Gathering Storm Clouds: Scientific Evidence for Global Environmental Change (Complied from notes for the first of the 2007 Massey University Winter Lecture series, May 2)

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Introduction

Hardly a day passes without some aspect of global environmental change featuring prominently in our newspapers, on radio or on TV. Since about 2005, news on global change has migrated from small items in the body of the paper to front page news. Most prominently featured almost every day now is some new information about climate change. There is good reason for this recent trend in media interest, and the underlying message is consistent and clear. It is that unless we urgently change the way we live, particularly those of us in the developed world, then our children, grandchildren, and the countless millions in the developing world will face an uncertain future of unthinkable hardships. The issue of global change is very complex, because it has to do with every aspect of life on planet earth, from the teeming microbial world of the soil to our world of 6.5 billion people. I will only touch on some aspects, but I hope what I have to say will raise your awareness to the extent that you will want to act.

Compelling evidence for global environmental change.

I'll begin by briefly covering some of the evidence for global environmental change, devoting most space to climate change as a particularly ominous indicator of gathering storm clouds. Most of what I tell you is based on solid science published in leading scientific journals and reports. Later, I'll focus on New Zealand, mainly from a global perspective, because what we do in our own lives in NZ is inextricably linked to what is happening in the rest of the world.

The largest assessment of the health of the Earths major ecosystems ever undertaken was called for by the UN Secretary General in 2000, and authorized by governments through four conventions. The result was the Ecosystem Millennium Report, published in 2005 (www.MAweb.org). The project was overseen by a partnership of UN agencies, conventions, businesses, and NGO's through a multi-stake holder board of directors. The assessment was undertaken by 1360 experts from 95 countries, and involved an 80-person independent board of review editors, with review comments from 850 experts and governments. So it is a very comprehensive and thorough assessment!

Among the high level conclusions they reported were:

- Any progress achieved in addressing the goals of poverty and hunger eradication, improved health, and environmental protection is unlikely to be sustained if most of the ecosystem services on which humanity relies (60%) continue to be degraded
- Ongoing degradation of 15 out the 24 ecosystems examined is increasing the likelihood of potentially abrupt changes that will seriously affect human well being (e.g., new diseases, abrupt changes in water quality, shifts in regional climate)

Among the detailed findings reported were the following:

- Since 1950, human-induced changes in ecosystems to meet food, freshwater, timber, fibre and fuel needs have been greater than at any time in history.
- Human well being and economic growth has been at the expense of worsening ecosystem health, and poverty (of some groups, mainly in the developing world)
- Degradation will worsen over the next 50y
- Reversing the trend will only occur with changes in current policy, institutions and practices; this is not yet evident.

A very recent example of how environmental degradation in one region can have large effects in another is a paper published a few months ago. Zhang et al 2007 (Proceedings of the National Academy of Sciences) have shown that Asia's air pollution, billowing millions of tonnes of soot, smog and wood smoke is disturbing the climate across the Pacific, making the weather cloudier and stormier, disrupting winter weather patterns along the west coast of North America and even into the Arctic! .

The findings of the Ecosystem Millennium Report 2005 are a wake up call to every nation on the planet. Ecosystem degradation can rarely be reversed without actions that address one or more indirect drivers of change. These include: population change (including growth and migration); change in economic activity (including economic growth, disparities in wealth, and trade patterns); socio-political factors (e.g., including factors ranging from presence of conflict to public participation in decision making); cultural factors and technological change.

The warning signs for widespread environmental degradation are not new. One example that illustrates this is the declining state of the world's commercial fish stocks. One recent report on the continued decline in global commercial fish stocks has suggested complete collapse could occur by 2050! In Europe, for example, fishing pressure in the North Sea over many years has resulted in a progressive decline in fish landed in the UK from about 900 000 tonnes in 1990 to 60 000 tonnes in 2000. The cod fishery in the North Sea has collapsed (as it did in Labrador in 1992), and despite drastic reduction in fishing there is no sign of a recovery. In a paper published four years ago (Myers and Worm, 2003), the authors concluded that 90% of the big fish–tuna, cod, swordfish-are gone. The authors' conclusions were based on a detailed analysis of fishing records from around the world. Biologists generally differ on the extent of this depletion, but all agree that there are too many boats chasing too few fish. This is set against a background of the very efficient killing power of fishing technology, a shadowy network of international companies making huge profits, negligent fisheries management and enforcement (NZ is considered as one of very few doing a good job in this regard), and consumer indifference to the fate of fish they choose to buy. It is also interesting that in the North Sea, despite removal of fishing pressure from cod in the past few years, there is no clear evidence for recovery of stocks. One reason suggested for this is that warming surface waters caused by climate change appear to be killing the plankton on which the cod feed (See Special Report on this topic in National Geographic, April 2007).

Climate Change-a very ominous warning

By far the most ominous warning that we are not managing the planet sustainably is climate change. Recent scientific evidence sends a stark message that dark clouds most certainly lie ahead, and that time for us to act to avert a global catastrophe later this century is rapidly running out.

