forest subject to browsing by mammalian pests and possums. Kamahi would, in the absence of possums, comprise around half the biomass of trees in many forests of Gisborne District. Possums commonly kill Kamahi.

Possums can similarly decimate understorey shrubs and regenerating seedlings. These effects combine to release carbon into the atmosphere, either when dead trees rot, or when material is eaten and excreted.

It should be emphasised that possum control is essential for the health of the forest, and to promote biomass accumulation, allowing carbon sequestration to attain a maximum value.

International conventions and agreements

The United Nations Environment Programme Convention on Biological Diversity (CBD) provides an international framework for biodiversity conservation. This convention requires consideration of integration of biodiversity into the implementation of the United Nations Framework Convention on Climate Change (UNFCC) and the Kyoto Protocol.

In addition, New Zealand is party to the Convention on Wetlands of International Importance (Ramsar Convention), primarily focused on wetland conservation for biodiversity reasons.

New Zealand has considerable scope to achieve its commitments simultaneously under all these conventions: restored ecosystems could be considered dual (even triple-) purpose.

Chapter 4: Climate change impacts for agriculture and horticulture

Key points from this section:

- We may be subjected to more climatic extremes;
- Growing seasons may change. Some crops might no longer be economic in Gisborne District;
- A warmer climate will favour the spread of invasive sub-tropical grasses from the north;
- Drought risk will intensify for all areas that are currently drought prone;
- An expected increase in intense rainfall events will mean much valuable precipitation is lost as runoff, and may exacerbate soil erosion;
- There will be increasing pressure on water resources, for both stock and irrigation;
- It is unclear what the effects will be on the groundwater aquifers;
- Irrigation of pasture may become popular in some areas where it is practical to do so;
- Ultimately, downstream users will be competing with those upstream for water resources;
- Agriculture is responsible for around 55% of New Zealand's greenhouse gas emissions, and yet mitigation options are limited;
- Retirement of marginal land for the creation of carbon sinks, and planting more trees in general, are the current options for mitigation;
- Animal vaccines and feed additives, as a means of reducing emissions, are years away;
- Pest insects are directly favoured by a warmer climate and we can expect greater numbers of those already present, and numerous new invasions in the future;
- We may need to use significantly more chemical insecticides, and possibly new types;
- Animal health effects are already noticed and Gisborne's climate is likely to become increasingly marginal for sheep;
- Animal diseases are likely to increase in prevalence across the whole range: parasites, flystrike, fungal and bacterial diseases;
- Heat stress on animals may be severe with an increase in the frequency of very hot summer days;
- Farmers will need to consider provision of shade trees, more water storage, and possibly alternative forage trees and crops;
- Soil conservation measures will become more critical in view of an expected increase in intense rainfall events;
- Warmer temperatures could be advantageous for arable crops, however moisture availability may be critical, temperatures may get too high, and increased cloud cover would delay crop maturity;
- Perennial crops with chilling requirements (eg kiwifruit) will ultimately become uneconomic in Gisborne District;
- The season for apples could theoretically be advanced, however very hot temperatures or increased cloud cover may be deleterious;
- Wine grapes may benefit from warmer conditions, however fungal and insect pests will increase;
- The effects of climate change look to be disadvantageous for farming, horticulture and cropping, all things considered.

Climate extremes will be significant

Small changes in average climatic conditions can lead to large changes in the frequency of extremes. Extremes, more so than incremental changes, are expected to have the biggest impact on farmers. Gisborne District may experience more frequent and severe droughts, and be at greater risk for very intense rainfall events, putting the district at increased risk for soil erosion and floods.

It is unclear at this stage whether an increase in 'storminess' will mean more intense storms, a greater number of cold fronts passing over, or some combination of the two.

Farmers are the managers of a significant portion of the land and water resources in Gisborne District, and the future of the region's economy, environment and society depends greatly on the viability and adaptability of farming. Adapting to risk and uncertainty will be a challenge for farmers and growers.

Since we already experience heavy rain and drought from time to time, it is easy to be complacent and think "we'll cope when it happens". But what if there was no significant rain for six months, droughts two or three summers in a row, or repeated floods resulting in long intervals with damaged infrastructure? Some changes in practices and preparedness would certainly be needed.

In 2005 a Gisborne farmer reported seven months of no significant rainfall, followed by 400mm in a couple of days, and then a return to drought conditions *on his farm*. The District as a whole did not experience these conditions. This apparent micro-climatic effect graphically illustrates what the scientists mean when predicting an increase in extremes.

Growing seasons may change

Night time and winter minimum temperatures may be elevated due to the insulating effect of increased cloud cover. This may lead to a decrease in frost days, fewer out-of-season frosts, more frequent freeze-thaw cycles at altitude and fewer low-altitude snow falls. These effects may impact upon cycles of deciduousness, dormancy, chilling and ripening requirements for crops, and diapause in invertebrates.

Frost days and hot days

Frost days are likely to decrease while the incidence of hot days (over $25^{o}C$) will increase.

Days of air-frost (days when temperature falls to $0^{o}C$ or below) vary considerably across the district and are much more frequent inland than in Gisborne City or in coastal settlements.

Cool nights are of particular significance for some perennials such as apples and kiwifruit. These species must receive chilling in order to break winter dormancy and initiate bud-burst. Chilling is a cumulative effect, and the most abundant and synchronous flowering occurs after the crop has received an optimum number of hours below a given temperature. Chilling requirements vary between cultivars.

Milder night time temperatures (due to potentially increased cloud cover) may reduce chilling hours, and affect the quality and quantity of fruit.

After bud-burst, development to full flowering is then enhanced by warm temperatures. The expected decrease in late out-of-season frosts would be positive, as frosts can severely damage flowers. Quantifying changes in number of frost days is difficult: climate change scenarios lack sensitivity for this parameter.

Mid-range climate change scenarios may result in 5 fewer frost days by 2050 and 10 fewer by 2100[9]. Towards the end of this century, that would mean no frosts for Gisborne City and parts of the Poverty Bay flats.

A decrease in frosts coupled with warmer average temperatures would be advantageous for some other perennials grown locally, including persimmons, avocados and citrus.

For hot days (where temperatures of 25^oC or above are reached), mid-range climate predictions are for an increase of 10 to 15 additional hot days by 2050 and 25 to 30 additional hot days by 2100. A high-range scenario predicts approximately +15 hot days by 2050 and as many as +50 hot days per year by 2100[10].

Gisborne currently experiences up to 6 *very hot days* per year when temperatures exceed 30^oC. An increase to 15 very hot days (mid-range) to 21 very hot days (high-range) by 2100 is predicted. The latter figure implies temperatures over 30^oC on 20% of summer days[11].

Effects on pasture

Pasture differs from other agricultural crops in comprising a mixture of species: nitrogen-fixing legumes, C_3 and C_4 grasses[12]. Climate change will affect the overall productivity of pasture, and may dramatically alter the species composition.

Temperature influences a number of plant processes (photosynthesis, leaf appearance, leaf extension, tiller production) and the optimum temperature for each of these processes differs within and between species. For New Zealand pasture the optimum range for the predominant C_3 species is likely to be 16 to 20^oC.

Winters may become shorter and milder; therefore the growing season could increase in length, all other factors being equal. Pasture species may experience increased photosynthesis with warmer temperatures and higher levels of CO_2 in the atmosphere. All this growth would be likely to occur outside of summer; during summer moisture is likely to be a critical limiting factor.

By 2030 there could theoretically be a 10 to 20% increase in annual pasture yields for New Zealand as a whole; the effect is much more pronounced in the south than in the north, is very modest for Gisborne, and is expected to taper off towards the middle of this century (see table below).

Decades	2000-2010	2010-2020	2020-2030	2030-2040	2040-2050
Predicted increase in pasture yield	3.8%	4.2%	3.4%	2.6%	1.2%

Above: The so-called CO_2 fertilisation effect: average projected changes in pasture yield for Gisborne, assuming increasing atmospheric CO_2 concentrations to 2050. Adapted from Warrick *et al* in Kenny, 2001.

The model assumed increases in atmospheric CO_2 and mean temperature. Hot, dry conditions are not optimum for C_3 species ryegrass or clover, and less productive, water-efficient C_4 species may tend to dominate. Legumes respond more strongly than the other species to increased atmospheric CO_2 but are less tolerant of water shortages than grasses.

9, 10 & 11. The Effects of Climate Change and Variation in New Zealand. An Assessment using the CLIMPACTS System, 2001.

12. C_4 carbon fixation is a metabolic pathway found in 5% of land plant species (C_4 plants). They are competitively superior to plants possessing the more common C_3 pathway (95% of land plant species) under conditions of drought, high temperatures and nitrogen limitation. The C_4 plants also possess a characteristic leaf anatomy.

Paspalum and kikuyu

The observed tendency for milder winters in recent decades correlates with the measurable spread of C_4 grasses southwards, especially kikuyu *(Pennisetum clandestinium)* and paspalum *(Paspalum dilatatum)*. These two species may be considered representative of subtropical grasses; they are already present in New Zealand, but there are other species that may arrive here.

Paspalum was observed to move southwards 1.5^{o} in latitude (from north of a line between mid-Waikato/East Cape to north of Wanganui/ Cape Kidnappers) between 1976 and 1988.

These grasses are productive only in the summer months, and are considered poorer quality feed than the typical pasture mix. Kikuyu is potentially more of a management problem than paspalum due to its more invasive growth habit and poorer forage quality. Nevertheless, it could ultimately become farmers' saviour in very dry years.

Droughts and El Niño weather patterns have a greater impact on the composition of pasture grasses than downward-trending average precipitation. During a severe dry spell some species may not survive, so pasture composition can be altered drastically.

It is unclear at this stage exactly how the composition of pasture plants will respond to changes in the frequency of hot days, frost days and cloud cover.

Drought may mean increased requirements for conserved or bought-in feed – including green-feed crops and stored feed such as silage.

Effects on soils

Climate change is expected to affect the organic matter content of soils, as can change in land use or intensity of production. This is significant because soil organic matter is critical for the stability and structure of topsoil, stores most of the soil nutrients, promotes water infiltration and retention, and helps protect against wind and water erosion.

Topsoil is a major carbon reservoir and can release carbon to the atmosphere via decomposition of organic matter. This process is important in understanding both carbon emissions and sequestration by soils.

A soil organic matter turnover model[13] was incorporated into the CLIMPACTS system to predict changes in soil organic matter content over time in different environmental conditions (Parshotam and Tate, 2001). As the modelled pasture 'grows' under each of the climate scenarios, carbon is apportioned to above and below ground components. Carbon inputs to the soil are the sum of the below-ground carbon (roots) plus carbon in the leaf litter produced.

Results revealed a gradual decline in soil carbon content of up to 3% under all climate change scenarios over the period 1990-2100. The effect would be expected to vary from site to site.

The model assumed that land use did not change over time. We would expect to see far more significant changes in soil carbon if land use changes.

13. The Rothamsted Soil Organic Matter Model, adapted for New Zealand conditions. The parameters are temperature, precipitation, PET (potential evapotranspiration), soil clay content, plant residue inputs, vegetation type, 'farm yard manure' (if any) and soil cover.

The most dramatic change would be for soil under forest or pasture to be put into cropping; this could cause a 30 to 50% loss of soil carbon (due to accelerated decomposition of the existing organic matter in soils with simultaneously reduced input of plant material into the soil). The former happened in New Zealand's historical past, but is unlikely now.

Soils sustain a diverse population of organisms, most of which are concentrated in the litter layer at the surface (earthworms are an exception: they may burrow deeper). These essential organisms are found in the layer of soil that is most vulnerable to the effects of climate- and land-use change. If valuable arable soils are degraded, they may become unsuitable for cropping, regardless of the suitability of the climate.

More research is needed in this area to identify where New Zealand's most vulnerable soils are.

Assessing drought risk for Gisborne and the East Coast

Detailed modelling was done by NIWA using a combination of two different global-average temperature projections (+1.8^{o} to +2.9^{o} by 2080) together with two regional climate models. Two sets of data were produced, termed the low-medium and medium-high scenarios. Data were then "downscaled" using a statistical technique to take account of New Zealand's complex topography.

The models represent just two plausible scenarios; what we observe to happen in the future may of course be outside of the range NIWA predicted.

Drought is influenced by a number of factors: the amount of rain that falls, how high temperatures are and wind. Wind is a big influence in Gisborne District: soil moisture can be drastically reduced by a few days of strong, hot, dry north-westerlies.

To quantify drought, NIWA considered potential evapotranspiration deficit (PED) accumulated over a July to June 'growing year'.

Accumulated PED is used because droughts are a result of dry conditions over a period of time. PED translates to the amount of water that *would need to be added* to a crop or pasture over the course of the year to prevent loss of production due to water shortage.

Drought *risk* is the *probability* that a given level of dryness (accumulated PED) will be exceeded in any year.

Drought risk findings

Drought risk is expected to increase this century in all areas currently considered drought-prone. This includes Gisborne and the East Coast.

Coloured maps were produced by NIWA to show expected intervals for recurrence of what we would currently term a "one-in-20-year drought", measured as accumulated PED. A one-in-twenty-year drought is simply a yardstick[14].

This does not mean that such a drought currently occurs precisely once every twenty years. It is more realistic to consider the probability of a drought of this magnitude is approximately 5% in any one year, and that each event is independent of any other.