In February 2007, the Intergovernmental Panel on Climate Change released the first of a series of Fourth Assessment summary reports for policy makers on climate change (http://www.ipcc.ch). These reports are made about every 5 years, and represent the collective wisdom of several thousand scientists (authors and expert reviewers) from around the world.

The first dealt with the scientific evidence for climate change (Working Group I), and was released in Paris on 27 February. Others followed in March (Working Group II: Climate Impacts, Adaptation and Vulnerability), and on May 2 (Working Group III: Mitigation of Climate Change). The Working Group I report on the science doesn't contain much new information over the information presented in the Third Assessment 5 years ago. However, in the most recent report, conclusions are stated with even greater certainty. For example, there is now a 90% certainty that human activities are the primary cause.

Some of the key findings are:

- Warming of the climate system is unequivocal (air and ocean mean temperatures, snow and ice melting, sea level rise)
- Long term changes at all scales are occurring (weather extremes e.g., hurricane intensity, heat waves, droughts), increasing ocean acidity
- Palaeoclimate data show warming of the past 50 years is unusual, when compared to the past 1300 years
- Most of the warming is very likely due to the observed increases in atmospheric greenhouse gas concentrations
- Anthropogenic warming and sea level rise would continue for centuries even if greenhouse gas concentrations were to be stabilised

This report is characteristically conservative in what it has to say, being based on the work of several thousand scientists (authors, reviewers) from around the world, and with input on the final wording from officials, including those from major oil producing countries.

Some of the very recent evidence on feedbacks including (e.g., rapidly increasing ebullition of methane from the tundra in Siberia and Canada, and the escalating changes in ice sheet flows that appear to be accelerating sea level rise (New Scientist 10 March 2007) are not included.

The more recent IPCC Summary Reports released on Climate Impacts, Adaptation and Vulnerability (March 2007) and WGIII (May2007) clearly indicate not only the extent and quickening rates of change, but also that we still have time to avert a global catastrophe if we are willing to act now using existing technologies, and new ones as these become available.

The Greenhouse Effect

In order to understand the urgency for action and what needs to be done, it is first necessary to understand how the greenhouse effect works. Firstly, it has to be said that without it life on earth as we know it would not exist. Our planet would be about 33 degrees cooler than it is today. This results from the warming of the atmosphere by a group of minor gaseous constituents collectively known as greenhouse gases. This occurs when these gases (including carbon dioxide, methane, nitrous oxide, water vapour) absorb solar energy radiated back through the atmosphere from the land and oceans of the world. Secondly, the greenhouse effect largely occurs in the troposphere, the thin *ca*. 12 km atmospheric layer in which all life on earth exists and where our weather is made. This helps to explain why global warming is occurring. The troposphere clearly has a limited capacity for accommodating the increasing additions of these greenhouse gases. Since the 18 th century, increasing emissions from widespread agricultural and industrial activities and land use changes (especially deforestation) began to modify the Earths "natural" greenhouse effect producing what we now call the "enhanced greenhouse effect".

The ice core record and what it tells us about our current problem

The magnitude of the current "enhanced greenhouse effect" can be most clearly seen by examining ice cores that record changes in temperature and greenhouse gas concentrations that have occurred over the past 650 000 years or so. This has been made possible by the careful recovery of ice cores from e.g., Antarctica, and then extracting the tiny air bubbles that were trapped in the snow that fell to form the ice over past millennia. What the analyses of this ancient air show is that the world's climate has varied fairly regularly in the past, following a cyclical pattern of interglacial (warm periods) and glacial (ice ages) periods. These are caused by complex interactions between a number of natural processes, including changes in the earths orbit around the sun, solar output, atmospheric chemistry and reflectivity. The ice core data also show a close synchrony between temperature and the atmospheric concentrations of carbon dioxide and methane. Some debate still continues about cause and effect, but two major conclusions can be drawn from these data. Firstly, over the past million years, global mean temperature fluctuations between glacial and interglacial periods have never exceeded about 6-6.5 ˚C. Secondly, atmospheric concentrations of carbon dioxide and methane in the past have not exceeded 280 ppmv and 700 ppbv respectively. Current atmospheric concentrations are, for carbon dioxide 386 ppmv, and for methane 1775 ppbv. Carbon dioxide continues to increase about 2 ppmv per year, while rates for methane have slowed in the past few years, probably due in part to better management of natural gas leaks So, since about 1700 AD, these gas concentrations have increased by 38% and 250% respectively. Over the same time global mean temperatures have risen about 1˚C, most of this in the 20 th century, and temperatures continue to increase. That in a nuthell is the nature of the problem we now face.