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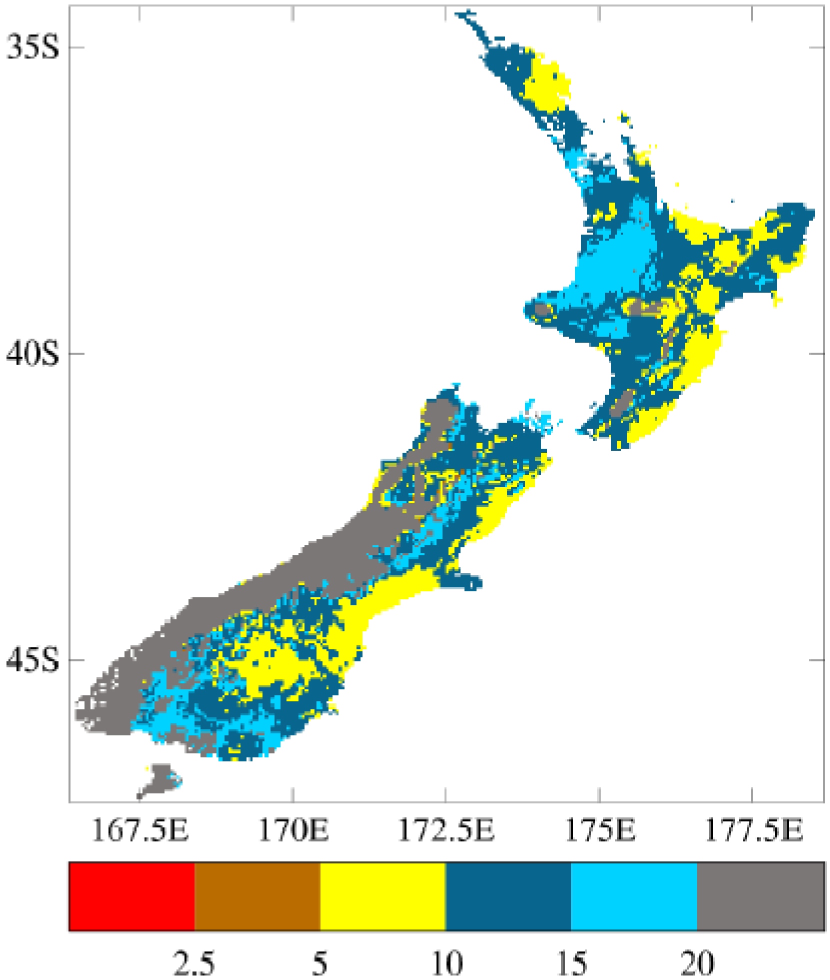
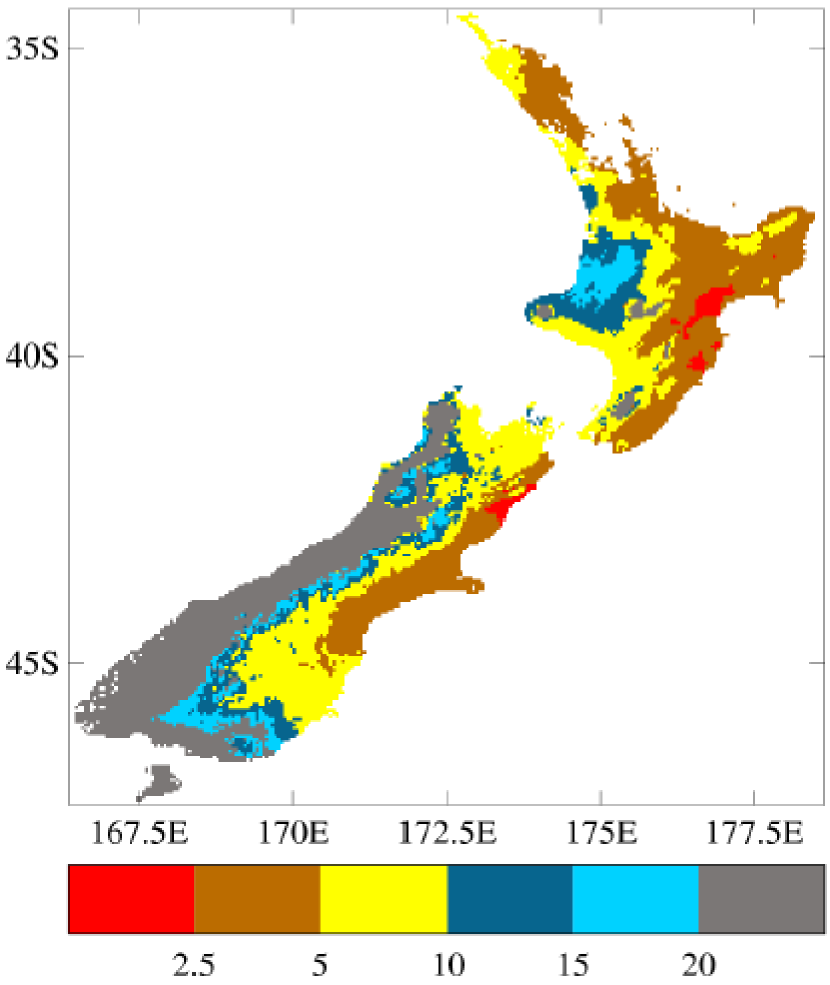
14. The drought of 82/83 is now generally considered to have been more severe than a one-in-twenty year drought.

Map 1 below shows predicted average recurrence intervals (in years) in the 2080s under the low-medium climate scenario (+1.8^{o} by 2080). Gisborne District contains areas coloured yellow (including the Poverty Bay flats, and the East Coast to approximately Tokomaru Bay). For these areas a one-in-twenty-year drought would be expected to occur (on average) between once in five and once in ten years; that is two to four times more frequently than at present.

For the hill country areas (blue) a one-in-twenty-year drought could occur on average every fifteen to twenty years. *(Source: New Zealand Climate Change Office).*



Map 2, below, defines predicted recurrence intervals of a one-in-twenty-year drought for the medium-high climate scenario (+2.9^o by 2080). Gisborne District is coloured brown on this map. This means a current one-in-twenty-year drought is predicted to occur on average between once in every 2.5 years and once in every five years; that is 4 to 8 times more frequently than at present. *(Source: New Zealand Climate Change Office).*



Irrigation to offset PED

Accumulated PED theoretically equates to the amount of water that would need to be added by irrigation for no deficit (no wilting or loss of production) to occur. The real situation is of course complex due to availability of water and the practicalities of getting it on the paddock. The timing and interval between periods of irrigation are also critical to ensure economical use of water.

Currently Gisborne and Hawke's Bay can experience an annual water deficit in the range of 300 to 500mm. The table, over, gives predicted changes in PED in mm (for Napier).

The projected increases mean that dry conditions would extend into spring and autumn months. For the medium-high scenario this would equate to the drying off of pasture a month earlier in the spring.

Below: Predicted changes in PED (potential evapotranspiration deficit) for the various climate change scenarios.

Location	Present PED (mm) during 1-in-20 year drought	Possible PED (mm) during 1-in-20-year drought under low-medium scenario	Possible PED (mm) during 1-in-20-year drought under medium-high scenario	Average return interval (years) for 1-in-20 year drought under low-medium scenario	Average return interval (years) for 1-in-20 year drought under medium-high scenario
Napier*	740	820	1010	9.5	2.5

** In the original report from NIWA figures for Gisborne were not tabulated.*
We would expect Gisborne figures to be similar to those for Napier.

When the rain comes…

Of course, episodes of rain do not simply cancel out moisture deficit, mm for mm. If there is a sudden deluge in the middle of a drought, much will be lost as run-off without actually percolating into the soil. In fact, if the topsoil is dry and hard, most of the precipitation could be 'lost' this way, and significant damage can be done by raindrop impact and sheet erosion on dry topsoil.

Irrigation of pasture

Use of irrigation is commonplace in Gisborne District for annual crops and orchard trees. We may see a swing towards the use of irrigation for stock farming. Cattle are fed irrigated pasture in Canterbury and Central Otago, and it may become necessary to irrigate grass (or fodder crops) locally.

Local case study: Is it practical to irrigate pasture?

Irrigation of pasture during dry summer conditions has been experimentally shown to double pasture production (Coop, 1996 *in* Clark *et al*, 2001).

Graham and Ruth Quilter of Otoko and their son Jonathan have installed K-line irrigation to irrigate 40 hectares of flat paddocks. The purpose is to provide top quality feed for dairy bull calves.

The cost of installing K-line irrigation is around $2,500 per hectare. If pasture production can be doubled in a dry year, the system will really come into its own. As Jonathan puts it: "Where can you buy additional flat land for $2,500 per hectare?"

The pipes are all underground, safe from floods, and the "pods" (containing the sprinkler heads) can be shifted by one operator and a vehicle. The Quilters use a modified 4-wheel drive as they found the load to be too heavy for a quad bike. An hour and a half to two hours per day of manpower is required to shift the pods while the system is in use.

The irrigation has been in place for three summers. It was used during the first two, but the Labour weekend floods of 2005 inundated the flat paddocks. As a result there was "no decent pasture on there worth irrigating last summer".

A visual pasture assessment and weather forecasting is used to decide when irrigation is needed. It is important to anticipate so that clover does not reach wilting point since it takes 10 to 12 days for a complete cycle of irrigation.

A combination of electricity and diesel powers the water pumps. With both fuel and electricity prices rising, there will be some impact on profitability.

Good weed control is important since they are being watered along with the pasture. Interestingly, facial eczema has not been a problem, despite high humidity above the irrigated paddocks. This may be due to the fact that spores are washed down into the base of the pasture, and the cattle are always on good-length grass.

Could irrigated pasture for cattle become commonplace in Gisborne District as the climate becomes drier? There are limited areas where it could be done, and much depends on availability of water resources. In Gisborne District surface water resources rapidly diminish during extended dry periods as whole catchments tend to be affected. While irrigation could theoretically be installed on rolling hill country, the cost and difficulty of supplying water would probably make it uneconomic.

On rolling land that can be traversed by tractor, it is more likely farmers would turn to drought-resistant brassica crops.

Another consideration: the more water stored or used by farmers "upstream", the less there is to enter rivers, supply downstream users and ultimately enter the groundwater aquifers of the alluvial flats.

These are complex issues of competing water use and will need to be considered in the future.

Overview of climatic factors pertinent to hill country farmers of Gisborne District

- The district experiences drying equinoxal winds from the north-west – possibly expected to increase in intensity.
- Poor grass growth, especially on exposed N/NW faces.
- S and S/E winds can bring cold, wet weather to exposed faces, even occasional snow.
- E and NE winds can bring rain.
- Many farms are in the 'rainshadow' of the Raukumara Ranges – expected to become 10 to 20% drier with climate change.
- Water short on coastal hills and hilltops. Increased pressure on water supplies, storage and reticulation. Dams and springs for stock water may no longer be sufficient.
- Reduced base-flow in streams and longer dry spells for ephemeral watercourses.
- District vulnerable to occasional severe cyclonic and intense cell-type storms, leading to accelerated soil erosion, stream-bank erosion, flooding and infrastructure damage.
- Ever-present pressure from internal parasites, flystrike, facial eczema, foot problems, weeds and pests. These will never go away, and in fact may become significantly worse, with increased associated costs.
- Heat stress on animals (and people) may become more significant.
- Electricity supply may be less secure if hydro-storage in lakes is reduced, or river temperatures become critically high for aquatic life.

Possible opportunities and adaptations

- Shorter winters with longer growing seasons may allow earlier lambing and calving.
- Winter production, both pasture and timber, may increase.
- Work towards converting unreliable rainfall into a reliable source by storing water from springs, rainfall events and the roofs of buildings.
- Consider potential future needs for irrigation of both crops and pasture when siting dams.
- Consider genetics and breeding for tolerance to pests, disease and heat.
- Change timing of lambing/calving to match feed availability.
- Consider fodder crops, feed banks and multi-purpose shade/shelter/erosion trees.

- Plant trees to shade yards – humans and animals will appreciate it.
- Look at fencing/retirement of marginal land and waterways.
- Diversify into alternative or niche crops, forestry (diverse types) or other business opportunities.
- There *may* be opportunities for a financial return by planting trees for the purpose of carbon sequestration, but this is nowhere near certain yet.
- Explore options for energy efficiency and generation: wind, solar.
- Use soil testing to assess nutrient requirements and work towards building organic matter in the soil.

Opportunities for mitigation of climate effects by the agricultural sector

Two potent greenhouse gases, methane and nitrous oxide, represent about 55 percent of New Zealand's emissions profile, and mainly come from agriculture.

Methane, CH_4, is a by-product of fermentation of feed by microorganisms in the rumen.

Nitrous oxide, N_2O, is produced (mainly) during the breakdown of animal excreta by soil microorganisms.

Some forage species (e.g. white clover, lotus and sulla), improve animal performance, yet produce less methane per unit of feed eaten. Experiments are currently underway to look at whether ryegrass cultivars selected for improved animal performance may also reduce methane yields.

Some farmers believe that by increasing pasture production, the humus content of soils (and hence the soil carbon content) will increase to outweigh methane or nitrous oxide emissions completely, but this is incorrect.

Our soils already have higher soil carbon levels than the world average. Studies by Landcare Research revealed that soil carbon levels in New Zealand's grazing lands are at, or near, a steady state. This is a result of the predominance of pastoral land use, which conserved and even increased carbon in soils cleared of indigenous vegetation, and also of the relatively slow decomposition of soil carbon stored during millennia under forest.

It has been found that the net result of fertiliser application is that the quality of soil humus may improve, however without any quantitative increase in soil carbon.

A change in management for our pastoral systems is therefore unlikely to sequester more carbon into soils. The other options are in retirement of marginal land, tree planting and erosion control.

Carbon sequestration by conservation trees

Trees are able to capture and store carbon dioxide in their biomass (about half the dry weight of the wood comprises carbon) and in the soil. Large-scale afforestation is not the only way to accomplish this: establishing fast-growing poplar windbreaks, shelterbelts and amenity plantings, including space-planted poplars in farmland, could sequester a significant amount of carbon while allowing stock farming to continue.

Poplar shelterbelts on the Canadian prairies were found to contain 61 to 222 tonnes of carbon per kilometre after 40 years, and may be considered for carbon credits in North America (Kort and Turnock *in* Isebrands *et al*, 2001).

Warmer climate scenarios may influence diseases of poplar, and the activity of boring insects. Poplar have enormous genetic diversity that should allow new varieties to be bred in response to new conditions and requirements as they arise.

Animal vaccines to reduce emissions

Extensive publicity has been given to a vaccine being developed in Australia that is claimed to reduce methane production by 11 to 23 percent. This approach shows great promise as it may involve a once-in-a-lifetime injection and be applicable to all classes of ruminants. The vaccine is still at the development stage and is unlikely to be available for testing for at least three to four years.

Feed additives

It may also be possible to reduce methane emissions by altering rumen fermentation with feed additives. Compounds called ionophores have been found to reduce both the amount of methane emitted and of nitrogen excreted. Unfortunately none of this evidence comes from New Zealand conditions.

There may be significant consumer resistance to use of ionophores since they are a type of antibiotic.

A second group, probiotics, are microbial feed additives that can increase feed conversion efficiency and may perhaps reduce methane production. No information is available on probiotics under New Zealand conditions either.

Increasing carbon stores in arable soils

The restoration of soil organic matter, depleted through intensive cultivation of arable soils, is a realistic and sensible idea. Options to sequester more carbon in arable soils include: adopting conservation tillage practices and crop residue management; intercropping; growing winter cover crops; green manuring; fallowing; establishing shelter belts and windbreaks and retiring erodible lands from cultivation.

However, there may be additional inputs of fertilisers and fossil energy required to achieve a boost in soil carbon, and nitrous oxide emissions might actually increase from nitrogen-fertilised soils. The soil carbon sink could be of limited duration because subsequent (worse) soil management would cause another significant drop.

In some cases, soil carbon has been augmented up to 50 percent in soils treated with no-tillage compared with conventional tillage. This is a practice we should encourage locally, to ensure the structure and versatility of our valuable cropping soils are retained, quite apart from the additional bonus of achieving carbon-sequestration from a Kyoto point of view.

Nationally, the scope for sequestering volumes of carbon in New Zealand cropping soils is in fact small: such soils only total 210,000 hectares, a proportion of which are already well-managed by inclusion of a pasture phase in the cropping rotation.

There is very little information on nitrous oxide emissions in New Zealand cropping soils. No differences in nitrous oxide emission between conventional and no-tillage were observed after five years of cultivation. In any case, nitrous oxide emissions from arable land are virtually insignificant in comparison with grazed dairy pastures.

Insect pests

Warmer temperatures have a direct effect on lifecycles of invertebrates. Being exothermic ("cold-blooded") the metabolism of invertebrates is directly influenced by ambient temperatures. In the case of insect pests, warmer temperatures will mean shorter instars, quicker lifecycles and a greater number of generations in a longer growing season.

There will be new opportunities for pests normally limited by cold winter temperatures: If any species has the capability of surviving in any given environment, there will be few barriers to it invading.

The green vegetable bug is an exotic insect that has been in New Zealand for decades, however it has only in recent years become a problem in Gisborne (possibly related to climate change).

Dr. Jim Walker of HortResearch says there are "literally hundreds" of new insect pests that may establish in New Zealand, sourced from the warmer regions of Australia and the tropical latitudes.

Dr. Walker believes if this occurs there will be an inevitable increase in the need for chemical control, and possibly completely new products may be needed.

Potential sources of new invasive insect pests

A computer model, CLIMEX, was used to determine global regions climatically analogous to Auckland from which recognised pest insect species could arrive and establish (Peacock and Worner, 2006). The pest insects in the CLIMEX database are those known to affect commercial agricultural products; pests that may be significant to indigenous vegetation were not considered in the study.

Fifteen overseas regions were identified as being climatically similar to Auckland: these regions are located in the Americas, western Europe, the Mediterranean, Asia, South Africa and Australia.

New Zealand already shares 90% of pest insect species with south-east Australia, and a high proportion with climate-analogous areas of western Europe (78%) and the west coast of the United States (68%).

So great a number of pest species are already shared with Australia, the authors asked the question: why have the remaining 10% of species not established here yet?

Close proximity and economic ties between New Zealand and Australia mean it is highly probable any new insect pest that establishes there will eventually also establish in New Zealand. For example, several new species of aphids have been found in New Zealand shortly after their arrival in Australia. Thus, we need to keep a close eye on biosecurity alerts in south-east Australia, and in the other regions identified as potential pest-sources.

Some of the other analogous regions pose a lesser threat simply because there are fewer opportunities for insect pests to disperse from these regions to New Zealand.

Argentine ants

Argentine ants, described as amongst the "100 most invasive insect pests in the world" are already present in several locations within Gisborne: within an area of the CBD between Customhouse Street, Waikanae Stream and Taruheru river. It is not known how long the ants have been in Gisborne, nor whether they may be more widely distributed. They will however be impossible to eliminate, and the focus is on control using *Xstinguish* bait[15].

Temperature is a major limiting factor to the spread of Argentine ants. At present the warmer coastal areas of Gisborne District are considered at high risk for this pest, but the hill country is low-risk and the ranges are not at risk. As the climate warms we would expect the distribution to expand.

Argentine ants are a nuisance to people, but may have serious effects on ecosystems as they may displace native ants and other foraging insects. Attacks on nesting birds have been reported in New Zealand.

They could also become a serious pest of orchards, as they seek sweet food. It has been noted in the literature that individual trees have been protected against Argentine ants by tying insecticide-soaked string around the trunk.

There is potential for economic loss through:

- The dispersal of *Homopterans* (e.g. scales, aphids), which Argentine ants disperse and protect in return for the honeydew excreted.
- Potential to chew holes in plastic drip irrigation pipes (this has caused losses in orchards overseas);
- Contamination of food products;
- Robbing of bee hives and predation of bees, affecting both honey production and pollination;
- Potential to kill newly hatched poultry chicks;
- Possible trade restrictions with countries that do not currently have Argentine ants (including China and Korea);
- Possible transmission of pathogens from one plant to another through ants feeding on sugary exudates and the transfer of sap-feeding *Homoptera*.

Wasps

Wasps predate indigenous invertebrates and can reduce bird populations through competition for nectar, honeydew and insects. They have also been seen to attack nestlings. A warm, dry climate favours wasp proliferation, and they are likely to become a greater nuisance as the climate warms.

In recent years there have been a number of new wasp species arriving in Gisborne District, particularly Asian varieties.

15. Xtinguish bait, specific to Argentine ants and modified by Landcare Research for New Zealand conditions, is available through the Gisborne District Council at cost.

Willow sawfly

Willow sawfly *(Nematus oligospilus*) originates from South America and is considered a pest insect in Gisborne District because the larval-stage caterpillars feed on willow trees (*Salix* spp.), most of which have been planted as soil conservation trees and to stabilise riverbanks.

Established in this district since 1998, sawfly has been observed to defoliate willow trees several times in a season. We do not yet know what extent or number of defoliations a mature tree can sustain, nor whether sawfly have reached their climax distribution within the district.

Scientists from HortResearch have determined that sawfly develop through 5 to 7 instars (stages between moults) and that generation times vary fourfold from 108 days at cool temperatures (11.3^{o}C) to only 22 days at temperatures greater than 23^{o}C. The data were interpreted to mean that sawfly might locally undergo 5 to 7 generations in a year, a development rate only likely to be exceeded in the far north. This compares with only 2.7 generations per year expected in Invercargill.

Whether 5 to 7 generations of sawfly per year will prove fatal to some willows, and over what timeframe, is yet to be discovered. In the meantime HortResearch has commenced work on breeding sawfly-resistant willows for the future.

This example graphically illustrates how the virulence of insect pests strongly correlates with temperature. We can assume that as the climate warms, pests currently at a low level could dramatically increase, increasing production costs for growers of all types of crops and trees.

Animal pests

The primary pest animals in New Zealand are mammalian, warm-blooded, and therefore not directly affected by temperature. This is why the most serious pests - stoats, rats and possums (which are marsupial) – are so widely distributed.

Warmer, drier winters may however extend the breeding season of rodents, goats, pigs and possums, and even if food availability is a limiting factor, it may allow them to recover more quickly from control operations.

Drier, warmer summers may increase the rabbit population in Gisborne District by lowering the mortality rate.

Animal health in a warmer, drier climate

Local veterinarian Lindsay McKnight says he has already seen marked changes in prevalence and distribution of sheep diseases in the past ten years, and particularly within the last five.

The Eastland Vets team have observed a geographical expansion in the ailments affecting sheep in the “front country” to higher-altitude areas. In addition, Lindsay has noticed specific microclimates developing in localised areas, creating zones “inhospitable to sheep”.

Cattle are relatively tolerant to climate-influenced diseases, but for sheep the predictions are not optimistic. Lindsay says facial eczema, fungal diseases, internal parasites, fly strike and pneumonia are all likely to become more prevalent in a warmer, humid climate. Very warm summers with occasional rainstorms would be particularly problematic.

We need only to look to the problems faced by sheep farmers in Northland to see what is likely to happen locally. Sheep farming is already considered borderline to uneconomic in the far north, and this climatic 'zone' will inevitably shift further south.

Lindsay advises any of his clients who are interested in climate change to source rams from Northland in order to introduce more tolerance to facial eczema. Some local farmers currently have breeding programmes underway to favour eczema-resistance.

There are also attempts underway to breed for internal-parasite resistance, but this process could take 20 years or more. One farmer in Raglan has been breeding sheep for eczema-resistance together with increased tolerance to pneumonia.

Lindsay says in light of internal parasites becoming increasingly resistant to drenches, breeding animals for resistance is the way to go.

Fungal toxins

There are a number of fungal toxins (mycotoxins) currently being investigated that are harmful to sheep, although their effects are not yet well understood.

Fusarium spp. of fungi produce several toxins. One, zearalenone is an oestrogenic mycotoxin that, like the contraceptive pill, may temporarily stop ovulation in sheep, reducing lambing percentages.

Zearalenone has been found in paddocks from the far north to the far south, however the highest concentrations are typically found in Gisborne District, probably due to our warm, humid autumn conditions.

It appears in pasture from January onwards, gradually increasing to a peak in March or April, dropping off in July. This unfortunately coincides with the mating of sheep.

Zearalenone along with trichothecene compounds (also produced by *Fusarium* fungi) are the possible cause of poor growth in lambs (autumn ill thrift), diarrhoea and suppression of the immune system among other problems, on some farms, in some years.

Fusarium and its toxins probably cause losses in the millions of dollars, and zearalenone may prove to be our most significant mycotoxin disease, causing even greater losses than facial eczema.

Recent studies at Ruakura have shown that resistance to zearalenone is inherited, but that heritability is less than that for resistance to facial eczema or to ryegrass staggers.

It may be possible to ultimately offer a zearalenone-resistance testing-service for ram breeders, if the breeders show interest.

At the moment, the only practical precaution is to not let sheep graze the pasture too low, so that only the green tops of the grass are eaten and not the dead litter material at the base of the sward, where the *Fusarium* fungus resides.

Another mycotoxin is ergovaline, produced by several *Neotyphodium* spp. fungi. Livestock maladies associated with ergovaline include appetite depression and poor weight gain, hormonal imbalances leading to reduced fertility and lactation, heat stress when overnight temperatures remain high, and even gangrene of the animals' limbs.

At present the above mycotoxins, plus others, are grouped together under the term ‘anti-quality factors’. It is likely these problems will be exacerbated by climate change.

How else can pastoral farmers prepare now for climate change?

In the short term (10 to 20 years), by continuing preparedness for current climatic extremes: conservation tree planting, afforestation or retirement and revegetation of marginal land, creation of secure water supplies both for stock and for human consumption. More thought needs to be given to planting for shade and shelter, and some trees should be of multi-purpose types – able to be coppiced or pollarded for feed.

Farmers need to continually be alert to climate and weather information and warnings.

In the medium term (20 to 50 years) there may be a need for increased monitoring and regulation of surface- and ground water usage, alongside plant-breeding programmes to produce more drought- and high temperature–tolerant pasture species, while still maintaining high feed quality.

Individual farmers may decide to consider larger-scale water storage and irrigation systems.

Long term, whole-catchment planning would be desirable, with timeframes of 50 to 100 years; much longer than farmers and regional councils currently consider.

Holistic planning will be needed, taking account of wide ranging issues such as biodiversity, bio-security, erosion and degradation, and water resources.

Irrigation on the Poverty Bay Flats

The Poverty Bay Flats comprise Class 1 soils, amongst the most versatile and productive in the country. Fortunately, Gisborne’s climate currently provides rainfall over the summer, and irrigation is mainly used as a ‘top up’ when a soil moisture deficit does occur. The soils of the flats have good moisture-retention, and there is an extensive system of groundwater under the flats.

The Waipaoa River and the Makauri Aquifer are the main sources of irrigation water for the Poverty Bay Flats. Data collected by the Council from bores on the flats indicates seasonally fluctuating levels of groundwater with a late-summer minimum level and recovery occurring over winter, as would be expected.

At present the aquifers are deemed to have recovered completely by the start of the next irrigation season, indicating the resource is currently sustainably used. What may tip the balance is increasing demand for irrigation while recharge slows due to increased evaporation and decreased rainfall in the catchment.

As the climate warms, Gisborne and the East Coast may experience up to a 20% decrease in precipitation by 2080. Coupled with increased evaporation rates, this will translate to a 10 to 40% decrease in water entering rivers and streams.

Gisborne and the Poverty Bay flats are presently in a fortunate position with regards to water resources. In some other districts they are already critical. Surface water resources are fully allocated on the Heretaunga Plains, and restrictions are used to safeguard recharge of groundwater.

Ongoing monitoring is the only way to observe how the aquifers respond to increased drawdown. If there is incomplete recharge at the end of the irrigation season, then water takes may need to be restricted.

The same applies to water from rivers and streams. Minimum flows may need to be set to ensure some water is still flowing over the summer months to maintain aquatic life.

Climate change consequences for crop growers

The most important species grown locally are broccoli, tomatoes, sweet corn and squash.

Higher temperatures are theoretically beneficial for annual arable crops. They may be able to be sown earlier and could reach maturity faster due to higher levels of CO_2. But improvements may be offset by decreased yields if temperatures are too high, moisture insufficient, or there is too much cloud cover.

Climatic variability may also increase, and since vegetable processing industries rely on pre-season estimates of what the harvest date is likely to be to establish timing for processing at the factory, deviation from estimates can mean significant costs.

Climate change effects on perennial crops: Apples

Modelling of temperature impacts on apples by Austin and Hall (2001) showed that as the climate warms dates of bloom and maturity would become progressively earlier. The changes are not likely to be significant before 2050, however by 2100 bloom would be about a week earlier and maturity about two weeks earlier (using a mid-range climate scenario).

The authors concede that in the model used, warmer winter temperatures and reduced chilling were not treated in detail, and changes in pests and diseases were not considered.

There is likely to be a climate-induced effect on increasing fruit size for apples, but the effect is small compared to that induced by normal seasonal variability: La Niña phases favour larger fruit than El Niño.

Hot, dry summers, which can be expected to become more frequent as the climate warms, may increase the possibility of sunburn and water-core damage to apples.

By 2050 when climate impacts become significant for apples, it is possible there may be new cultivars available.

Since a warmer atmosphere can hold more moisture (about 8% more for every 1^{o} increase in temperature), cloud cover could conceivably increase. One effect of cloudiness is to reduce day-night temperature variability and this could reduce fruit quality, including internal pressure (reducing crunchiness of apples) and red colour development.

Cloudy days can significantly delay development of sugar levels, colour and ripening across all types of fruit. Anecdotal comments from Gisborne growers imply that cloudy weather and lack of sunshine last October and November may have reduced horticultural yields for the 2005 – 2006 season by as much as 10 to 20% (even though it was warm).

Kiwifruit

Kiwifruit have been extensively modelled by Hall *et al* (2001). Kiwifruit have a known chill requirement, which if not met has traditionally been overcome using a spray (hydrogen cyanamide) to initiate bud burst in warm areas.

Modelling of kiwifruit flowering behaviour shows that as the climate warms flowering is progressively delayed (due to slower accumulation of chilling hours). After bud break, time to full flowering is then compressed due to warmer temperatures, while maturation of fruit is pushed later into autumn.

There is a flowering threshold for kiwifruit, below which production is uneconomic. Hayward (green) kiwifruit production already falls below this threshold most years in Kerikeri (Northland). This situation will progressively get worse as the climate changes. At present it is possible to grow Hayward kiwifruit in Te Puke most years without use of hydrogen cyanamide.

But by 2050 production in the Bay of Plenty (and, we can assume, Gisborne) would be uneconomic without hydrogen cyanamide. One question is whether the use of this chemical will be acceptable to future consumers.

A reduction in the possibility of late frosts, which damage flowers, is however an advantage for kiwifruit.

Other perennials

Wine grapes, in general, could benefit from warmer, drier summer conditions, as long as their moisture requirement is met, although varieties may change.

There could however be severe problems with insect pests and fungal diseases as the climate warms. Organic growers would face big challenges.

Increased cloud cover would adversely affect sugar content of grapes and citrus.

Chapter 5: Rural fires

The risk of fire and catastrophic loss of vegetation cover becomes ever more likely as the climate warms. If the climate is warmer, windier and drier, we are likely to see a greater number of larger, more intensely-burning fires. If water is not readily available due to low river flows and dams drying out, more labour intensive and invasive methods of fire fighting may need to be employed, for instance the use of bulldozers.

Fires would consequently take longer to put out, and require more resources and staff. Not only will the direct cost of fire fighting escalate, but the flow-on effects for the district may be serious if production forest is lost, leading to loss of jobs in harvesting and processing. If large areas of forest cover are lost from erosion-prone land, severe soil erosion may result. In addition, fire would return most (if not all) of the carbon sequestered in a forest sink, to the atmosphere.

In forest (both indigenous and plantation) drought significantly increases fire risk. The duff layer and fine fuel (twigs and leaf litter) on the forest floor become drier and can burn faster and more completely, making the fire more intense and quicker spreading.

If the duff layer and soil are extremely dry, the fire can even burn tree roots underground. These fires are very much harder to put out, and may require tree stumps and roots to be dug out. In these situations, fire fighting takes a lot longer, is more invasive (bulldozers may be required) and requires a lot more staff input. A fire that might otherwise be a "one-day job" can take three- to six days (or possibly longer) to put out. This was what happened during the dry summer of 1997-98.

The fire season is expected to become much longer, particularly if drought extends into autumn and spring, and strong westerly winds increase in frequency. It follows that there will be longer total fire bans, and this will impact on landowners who 'traditionally' burn (for instance after forest harvesting), and also rubbish fires, bonfires, hangi and umu.

Grass fires may also become more frequent and severe as the climate warms. Drought is very significant for grass fires because if every bit of fuel is dry, 100% of material present may burn completely. This can result in a very hot and fast-moving fire, with flame heights up to 2 – 3m (or even higher), especially if fanned by strong wind.

Responsibility for fighting rural fires is split three ways in Gisborne District: The Eastland Rural Fire District covers land managed by the major forestry companies (around 140,000 ha plus one kilometre margins around forests), Department of Conservation looks after forest parks, national parks and reserves (125,500 ha), and the Gisborne District Council is responsible for the remaining rural land (450,000 ha).

Climate change is all bad news for fire risk. GDC Rural Fires, together with the other agencies involved, will need more trained staff, more equipment and more concerted fire-prevention. Even the 'best case' climate change scenario indicates greater fire danger for rural-fire staff and for residents.

Chapter 6: The role of forests in mitigation of climate change

Key points from this section:

- The government has clearly signalled its intention to retain carbon credits accruing to plantation forest, in order to avoid distortions in the timber market;
- Plantation forests do absorb carbon, but because they are harvested, the carbon is eventually released;
- On the other hand, permanent (indigenous) forest sinks will sequester carbon and help New Zealand meet Kyoto commitments. This will require land use change, and the incentive for landowners will come from allocating tradable carbon units;
- Legislation to enable the Permanent Forest Sinks Initiative (PFSI) is at select committee stage, and is intended to be in force in advance of the first commitment period of Kyoto (by 2008);
- The PFSI could enable land that is unsustainable for farming to generate an income by facilitating regeneration to indigenous vegetation;
- There is up to 120,000 hectares of ‘marginal land’ within Gisborne District, including multiple-owned Maori land, which may be suitable for ‘carbon-farming’;
- How much land, and which classes, is converted from farming to trees for the purpose of ‘carbon-farming’ may depend upon the price set for a tonne of CO_2: $15 is said to be the likely value at the commencement of carbon trading;
- There may be opportunities to create forested areas utilising ECFP funding for reversion, and these areas could become permanent forest sinks, if protected by a QEII covenant or Nga Whenua Rahui;
- Another possibility may be to plant pines as a nursery crop, but then facilitate a change to other species;
- There is uncertainty about what will happen after the First Commitment Period of Kyoto (2012). This could be a major stumbling block for landowners and may hinder uptake of afforestation projects.

Plantation forests and carbon sequestration

When New Zealand ratified the Kyoto Protocol in 2003 it was widely believed that the ever-increasing area of plantation forests would allow the country to not only easily meet its Kyoto obligations, but also receive a significant windfall in the form of carbon credits.

In reality there has been a sharp decline in forestry planting (and re-planting) coupled with increasing energy and transport emissions. Treasury now estimates that New Zealand faces a deficit of at least $522 million for the first Kyoto commitment period of 2008-12.

So-called Kyoto forests are those established after 1990 on land not previously forested. The Government can earn carbon credits for these, but is liable for the emission of carbon previously stored in the trees if forests are felled and not replanted.

The Government has stated it will accept liability up to a “deforestation cap” 21,000 tonnes of emitted carbon, believed to be about 10 per cent of the expected harvest between 2008 and 2012.

If more than that is not replanted, forest owners fear they will be required to bear the cost of the Kyoto liability. The deforestation cap is therefore very unpopular amongst forest owners.

MAF estimates that of 40,600 ha harvested last year, 8,600 ha were not replanted. At the same time the area of new plantation forest established fell to 6,000 ha from 10,000 ha in 2004 - continuing the decline from a peak of nearly 100,000 ha in 1994.

It is likely that the decrease in prices for timber and increased profitability of farming, across dairy, sheep and beef, has caused the swing away from forestry. The changing fortunes of pastoral farming and forestry have long behaved in this cyclical way.

Plantation forest owners unhappy

Relations between the forestry industry and the Government became so strained under previous Climate Change Minister, Pete Hodgson, that forest owners banned officials from their land for carbon monitoring purposes.

In April 2006 a group[16], representing about 80 per cent of the plantation forest industry, sent a brochure to all members of Parliament calling for the establishment of a carbon market and the removal of the deforestation cap.

In Europe, individual forest owners can apparently earn carbon credits by trading with polluting industries.

The forest owners group believes if they are financially encouraged to plant more trees New Zealand's Kyoto target can be met. This would require 60,000 to 70,000 hectares of new forest a year (a rate of planting that was achieved in the 1990s, the heyday of forest planting).

However, a Cabinet paper obtained under the Official Information Act stated that: "Latest indications are that forest owners intend to deforest about 47,000ha during the first Kyoto commitment period" (2008 to 2012). This could possibly add 32 million tonnes of carbon dioxide equivalent to New Zealand's deficit, almost doubling it.

The forest owners group has stated that it is the way Kyoto is being handled, specifically the deforestation cap and non-devolution of carbon credits, which is the reason for the drop in forest plantings.

Minister of Forestry, Jim Anderton, countered the forest owners group, stating that any policies to encourage planting, even if urgently implemented, would make little difference to our Kyoto liability within the first commitment period. He added that planting has been reducing since before Kyoto was signed and reiterated that it is the relative profitability of pastoral farming that is driving a shift in land-use away from forestry.

Where to from here?

On January 30 this year the Forest Owners Association relented on their access-ban by advising members to at least help officials identify which forests would qualify as Kyoto forests.

Various departments across government have staff working on a comprehensive policy package. Issues affecting the forestry sector have been identified for specific attention and Mr. Anderton has given his assurance that the ideas put forward by the forest owners group will be considered.

It is likely to take some time for policy to be drafted due to complex considerations including future energy generation and transport, agriculture and forestry, conservation, health, and the nation's vulnerabilities as an economy heavily reliant on primary production in a changing climate.

16. The New Zealand Forest Owners Association, the Federation of Maori Authorities, the Kyoto Forestry Association and the NZ Farm Forestry Association.

In the mean time

The forestry sector is likely to find the process of policy development slow and frustrating.

Any attempts to lure investors into commercial forestry projects under promise of profits from carbon trading (requiring credits to be devolved by Government) are purely speculative.

In any case, if carbon credits were to be devolved to plantation forest owners, they would, upon harvest of the timber, be required to buy emission units on the international market to replace the ones sold.

If, as is likely, the price of credits rises over time, plantation forest owners could even face a loss.

The Government believes it can best manage this situation because of its wide portfolio of options and because sink credits are generated across many forests.

Using afforestation/reforestation is still a preferred course to meet Kyoto obligations, although the Government concedes that carbon units will also have to be purchased from overseas during the first commitment period (2008-2012) to meet a shortfall.

Forest owners who establish new *permanent* forests under the Permanent Forest Sink Initiative will receive tradable emission units in proportion to the carbon sequestered in their forests. This mechanism is soon to be provided for in legislation (but is not yet enabled).

The Permanent Forest Sink Initiative

This government initiative is the only mechanism whereby landowners can benefit financially from creating carbon sinks. To be eligible, the land must not have been covered in forest as at 31 December 1989.

The new forest is intended to be permanent, and will require a binding contract or covenant between the forest owner and the Crown. The covenant would be in perpetuity, binding any future owners of the forest. The PFSI will be managed by MAF's Indigenous Forestry Unit in Christchurch.

The forest may comprise indigenous or exotic species. For areas of patchy scrub intermixed with pasture, the boundaries would be determined on a case-by-case basis.

Eligibility of a forest to qualify for the PFSI will require adherence to an agreed management plan. The emission units would be paid against the amount of carbon sequestered by the vegetation between 2008 and 2012 (the first commitment period for Kyoto). Units would be awarded to landowners after 2012 once the amount of carbon stored in the forest is verified. They could then be traded with whomever the landowner wishes. It is unclear at this stage what the emission units would actually be worth.

The new forest must be "direct, human-induced... through planting, seeding, and/or the human induced promotion of natural seed sources". The forest could be indigenous, exotic, or a mixture of both. Stock-exclusion fencing will be necessary, but active planting of seedlings is not a specified requirement.

After 35 years there is provision to remove some timber from the forest provided a closed canopy is retained. Unauthorised harvest or clear-felling would incur penalty payments. If the forest is blown or burnt down, landowners would be required to purchase emission units to cover carbon emitted to the atmosphere, but would not incur additional penalties.

Landowners would be responsible for all costs associated with forest establishment, ongoing monitoring and verification.

Possible opportunities for Gisborne landowners

The PFSI may appeal to landowners wishing to retire marginal land. On the East Coast this could coincide with target and qualifying land under the East Coast Forestry Project.

Some erosion-prone land is eligible for the "reversion" option under the East Coast Forestry Project, where kanuka/manuka scrub is already established, or there is a suitable seed source to allow this to happen. ECFP reversion blocks require stock and feral animals to be excluded, but a fence is not specified, and in some cases is not needed.

The PFSI is compatible with creation of a QEII reserve area, where significant regeneration will take place once the area is fenced. This may be attractive to some landowners as a way of generating some extra funds for fencing or planting.

Thinking outside the square: Pines as nursery-crop for other species

Another interesting possibility in this district could comprise planting an area with pines on ECFP-target and qualifying land, then registering the forest as a Permanent Forest Sink.

Indigenous vegetation would establish beneath the pine canopy if there is a suitable seed source near by. The exotic trees could then be progressively removed by thinning. Emergent indigenous tree species would eventually take over and replace pines as the canopy. The landowner could receive carbon credits accruing to the regenerating indigenous vegetation (though not for the pines, which would be left to rot after thinning).

Another possibility could be inter-planting pines with high-value species. This could be done at the outset, or more likely after thinning the pines at around 4 years, to create gaps in the canopy.

For example, rimu seedlings could be planted amongst the pines after the first thinning. Management would take the form of continuing to progressively thin pines at intervals, allowing indigenous reversion to progress.

Ultimately, the pine forest will have given way to an indigenous forest with high-value timber species within. High-value exotics, such as black walnut, could also be included. The PFSI is expected to allow selective removal of some of these trees after 35 years.

The PFSI requires a covenant on the forest-block. In the above examples a QEII reserve would not be suitable if there is an intention to selectively remove some trees for timber further down the track. A MAF-approved covenant[17] could be used, which is less restrictive regarding selective harvest.

On Maori-owned land, Nga Whenua Rahui would allow for selective harvest of some trees.

Pine trees alone may not be suitable to create a permanent forest sink without active management. A pine forest 'let go' would result in very spindly, weak trees at risk of being blown over. If large tracts of forest were lost this way, most of the sequestered carbon would be emitted to the atmosphere.

Land planted with poplars or willows for erosion control may possibly fit the criteria of the PFSI, provided stock are excluded. In some cases this could possibly generate funds for landowners to offset maintenance of the trees, and allow replacement at the end of their useful life.

17. MAF covenants currently have a term of 30 years, but this is likely to be increased to 50 years in the near future.

There is some uncertainty

What if, beyond 2012, the Kyoto Protocol no longer allows for emission units to be generated from the forest? It is proposed that all harvesting and land-use change restrictions would then be annulled. However, there may still be liability in respect of units already claimed by landowners should the forest be clear-felled.

Resource consent would most likely have to be sought for any proposed land-use change, and District Plan rules may apply to the vegetation present.

Reversion to kanuka/manuka on marginal land

Manuka/kanuka shrublands have only recently been recognised as a large potential carbon sink, having measured rates of carbon accumulation of 1.8 to 2.2 (+/- 0.3) tonnes of carbon per hectare. There was found to be a gradual loss of soil carbon as regeneration progressed, but this was largely offset by the accumulation of carbon in the soil litter layer.

Regenerating manuka/kanuka scrub fits the definition of a Kyoto forest because direct human intervention is needed to initiate regeneration (exclusion of stock, cessation of livestock farming, and a halt in scrub clearing activity).

In Gisborne District, manuka and kanuka grow quickly to become quite significant forest trees. A stand is considered mature (from a carbon-sequestration point of view) at around 60 years of age, after which carbon accumulation plateaus. In many cases, at around 100 years, additional forest species begin to break through the canopy and another carbon-accumulation phase begins that may extend from 150 to 500 years.

Around 120,000 hectares of land in Gisborne District is considered ‘marginal’ for continued livestock farming (environmentally and economically unsustainable). This is due to the combination of steep slopes and soft underlying rocks making the land prone to severe erosion. In addition, scrub has been retained on many properties in gullies and on steep faces, therefore there is a viable seed source close at hand, making regeneration possible.

‘Carbon farming’

The economic return from scrub-reversion on marginal farmland of the East Coast was estimated by Trotter *et al* (2005).

The average stock carrying capacity of ‘marginal land’ is currently believed to be only about 3 stock units per hectare[18]. Reversion to scrub could theoretically provide a future income comparable to livestock farming on up to 120,000 ha in Gisborne District[19].

The calculations of dollar income do not take account of the significant value of indigenous vegetation for soil and water conservation and biodiversity. Well-established stands of manuka/kanuka are almost as effective as plantation forests at preventing soil-slip and reduce erosion rates by 90% relative to pasture. There would be costs for fencing the reversion area, and for weed and possum control. Conversely, inputs in the form of manpower, maintenance and fertiliser would be reduced, and there could be enhanced opportunities for production of honey and manuka oil.

18. Equivalent to gross revenue of around $50 NZD per hectare.
19. Once carbon emission-unit prices reach $20 NZD per tonne

New Zealand as a whole is responsible for annual energy-related carbon emissions of 8.81 million tonnes. If all the country's marginal or uneconomic farmland was allowed to revert to indigenous vegetation - either manuka/kanuka, mixed scrub and broadleaf species, or directly to indigenous forest - (these total around 1.45 million hectares), it could facilitate carbon sequestration of 2.9 +/- 0.5 million tonnes per annum, once the stands were well established.

Current Research into likely uptake of 'carbon farming'

Stanford University PhD candidate Jason Funk is two years into a project to investigate the possible impact of carbon policy on land use change, focussing on Maori-owned land on the East Coast. "Suitable land" for indigenous reversion includes land that fits the current criteria of the ECFP (LUC classes VII and VIII) where there are seed sources available, or it may be already regenerating.

His project will attempt to answer the question: If carbon can be traded at $15 a tonne, and there is a change in the relative value of sheep/cattle and trees, how much re-afforestation will be triggered, and where will this occur?

To receive income from carbon trading, the land would have to qualify as a Permanent Forest Sink and be protected by a covenant, such as Nga Whenua Rahui.

The model assumes that land use will change to whatever will generate the most income. In reality the situation is complex, especially for Maori Land where a consensus must be reached amongst multiple owners. Nga Whenua Rahui also allows for a 25 year 'generational review' of the status of the land, and for some restricted harvesting of trees.

Interviews with selected Maori land owners revealed an interest in the possibilities of income for carbon sequestration, and a definite preference for the term 'carbon farming' over 'reversion' of land: the former implies active management is being undertaken.

Funding has been obtained to allow some pilot carbon-farming blocks to be set up on Maori land with three different ownership structures: an Incorporation, a Trust and a block of land with no clear management structure. How much carbon is actually accumulated by the forest as it grows will be quantified using the Landcare Research-designed "carbon calculator", which takes account of soil characteristics and rainfall at the site.

Data from Jason Funk's project should be available within eighteen months (by the start of Kyoto First Commitment Period, 2008).

EBEX21®

EBEX21® stands for **E**missions/**B**iodiversity **EX**change. This scheme will match up businesses or organisations wanting to voluntarily reduce greenhouse gas emissions with landowners or organisations having land suitable for revegetation/carbon sequestration.

The scheme was initiated in 2001 and is coordinated by Landcare Research. The joint aims of EBEX21® are to reduce net greenhouse gas emissions, improve biodiversity and increase energy and resource efficiency.

Landcare Research has carried out extensive research into carbon sequestration by vegetation and soil. Staff have the expertise to measure and monitor an organisation's greenhouse gas emissions, provide advice on how emissions can be managed and reduced at source, and as a final step facilitate the opportunity to offset remaining emissions with indigenous revegetation projects.

The CarboNZero® brand

Organisations that have been verified as having reduced CO_2 emissions as far as is possible, and offset the remaining surplus via EBEX21® forests, are able to use the CarboNZero® brand on their product or service.

What land will qualify as EBEX21® forest?

The proposed area must be at least 50 ha in order to be economic for monitoring and staff time.

The proposed reserve would have been in pasture or have had less than 30% tree cover[20] at 31 December 1989 (for example, pasture with scattered manuka/kanuka, or gorse/broom with no native tree seedlings underneath). There must be a seed source of trees that can reach 5m at maturity either present within the reserve, or within a kilometre.

The boundaries of the proposed reserve are defined on an aerial photograph and the EBEX21® team assesses the predicted annual rate of carbon sequestration. Permanent plots are set up within the reserve for long-term monitoring of carbon accumulation and storage, and biodiversity.

Stock must be excluded from the reserve[21], and the regenerating forest must be protected in perpetuity by a covenant (a QEII Open Space Covenant or Ngā Whenua Rahui kawenata are considered appropriate). In addition the landowner enters a contract whereby they agree to manage revegetation of the site and not fell any trees.

The regenerating forest will accrue 'CO_2 credits' which the landowner is able to sell, tonne for tonne, to purchasing organisations. The initial contract will last until 1 Jan 2008 when the Permanent Forest Sink Initiative Regulations are expected to come into force. After that time carbon-dioxide credits that accrue may be sold to buyers not related to EBEX21®.

Landcare Research will verify the amount of CO_2 removed from the atmosphere by the regenerating forest, maintain an inventory of carbon accumulation and biodiversity change at the site, and seek future buyers for credits if landowners choose to continue with the scheme.

Landowners are asked to contribute 10% of the land area for which they will not receive payment for carbon credits. This land will be pooled with other landowners' reserves to provide credits as self-insurance against unforseen loss of any individual areas of forest through major disturbances such as fire or storm damage. In those situations the extra pool would cover the lost credits.

Compatibility with the Permanent Forest Sink Initiative

All the 'rules' for EBEX21® are aligned with those proposed for the PFSI, so that from 2008 landowners can switch to that scheme should they wish. One advantage of the PFSI over EBEX21® is the greater flexibility of the 'Kyoto approved' carbon credits issued under the PFSI. Those credits are expected to be internationally tradable, or could be sold to the New Zealand Government.

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20. Defined as including only trees that can reach 5 m in height.
21. Therefore, space-planted conservation trees (poplars and willows) with stock grazing beneath would be ineligible.

Uptake of EBEX21®

To date, there has been plenty of interest from landowners wishing to set aside reserve areas. These have not been equally balanced by sufficient purchasing organisations; the scheme is of course voluntary for emitters.

At this point in time the incentive for business to reduce and mitigate emissions is limited to being able to use the CarboNZero® brand as a point-of-difference in their marketing, and of course there are a minority with a strong interest in doing something positive for the environment.

There are currently seven properties with reserved land "on the books" widely spread around the country and these are managed as a pool. There have been 3,600 tonnes of carbon dioxide traded so far under EBEX21®. Purchasing organisations that have achieved CarboNZero® status include Toyota NZ, several conferences, a hotel chain, South Pacific Pictures (producers of the Shortland Street TV series) and Landcare Research itself.

Local individuals versus outside investors

There are clearly opportunities for money to be made via afforestation of land within Gisborne District, once the legislation enabling the PFSI is finalised.

Individual landowners and businesses could certainly take advantage of the various options to generate income via carbon credits or units (whatever form these take) while protecting the vulnerable land from erosion. These go hand-in-hand, as wherever erosion is accelerated, significant amounts of carbon are being lost from the soil.

Ideally, viewed from the air, Gisborne District would reveal a patchwork of land use, where production of various types (cropping, horticulture, forestry, farming) and conservation were all matched to the land use capability of the land and soil.

There are however still areas where large tracts of land require afforestation due to severe erosion. This has typically been achieved by investors buying up whole properties and planting the property boundary-to-boundary, with most of the profits generated going out of the district.

We need to be aware that in the case of overseas emitters or investors seeking land to put into permanent forest sinks, carbon credits generated will go offshore, and therefore not count towards offsetting of New Zealand's own Kyoto Targets.

Chapter 7: Climate and the ocean

Key points from this section:

- The Subtropical Front is an important area for plankton and fish stocks. Present climatic conditions enhance the productivity of the front, to New Zealand's benefit.
- A significant proportion of New Zealand's fish stocks come from the area of ocean close to the Subtropical Front.
- Phytoplankton are crucial to regulation of global climate. They represent a major carbon sink, through absorption of CO_2 from the atmosphere.
- El Niño and La Niña weather patterns affect both phytoplankton and fish abundance; Climate change may intensify El Niño and La Niña weather patterns.
- The intensity of mid-latitude storms affecting New Zealand may also increase.
- If westerly winds increase, the Antarctic Circumpolar Current would be strengthened, further isolating waters on Campbell Plateau and increasing the inflow of cold water to Chatham Rise.
- This may modify the Subtropical Front and associated cloud cover.
- Stronger westerlies could also enhance the influx of warm subtropical waters to New Zealand shores, although this effect may offset locally by wind-induced upwelling of cooler subsurface waters.
- For Gisborne and the East Coast, the amount of sediment and nutrient washing into the sea is probably more significant for the biodiversity of marine life then the effects of coastal fishing.

Role of oceans in climate regulation

The atmosphere, climate and the ocean are inextricably linked. It is impossible to fully consider the workings of one component of the system without consideration of the other parts.

Ocean covers around two-thirds of the surface of the Earth. The oceans are an enormous heat-reservoir and a massive sink for carbon.

A proportion of carbon residing in the ocean-sink comprises CO_2 that dissolves in sea water directly from the air. A very large quantity of carbon is fixed by photosynthesis then deposited as microscopic calcium carbonate shells of some phytoplankton. The tiny shells fall to the sea bed and may be buried and fossilised to become limestone rock.

These organisms are therefore very significant for the regulation of climate on a global scale.

Much of the world's cloud cover forms by evaporation over the oceans. The condensation of water vapour into droplets and clouds is believed to be initiated by tiny particles of sulphur compounds, emitted by marine phytoplankton.

Cloud cover has a significant effect on climate. Clouds lower in the atmosphere reflect a high proportion of incoming solar radiation back into space and therefore have a cooling effect. High-level clouds tend to re-emit infrared back to the surface and therefore have a warming effect.

The Subtropical Front

Roughly two-thirds of the way down the Southern Hemisphere a major oceanographic feature – the Subtropical Front – circles the globe. This boundary separates warmer, more saline, nutrient-rich subtropical water from cooler, oxygen-rich and nutrient-poor subantarctic water. It is clearly visible in satellite images of sea-surface temperature.

In the present day, the warm subtropical surface waters bathe the North Island and the west coast of the South Island, while subantarctic water surrounds the rest of the South Island and offshore islands to the south and east.

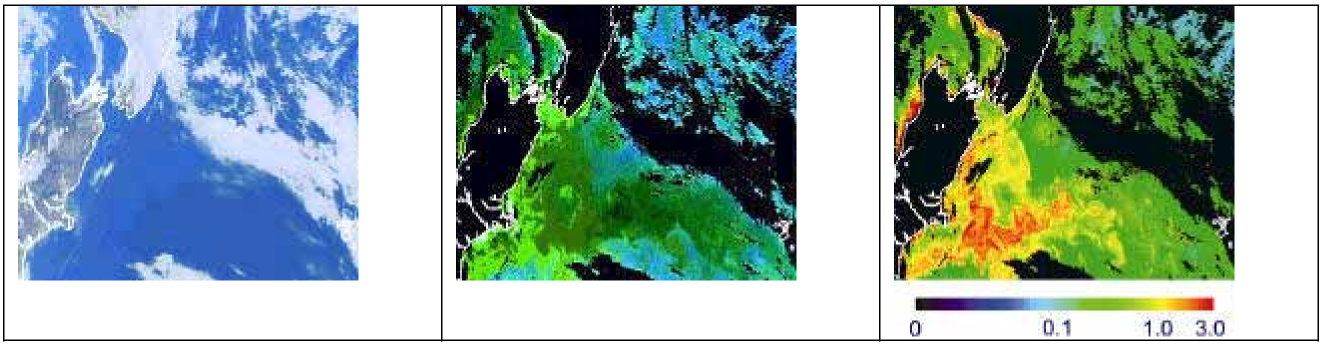
At the Subtropical Front, mixing of the subtropical and subantarctic waters creates ideal conditions for phytoplankton, zooplankton (microscopic plants and animals) and the creatures that feed on them. On the Chatham Rise and in the Subantarctic, the undersea landscape and currents enhance these conditions.

Satellite mapping of phytoplankton distribution

It is now possible to map phytoplankton distribution over large areas thanks to remote sensing by satellite. Images of chlorophyll *a* concentrations in the sea (indicating rich growth of phytoplankton), combined with traditional ocean-sampling techniques, will enable scientists to calculate how much carbon is held in the ocean in the biomass of phytoplankton.

Patterns of phytoplankton abundance may change as the climate warms. This would have significant implications for the concentration of CO_2 in the atmosphere, and also for fish abundance and distribution.

NIWA purchases daily satellite images for the purpose of monitoring phytoplankton concentrations and distribution within the EEZ. This area of research is ongoing.



Above: Three images of high-resolution (1.1 km) SeaWiFS data received by the NIWA satellite-receiving station on 31 March 2000 showing an enormous phytoplankton bloom over the Chatham Rise. The first frame shows the view visible from the satellite. The middle frame shows the colour of the sea after removing light that was scattered by the atmosphere. The last frame shows surface chlorophyll a concentration (in mg/cubic m) estimated using a bio-optical algorithm. (Data from the SeaWiFS Project, NASA/Goddard Space Flight Center and Orbimage)

Fish stocks

The abundant fish stocks within New Zealand's 4.8 million km^2 Exclusive Economic Zone are a fortunate product of New Zealand's location in the Pacific, the undersea landscape, ocean currents, and climate.

The Chatham Rise and Subantarctic fishing grounds provide 60% of New Zealand's fish catch, most of which comes from areas near the Subtropical Front. The main hoki, hake, ling, silver warehou, squid, orange roughy and deep sea (oreo) dory fisheries are located close to this area.

The other 30% of the fish catch comes from the west coast (mostly off the South Island), mainly during winter and spring when fish gather there to spawn. Species caught include hake, hoki, ling, and silver warehou.

Effect of El Niño and La Niña on fish species

There are links between El Niño and La Niña weather patterns and fish abundance in a number of important fish species including snapper, scallops, red cod, hoki, and rock lobster.

Westerly winds affect ocean currents around New Zealand and the temperatures of surface waters. These vary seasonally and between years, altering the patterns of upwelling of cold subantarctic water and therefore nutrient mixing in our seas. This in turn affects how much food is available and how many fish are produced.

During La Niña years, westerly winds are weaker and plankton food sources more abundant in the Hauraki Gulf and Coromandel. These years bring the best production of young snapper and scallops in these areas.

New Zealand is coming into a time of more frequent La Niña years linked to a negative phase of the Interdecadal Pacific Oscillation (IPO), apparent since 1999. This may enhance northern snapper fisheries, but could be detrimental for other species.

There is a need for further research into this area to enable better management of New Zealand's fisheries.

Sediment and nutrient run-off from land

For Gisborne and the East Coast, the amount of sediment and nutrient washing into the sea as a result of erosion, farming and human activities on land is probably more significant for the biodiversity of marine life then the effects of coastal fishing. The effect is most pronounced near the mouths of our major rivers, where the frequent flushes of sediment mean very little benthic (bottom dwelling) life can establish.

Recent research by NIWA has shown that with more sediment in the water, fewer larvae of paua and kina survive. Sediment also affects the tiny animals living on kelp that provide a major food supply for other rocky reef species. High sediment levels reduce the productivity of entire rocky reef ecosystems, with consequences for recreational, customary, and commercial species.

Future studies will look at the effects high nutrient levels are having on the marine environment. A study commencing this year in Southland will examine the effects of runoff from agriculture and intensive dairy operations on coastal ecosystems

Another potential threat to our marine environment is the introduction and spread of marine pests, like the seaweed *Undaria* and sea squirt.

Major ocean currents

Two great current systems collide into New Zealand. The *Subtropical Gyre* is an anticyclonic system driven by regional winds, and occupies most of the south pacific. From South America, the north arm of the gyre flows to Australia where it becomes the East Australian Current. Near Sydney the flow turns east as the Tasman Front, and intercepts Northland on the return journey to South America, the southern arm of the gyre.

In the Southern Ocean, persistent westerly winds drive the *Antarctic Circumpolar Current*. This powerful current flows west to east for 24,000km around Antarctica, and is the only current to connect all the southern hemisphere oceans. The Antarctic Circumpolar Current flows unimpeded, except where it is constricted by the submarine topography near South America and New Zealand. Whirling eddies are produced that are observable from space

There is now scientific evidence that climate warming that occurred after the last glacial period was accompanied by large changes in oceanic and coastal currents.

What changes may be expected?

If westerly winds increase, the Antarctic Circumpolar Current would be strengthened. This would further isolate waters on Campbell Plateau and increase the inflow of cold water to Chatham Rise, modifying the Subtropical Front and associated cloud cover. Stronger westerlies could also enhance the influx of warm subtropical waters to New Zealand shores, although this effect may offset locally by wind-induced upwelling of cooler subsurface waters.

El Niño and La Niña climate patterns could intensify. Stronger tropical cyclones may also alter current patterns temporarily.

The intensity of mid-latitude storms affecting New Zealand may also increase. Large-scale temperature gradients supply the energy and moisture for these storms, and it is believed the energy in the system will increase.

Severe, intense rain and floods are likely to cause coastal effects. For Gisborne and the East Coast, flood-waters would be so heavy with mud that upon reaching the coast they would dive to the seabed and flow rapidly down-slope. Coastal water would have very high turbidity and be enriched in nutrients close to the mouths of major rivers. This happens now, but the effect may be intensified.

Chapter 8: Effects of climate change on human health

Key points from this section:

- Climate influences health both directly (heat stress and the consequences of natural disasters), and indirectly (the resulting burden of disease due to disrupted agriculture, food supply and water quality);
- Secure and clean drinking water supplies are probably the most significant concern for Gisborne District, because in many rural areas and settlements they are already inadequate;
- Skin cancer may continue to increase, unless offset by changes in behaviour;
- There may be more civil emergencies such as floods and storms;
- There could be more dust and allergens in the air, but less winter smoke;
- Incidence of food poisoning will increase as the climate warms;
- Algal blooms and shellfish poisoning may become more frequent;
- New insect disease-vectors may become established in Gisborne District, and we wont be able to control or eradicate exotic insects indefinitely;
- Land-use changes, particularly from farming to forestry, would increase exposure to occupational hazards;
- Hardship, due to prolonged drought or severe storm damage, may have consequences for the physical and mental health of our citizens.

Temperature related mortality

As the climate warms, an increase in heat-related mortality would be expected, however this may be offset by a reduction in cold-related deaths.

Mortality from all causes was found to increase by 1.3% per degree on ‘hot days’ (over 20.5^{o}C) in a Christchurch study. It is possible many of these deaths were amongst people who were already frail or ill, and that they may have died within a few weeks anyway. Widespread use of air conditioning is a short-term solution, but is not environmentally sustainable (nor affordable), in the medium to long term.

There is also an increase in mortality following extremely cold weather, although the mechanisms for this are not fully understood. In New Zealand, heart disease deaths are up to 35% higher during the winter peak compared with the summer low. The typical observed winter increase in mortality (over 50%) is most significant for the elderly and for people with respiratory diseases.

In a warmer climate scenario, people may spend more recreation time in and around water, and the incidence of drowning may increase.

UV radiation

The effects of solar ultraviolet (UV) radiation on skin cancer, skin aging, and cataracts of the eye are significant in New Zealand. Together with Australia we have the highest skin cancer rates in the world.

Emissions of ozone-depleting chemicals (such as CFCs) have fallen significantly as a result of international agreements. However, because greenhouse gases trap heat close to the surface of the earth, the stratosphere has actually cooled, accelerating the destruction of ozone by the CFCs already there. Recovery of stratospheric ozone may therefore be delayed by 15 to 20 years.

There are no NZ estimates available, but a USA study puts the increase in skin cancer rates at between +5 to +20% by the middle of this century, due to continued ozone depletion. Currently deaths in New Zealand from skin cancer total 250 per year, and treatment for skin cancer costs the country $33 million annually.

This constitutes a significant health risk in Gisborne District with our beaches and outdoor lifestyle. We also have a significant proportion of our workforce employed in the outdoors in the agriculture, horticulture, forestry and fishing industries. Light-skinned people will be the most vulnerable.

Civil emergencies

World-wide the monetary cost of natural disasters, in particular storms, appears to be escalating.

Statistics from developed countries reveal that despite the trend toward increasing property damage, death and injury from climatic hazards have in fact decreased. Thus, hazard mitigation is possible if people are prepared.

However exposure to hazards will gather pace as residential areas become increasingly vulnerable to floods and storm surges due to sea level rise and a possible increase in the incidence of heavy rainstorms.

Air quality

Increased summer temperatures may exacerbate the effects of photochemical air pollution from urban traffic fumes. However, when it is windy, fumes and pollution tend to be blown away.

An increase in windy days from spring through to autumn could increase nuisance dust from ploughed or drought-affected paddocks. Dust is irritating to people, can coat leaves of vegetation and may get into water supplies.

PM10 refers to the component of dust comprising respirable particles less than 10 microns is size. These particles are a health hazard and the Council monitors the amount in the air of the city and environs.

Warmer winter temperatures may reduce the need for home heating, thereby reducing the output of PM10 from log burners.

Allergens

Climate change could increase the length of the hayfever and allergy season, and higher ambient concentrations of CO_2 have been experimentally shown to increase pollen production in specific plants.

High pollen levels have been associated with acute asthma epidemics, often in combination with thunderstorms, however other studies have indicated that the effects of weather and aeroallergens on asthma symptoms are either small or insignificant. Causation, initiation and exacerbation of asthma is complex and it is not entirely clear how climate change would affect this disease.

Sources of indoor allergens include mould and fungal spores, house dust mites and cockroaches. The abundance of all of these would be expected to increase in warmer conditions.

Drinking water

Fresh water could well become our most precious commodity as the climate becomes drier.

Domestic water supplies are of serious concern for rural areas of Gisborne District under any of the climate change scenarios. In fact many rural areas, especially on the East Coast, are already considered to be at high-risk for poor drinking water quality. Risk factors include lack of reticulated supply, inadequate rainwater collection and storage systems, and unreliable and/or unsafe supplementary sources.

If there is not enough regular rainfall, catchment area, or storage capacity, people will need alternative supplies of either bore water or surface water. This will often require treatment and transport, a problematic issue when many households rely on low incomes.

Gisborne's municipal supply from the Waingake catchments is likely to remain secure under climate change scenarios, although the volume of stored water may drop. Water quality is good as the catchment mainly comprises indigenous bush and undeveloped land. It will be necessary to ensure the bush does remain in good health and pest/animal management is maintained in an effective manner.

It is possible that in the future new industries may be set up in Gisborne with a high requirement for water (for instance more timber processing). If Waingake is unable to supply all the water to meet requirements, new industries may need to look for independent supplies.

Food related illness

Water- and food-borne diseases tend to show marked seasonality, with peaks in early spring and summer. Higher temperatures favour proliferation of micro-organisms and are often associated with an increase in gastrointestinal infections.

Medical Officer of Health for Gisborne, Dr. Bruce Duncan, says he would expect a "longer season" for food poisoning, as a direct result of warmer temperatures, and also because of lifestyle factors, including more barbeques and eating outdoors.

People may restrict hand-washing if water shortages occur, to avoid having to purchase trucked-in water, exacerbating the problem.

In most developed countries, food-borne disease incidence is observed to be increasing as a result of changes in behaviour, consumption patterns, and commerce.

Surface water quality

Heavy rain and storm water runoff can wash bacteria into rivers. High levels of bacteria in the rivers of Gisborne District generally follow, but are not directly proportional to, rainfall events.

Long-term monitoring indicates levels of bacteria peak within approximately two days of a significant rainfall event that follows a reasonably dry period. However, if rain continues beyond two days, bacteria levels within the river begin to decline regardless of rainfall intensity. This means peak bacteria levels in the rivers do not always coincide with peak rainfall.

The frequency of bacterial contamination of rivers may change in relation to intense rainfall events possibly becoming more frequent as the climate warms.

During times of drought, livestock numbers in the district may decline, for instance if stock are sent out of this district for grazing. This could reduce bacterial contamination of surface water.

Conversely, if stock congregate in rivers and streams during times of low-flow, contamination could be severe.

Coastal and offshore water quality

Phytoplankton respond rapidly to changes in environmental conditions and so are sensitive indicators of environmental change. Toxic algal blooms can affect humans as a result of direct contact with the skin or through consumption of contaminated fish and other seafood.

However, there is no straightforward relationship between the presence of an algal bloom and an outbreak of poisoning; human poisoning can occur in the absence of a bloom.

There are two main types of biotoxin poisoning associated with temperate-to-cool coastal waters: paralytic shellfish poisoning and diarrhoeic shellfish poisoning. If sea surface temperatures rise, shifts in the distribution of these diseases could follow.

Our coastline experienced toxic algal blooms form June to October 2003, affecting all the Council's monitoring sites, and the coast from Whareongaonga to East Cape was closed for shellfish gathering.

It has been reported that the incidence of fish poisoning (*Ciguatera*) is associated with ocean warming in some eastern islands of the Pacific. It is uncertain whether *Ciguatera* could extend its range to higher latitudes (including New Zealand).

Vibrio spp. are naturally occurring estuarine bacteria that have been associated with warmer water and may possibly be transmitted to humans under conditions of higher sea surface temperature. Some *Vibrio* are pathogens that can cause diarrhoea.

Coastal water quality is currently monitored by the Gisborne District Council at 35 sites, including the popular bathing and recreational areas.

Biotoxin monitoring is the responsibility of the Public Health unit of Tairawhiti Health. If a closed season for shellfish gathering is in force, the public is alerted by Tairawhiti Health through signage at access points to the popular kaimoana areas, and through media releases.

Vector-borne diseases

Vector-borne diseases are those requiring a biting insect, generally a mosquito, to facilitate the spread from person to person. We are fortunate that none of these diseases have naturalised in New Zealand – yet.

According to Dr Bruce Duncan, as the climate warms vector-borne diseases may conceivably become a very serious local threat to human health. The numbers of notified cases of vector-borne diseases have increased in Australia in recent years.

As the climate warms, the conditions become increasingly favourable for the survival and spread of exotic mosquitoes. Warmer temperatures directly affect the metabolism and speed up the lifecycle of insects, increasing the chance of insect pests surviving and becoming established in this district. Our defences include border security, surveillance, vector eradication, and primary health care.

Mosquitos *Aedes albopictus* and *Aedes camptorhynchus*, potential vectors of dengue fever and Ross River virus, have been detected at New Zealand borders.

There was an outbreak of *Ae. camptorhynchus*, the salt marsh mosquito, at Muriwai and in a confined locality south of Nick's Head in 1999. It may have arrived in Gisborne in a shipment of imported, used tyres. Fortunately on that occasion it was eradicated by a programme of ground and aerial spraying. The cost was significant – around two million dollars.

For vector-borne diseases to establish in Gisborne there are two requirements – one is the vector organism, and the other is an infected person. Several of these diseases are indigenous to the islands of the Pacific and on the Gold Coast of Australia, where many Gisborne people holiday.

Dengue fever

Dengue fever is a mosquito-borne flu-like illness that may be mild or severe, and occasionally causes death. Dengue is endemic in tropical and sub-tropical regions around the world, where it is a major public health concern. It does not currently occur in New Zealand.

There are four closely related viruses that can cause dengue. Development of a vaccine is therefore difficult and probably years away. Recovery from infection by one virus provides lifelong immunity only against that serotype, so it is possible to experience several infections, each increasing the risk of the most serious and potentially lethal complication: dengue hemorrhagic fever. At present, the only method of prevention is to control the vector mosquitoes.

The global prevalence of dengue has grown dramatically in recent decades. Some 2,500 million people, two fifths of the world's population, are now at risk from dengue. WHO estimates there to be 50 million cases of dengue infection worldwide each year.

This spread is attributed to the expanding distribution of both the viruses and of their mosquito vectors, the most important of which is the predominantly urban species *Aedes aegypti*. The mosquitos can breed wherever water is available – in domestic tanks or even discarded containers.

Ae. albopictus, a secondary dengue vector in Asia, has recently become established in the United States, several Latin American and Caribbean countries, in parts of Europe and in one African country. The rapid spread of this species is probably due to the international trade in used tyres.

The HOTSPOTS computer model was developed to predict where climatic and other risk factors might coincide in New Zealand. *Ae. albopictus* is the more cold-tolerant of the two species and could currently survive in Gisborne, along the East Coast, and in the north of the North Island, from Bay of Plenty, Coromandel and Waikato northwards.

Ae. Aegypti on the other hand, would be unlikely to establish in New Zealand at present. Under a mid-range climate scenario[22], suitable conditions would occur only in the far north by the middle of this century. Under a high-range scenario[23], Gisborne and the East Coast would provide suitable conditions for *Ae. aegypti* by the 2100s.

22.A mid-range climate scenario assumes some stabilisation of global greenhouse gas emissions.
23. A high-range scenario considers effects if greenhouse gas emissions continue to escalate.

Other vector-borne diseases

In New Zealand there currently are no mosquitoes that are capable of transmitting malaria; even under global warming scenarios considered by HOTSPOTS, the possibility of a malaria vector becoming established is considered unlikely.

Computer modelling is yet to be developed for *Ae. camptorhynchus* and the vector for Japanese encephalitis, *Aedes japonicus.*

Use of toxins

The need for widespread herbicide application to control invasive weed species, or large-scale aerial application of insecticides to target insect pests is likely to increase with climate change. Spraying, as happened in Auckland in 1997 against the spotted tussock moth, will remain controversial and may have wide-ranging effects on human health, whether real or imagined.

Insect pests are certainly going to continue to arrive in this district – in imported used cars, imported tyres (which may contain water, and with it larvae), and on ships entering our port. Mosquito traps are permanently monitored by Tairawhiti Health around the Gisborne port area.

At some point it will become uneconomic, or indeed unacceptable to the public, to use eradication sprays in the face of increasing arrivals of exotic insects.

Health effects of land-use change

Work related injury statistics for Gisborne indicate a balance between farming and forestry related injuries. Dr Bruce Duncan puts it as follows: “the more trees we grow the more injuries we see”. We may see the balance swing more towards forestry once again, should government policies encourage afforestation for the purpose of carbon sequestration.

Forestry work is seasonal, casual, and often provided by a transient work force. Good wages are available in the short term, but Dr. Duncan has observed that long-term reliance on seasonal work can create a “poverty trap”.

Forestry workers therefore tend to have a lower socio-economic status than farm workers, and this has a marked influence on their health, both physical and mental.

If Gisborne District becomes vulnerable to increasing incidence of floods, drought and strong winds, this will also impact on the socio-economic health of our people. If crops fail or are wiped out repeatedly, if growers are forced to change their operations drastically, and incomes are affected, there may be health effects across all sectors, from the primary producers to the service industries.

Gisborne people are resilient, but there is only so much adversity and economic hardship people can tolerate before health is affected.

Environmental refugees

Climate change will be very serious for some low-lying islands of the Pacific. Fresh water supplies are very vulnerable on islands, and rising sea levels may cause inundation, severe erosion, degradation and destruction of coral reefs, loss of crops and salinisation of soils.

Storm surges could be very destructive as many islands are only a few metres above sea level, and the frequency of cyclonic storms may increase.

Island nations of the Pacific may look to other countries for financial assistance in the face of huge projected losses and increased pressure on their own health services.

Displacement of people from islands in the Pacific could create a population influx into New Zealand. New Zealand has a long history of involvement with the Pacific Islands, and we have political and constitutional links, as well as a responsibility to our neighbours.

Such an increase in population would put pressure on our health system, and indeed all infrastructure, even though traditionally migrants and refugees seem to settle predominantly in Auckland. In addition, refugees may bring new diseases into New Zealand.

Chapter 9: Influence of climate change on tourism

Gisborne's climate, sandy beaches, surf and outdoor lifestyle are the major drawcards bringing tourists to our region, particularly during the peak season that extends from Christmas to the start of the first school term (normally the first Monday of February).

The absolute peak time for tourists is the three days form the 31st of December to the 2nd of January. These are people mainly here for New Year celebrations, in particular for specific events that happen during those days.

A warmer climate may extend the peak visitor season, however the cost of transportation (fuel) will be a major influence. Fuel increases have the effect of making people travel less frequently, and when they do travel they may chose a destination closer to home.

This might mean that overseas visitor numbers will be reduced, but domestic visitors may increase. While overseas visitors have shorter stays, they spend more than domestic tourists, who tend to stay longer but spend less.

The net effect may in fact be negligible to a slight increase compared to the income presently generated.

When it rains or is windy enough to make the beach unpleasant, the focus for visitors here for the sea and sun tends to shift towards cultural and heritage activities (food, wine, the museum, cultural tours). If wind days increase, there may be increased demand for these alternative activities.

Visitors who come here for hiking, hunting and tramping do not seem to be put off by cloud cover or wind; they carry on with their plans regardless.

There has been a long-term trend observed (since the 1950s) towards motel and hotel accommodation, and a swing away from camping. There are various reasons for this: one factor is the increased disposable incomes people have available. Increased wind days, and coastal erosion may combine to reduce opportunities for camping even further.

If there is an increase in weather extremes, for instance very heavy rain events, then the difficulty becomes managing the visitors who are already here.

If roads are damaged by storms during the peak tourist times, people may not be able to leave when planned. Also, there is sufficient fuel (petrol and diesel) available in the district to last only 4 days.

The long-term future of the sandy beaches of Gisborne District is of significant importance to local people and visitors alike. As already discussed in this report, future decisions may allow the sea to claim low-lying coastal land in order to conserve sandy beaches.

Chapter 10: Projects to reduce emissions

Key points from this section:

- Carbon credits may be allocated to some approved projects that will result in reductions in CO_2 emissions.
- Funds raised by trading allocated credits may enable some projects to go ahead which would have been uneconomic without this scheme.
- In Gisborne there are two possible projects: reducing petrol and diesel consumption either through voluntary means, or by investing in the railway line south;
- The proposed wind farm at Mokairau, which is currently on hold while potentially windier sites are prospected.

The Projects to Reduce Emissions programme is a Government initiative to encourage reductions in emissions of greenhouse gases.

Businesses or industries can be awarded carbon credits during the first commitment period of Kyoto (2008-12) for reductions made in CO_2 emissions that are above and beyond any reductions that would have occurred during business-as-usual, without the project.

The extra funds generated are expected to bring forward projects that would have otherwise been uneconomic.

All projects must take place within New Zealand and result in a reduction in the country's greenhouse gas inventory. This does not preclude overseas investors taking part, but there must obviously be a relationship with a New Zealand business or company.

Participants could be private or publicly listed companies, state owned enterprises, local authorities, or individuals. Subsequently, participants may sell the carbon credits that they receive either to governments or to private buyers. This will depend on international rules and the market at the time.

Project selection criteria

A key criterion is that any proposed project must achieve a minimum of 10,000 tonnes of CO_2-equivalent abatement over the five years of the first Kyoto Commitment Period.

Examples of projects of a size that would meet the criteria are shown in the table below.

Wind farm	1 MW
Electricity	3,200 MWh
Natural gas	40,000 GJ
Methane flared (Flaring of methane that otherwise would be released)	110 tonnes
Methane to electricity (Generation of electricity from landfill gas that otherwise would be flared)	3,200 MWh

Diesel	750,000 litres
Petrol	875,000 litres
Fuel oil	700,000 litres
Coal	1,000 tonnes

Note that these are quantities either produced by the project or displaced as a result of the project *in each year* of Kyoto commitment period one (2008-2012).

Results of the first tender round

The first tender round, held in 2003, offered 4 million carbon credits/emission units, and attracted 46 bids seeking a total of more than 15 million emission units. It resulted in carbon credits being awarded for a number of projects including wind farms, bio-energy, landfill gas schemes and hydro-electricity generation.

Second tender round

The second tender round (15 October 2004) offered 6 million emission units and attracted 51 bids seeking a total of more than 15 million emission units. Carbon credits were awarded for 24 projects including wind farms, hydro-energy generation, geothermal-energy generation, bio-energy and landfill gas.

Electricity projects were not given precedence for the second tender round, and a wider range of proposals were put forward including projects by small businesses, individuals, industry groups, and local government.

From these 24 eligible projects, the forecast emission reduction during 2008-12 could be approximately 7 million tonnes CO_2 (equivalent).

Are there any potential projects in Gisborne?

Use of rail to offset road traffic

Total consumed petrol volume (for the twelve months ending May 2006) was 32.3 million litres for Gisborne and Wairoa Districts combined. Total diesel was 42.8 million litres.

In order to give approximate fuel consumption figures, it might be assumed that Gisborne takes 82.28% of this fuel (based on the ratio of rates struck in Gisborne versus Wairoa Districts). Therefore, petrol consumption for Gisborne District is approximately 26,579,670 litres per year, and diesel approximately 35,220,120 litres per year.

The required reduction to qualify for PRE is 750,000 litres diesel (or 2.13%), and for petrol 875,000 litres (or 3.29%). At face value these seem like fairly conservative reductions, and may perhaps be achieved by increasing the use of rail for freight going to Napier (and beyond).

A cost-benefit analysis would need to be done to see if this is feasible. If offsetting road traffic with rail would qualify as a PRE, then capital would be available to upgrade the railway line to facilitate the project.

It would be interesting to find out fuel consumption within Gisborne City, as further reductions might be made if people are encouraged to walk or cycle. If the required reductions could be made, PRE might provide funds for dedicated cycle-ways and improved footpaths.

Bio-ethanol production

Bio-ethanol for transport fuels is produced by the fermentation and distillation of sugar crops such as maize and sugar beet. Currently New Zealand produces Bio-ethanol on a small scale from whey, a by-product in the dairy industry. It can also be produced from woody biomass but at a significantly greater cost.

Normally bio-ethanol is blended with conventional fuel at around 10% bio-ethanol to 90% petrol or diesel. The only reason to consider doing this would be to achieve a CO_2 saving towards our Kyoto commitments: bio-ethanol is expensive.

At the moment, growing crops to supply bio-ethanol is uneconomic. If conventional fuels continue to escalate in price, it may become an option in the future. Land will of course only be set aside to grow such crops if the return equals or exceeds the current land use.

Some older vehicles do not run so well on a bio-ethanol blend, and slightly more blended fuel (by volume) may be consumed. Producing bio-ethanol is not efficient either: between 30 and 90% of the CO_2 contained within the bio-ethanol is actually emitted during growing and processing of the crop.

However, because bio-ethanol is renewable, the theory is that the concurrently growing crop takes up equivalent CO_2 emissions. Over all, around a 1.5 to 5.5% CO_2 'saving' would be expected from fuel blended at 10%.

Studies in the 1980s identified that there is potential to produce enough maize and sugar beet to replace all petrol in New Zealand with a 10% blend many times over, but of course this would require substantial (probably unrealistic) changes to cropping patterns.

Mokairau wind farm

The current status of this project is that it is on hold indefinitely while further wind monitoring is carried out.

Monitoring using instruments atop a 30m tower provided five years of data. There has been an 80m tower on site for 18 months. It appears Mokairau may not be consistently windy enough and the current focus is on 'prospecting' for alternative sites. Funding from Projects to Reduce Emissions would be critical to enable a wind farm in Gisborne District: it is unlikely such a development would go ahead in the absence of PRE.

Artist's impression of the proposed wind farm at Mokairau.

Bibliography and references

Austin, P.T; Hall, A.J. 2001: Temperature Impacts on Development of Apple Fruits. HortResearch *in* Warrick, R.A; Kenny, J.G; Harman, J.J (*Eds*) 2001: The Effects of Climate Change and Variation in New Zealand, an Assessment Using the CLIMPACTS System. http://www.waikato.ac.nz/igci/climpacts/Linked%20documents/CLIMAPCTS_Assessment_Report.pdf

Bell, R.G; Hume, T.M; Hicks, D.M. 2001: Planning for Climate Change Effects on Coastal Margins. Ministry for the Environment, Wellington. www.climatechange.govt.nz/resources/reports/effect-coastal-sep01/effect-coastalsep01.pdf

Carswell, F; Frame, B; Martin, V; Turney, I. 2003: Exchanging emissions for biodiversity: In pursuit of an integrated solution in New Zealand. Ecological Management & Restoration Vol 4, No 2: 85-93

Carter, L. 2001: Currents of change: the ocean flow in a changing world. Water & Atmosphere online, Vol. 9 No. 4. December 2001. www.niwascience.co.nz/pubs/wa/09-4/currents

Charles, J.G; Allan, D.J. 2000: Development of the willow sawfly, *Nematus oligospilus*, at different temperatures, and an estimation of voltinism throughout New Zealand. New Zealand Journal of Zoology vol.27: 197-200.

Clark, H; Mitchell, N.D; Newton, P.C.D; Campbell, B.D. 2001: The Sensitivity of New Zealand's Managed Pastures to Climate Change *in* Warrick, R.A; Kenny, J.G; Harman, J.J (*Eds*) 2001: The Effects of Climate Change and Variation in New Zealand, an Assessment Using the CLIMPACTS System. http://www.waikato.ac.nz/igci/climpacts/Linked%20documents/CLIMAPCTS_Assessment_Report.pdf

Cowan, P. 1999: Vertebrate pests: impacts and future management. Manaaki Whenua Conference Proceedings 1999. Landcare Research, Palmerston North.

IPCC Third Assessment Report 2001: www.ipcc.ch/pub/un/syreng/spm.pdf

Hall, A.J; Kenny, G.J; Austin P.T; McPherson, H.G. 2001: Changes in Kiwifruit Phenology with Climate *in* Warrick, R.A; Kenny, J.G; Harman, J.J (*Eds*) 2001: The Effects of Climate Change and Variation in New Zealand, an Assessment Using the CLIMPACTS System. http://www.waikato.ac.nz/igci/climpacts/Linked%20documents/CLIMAPCTS_Assessment_Report.pdf

Isebrands, J.G; Karnosky, David, F. 2001: Environmental benefits of poplar culture. In Dickman, D.I. et *al., (Eds)* Poplar culture in North America. Ontario, Canada: NRC Research Press: 207-218.

Johnson, P; Rogers, G. 2003: Ephemeral wetlands and their turfs in New Zealand. Department of Conservation, Wellington.

Kenny, G. 2001: Climate Change: Likely Impacts on New Zealand Agriculture. Ministry for the Environment, Wellington. www.climatechange.govt.nz/resources/reports/impacts-agriculture-sep01.pdf

Kenny, G; Fisher, M; Robertson, F. 2003: The view from the ground, A farmer perspective on climate change and adaptation. Earthwise Consulting Limited and the Hawke's Bay Climate Change Adaptation Group.

Lee, W. 1999: Plant pests: aliens in paradise. Manaaki Whenua Conference Proceedings, 1999. Landcare Research, Dunedin.

Lovelock, J. 1991:Gaia – The practical science of planetary medicine. Gaia Books Limited, United Kingdom.

Manighetti, B. 2001: Ocean circulation: the planet's great heat engine. Water & Atmosphere online Vol. 9 No. 4. December 2001. www.niwascience.co.nz/pubs/wa/09-4/circulation

McGlone, Matt. 2001: Linkages between Climate Change and Biodiversity in New Zealand. Landcare Research and Ministry for the Environment, Wellington.

Morris, C; Amyes, N; Binnie, B: 2006: FITT Final Report 04FT156 Zearalenone testing to reduce reproductive loss. Meat & Wool New Zealand, AgResearch, Ruakura.

Mullan, B; Bowen, M; Chiswell, S. 2001: The crystal ball: model predictions of future climate. Water & Atmosphere online Vol.9 No. 4. December 2001. www.niwascience.co.nz/pubs/wa/09-4/crystal

Mullan, B; Porteous, A; Wratt, D; Hollis, M. 2005: Changes in drought risk with climate change. Ministry for the Environment (NZ Climate Change Office) and Ministry of Agriculture and Forestry, Wellington. www.climatechange.govt.nz/resources/reports/drought-risk-may05/drought-risk-climate-change-may05.pdf

Mullan, A.B; Salinger, M.J; Thompson, C.S; Porteous, A.S. 2001: The New Zealand Climate – Present and Future. National Institute of Water and Atmospheric Research *in* Warrick, R.A; Kenny, J.G; Harman, J.J (*Eds*) 2001: The Effects of Climate Change and Variation in New Zealand, an Assessment Using the CLIMPACTS System. http://www.waikato.ac.nz/igci/climpacts/Linked%20documents/CLIMAPCTS_Assessment_Report.pdf

Parshotam, A; Tate, K.R. 2001: The Impacts of Climate Change on Soils and Land Systems in New Zealand. Landcare Research *in* Warrick, R.A; Kenny, J.G; Harman, J.J (*Eds*) 2001: The Effects of Climate Change and Variation in New Zealand, an Assessment Using the CLIMPACTS System. http://www.waikato.ac.nz/igci/climpacts/Linked%20documents/CLIMAPCTS_Assessment_Report.pdf

Patrick, S.W; 2003: Wainui Beach Management Strategy. Gisborne District Council.

Peacock, L; Worner, S, 2006: Using analogous climates and global insect distribution data to identify potential sources of new invasive insect pests in New Zealand. New Zealand Journal of Zoology, 2006, Vol.33: 141-145.

Saggar, S; 2002: Can soil carbon be increased to offset methane and nitrous oxide emissions from pastoral agriculture? AgScience, Issue 6, March 2002.

Trotter, C; Tate, K; Scott, N; Townsend, J; Wilde, H; Lambie, S; Marden, M; Pinkney, T. 2005: Afforestaion/reforestation of New Zealand marginal pasture lands by indigenous shrublands: the potential for Kyoto forest sinks. Ann.For.Sci. 62 (2005): 865-871.

Warrick, R.A; Kenny, J.G; Harman, J.J (*Eds*) 2001: The Effects of Climate Change and Variation in New Zealand, an Assessment Using the CLIMPACTS System. http://www.waikato.ac.nz/igci/climpacts/Linked%20documents/CLIMAPCTS_Assessment_Report.pdf

Woodward, A; Hales, S; de Wet, N. 2001: Climate Change: Potential Effects on Human Health in New Zealand. Ministry for the Environment, Wellington. www.climatechange.govt.nz/resources/reports/effect-health-sep01.pdf

Wratt, D; Mullan, B; Salinger, J; Allan, S; Morgan, T; Kenny, G. 2004: Climate Change Effects and Impacts Assessment. Ministry for the Environment, Wellington. www.climatechange.govt.nz/resources/local-govt/guidance.html