The well known record of atmospheric carbon dioxide concentrations since 1950, initiated by the visionary US scientist Charles D. Kealing, clearly shows that current rates of increase in carbon dioxide are outstripping the capacity of natural processes in the ocean (air-atmosphere gas exchange and photosynthesis) and on land (photosynthesis and soil respiration) to absorb them. The IPCC WG III report on Mitigation of climate

change outlines several scenarios for emissions reduction. For example, if we decide to aim for stabilisation of atmospheric CO_2 at about 500 ppmv, then CO_2 will need to peak about 2020, and we can expect global mean temperatures to stabilize at 2.8˚C by 2100. To achieve this, 60% cuts in emissions from 2000 levels by 2050 will be needed, and projected impacts include 30% of species on earth will be at risk of extinction.

The enhanced greenhouse effect-a human problem (and an Inconvenient Truth)

Why do most of the world's scientists believe that we humans are the major cause of global warming? As already outlined, the recently released IPCC Summary report of Working Group I has stated that there is now a 90% certainty that human activities are the cause of the enhanced greenhouse effect. World leaders with one or two notable exceptions are sufficiently convinced that they are beginning to introduce national policies to substantially reduce their emissions. In May, Norway's Prime Minister announced that Norway has set targets for 30% emissions reduction by 2020, and carbon neutrality by 2050 Our government has also set a goal of becoming carbon neutral but as yet no time frame has been mentioned. The Blair government has set its target of 60% emissions reduction by 2050; the urgency for doing this was strongly influenced by the release of Sir Nicholas Stern's report in 2006 that clearly spelled out the economic implications of not acting swiftly to curb emissions.

A useful way of illustrating that the recent warming trends seen around the world are due to human causes, is to examine predictions over the past century from the best global models that capture all the complex processes and feedbacks controlling the global climate. If the greenhouse gases released solely by human activities are excluded from model predictions, then the fit between actual and predicted temperature trends is good up until about 1930, but then the model increasingly under-predicts actual temperature changes. When greenhouse gas emissions from human activities are included, the fit between the model predictions and actual temperature trends is excellent.

Why should we be concerned?

The second of the three IPCC Summary Reports, on Climate Impacts, Adaptation and Vulnerability, indicates why we need to be concerned. Among the high level conclusions were the following:

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- Observational evidence from all continents and most oceans show that many natural ecosystems are being affected by regional climate changes, particularly temperature increases. These include: changes in Arctic and Antarctic ecosystems (e.g., about 300 000 km^2 less ice in the Arctic circle than in the 1980's), enlargement and increases in glacial lakes, increased runoff from many glacier- and snow-fed rivers, earlier timing of many spring events, shifts in ranges of algal, plankton and fish abundance in high-latitude oceans, increases in ocean acidity (due to higher carbonic acid concentrations from increasing atmospheric CO_2 concentrations; this change indicates major problems for corals and marine crustaceans that rely on using calcium carbonate for their shells).
- A global assessment of data since 1970 shows that anthropogenic atmospheric warming has had a discernible influence on many physical and biological systems.

Other effects of regional climate changes on natural and human environments are emerging, although many are difficult to discern from adaptation and non-climatic drivers. These include: effects on high-latitude agriculture and forestry management, including forest fires and pests, aspects of human health such as heat-related mortality in Europe, infectious disease vectors in some areas, increased flooding and droughts in others. One specific, but little known, example is that changes in regional climate caused by rapid ocean warming of the Indian Ocean appear to be the most likely cause of shifts in monsoon rains, and subsequent crop failures and famine in the Darfur region of the Sudan. This work is described in three papers published in 2003 (Zeng, 2003. Science 302, 999-1000; Prospero and Lamb, 2003; Science 302, 1024-1027; Gianni et al., 2003, Science 302, 1027-1030). One major consequence of these regional environmental effects has been the genocide currently occurring in this region of the Sudan.

A recent study published this year suggested that about 680 million people around the world could be displaced by rising sea levels and increased storm surges later this century, resulting from accelerating sea level rise as ice cap melting accelerates.

One of the most disturbing aspects of the changes now being observed is that they are occurring far sooner than earlier projections had suggested, and many of the changes are accelerating. For example, melting of ice from the Greenland ice shelf is now twice as fast as just five years ago. The top predator in the Arctic is the polar bear, and early melting of the sea ice they depend on to catch seals in spring has meant increased drownings and scavenging in some of the northern coastal communities. In Barrow, the northernmost town in North America, buildings are collapsing as the permafrost retreats; and there are now problems with the stability of the Alaskan oil pipeline! Current projections of melting rates suggest the fabled NW passage could be open to year-round shipping by about 2070, possibly changing the global geopolitical balance as a result. The more rapid melting of the Arctic ice sheet may also be behind discernible changes to the salinity of the water in the Gulf Stream, the river of warm water that flows across the Atlantic from the East coast of North America to help maintain the temperate climate enjoyed over much of Western Europe. Intensive studies are now in progress to better quantify these changes, which in the long term could potentially shut down the Gulf Stream altogether, although probably not in this century. This has happened in the prehistoric past, and in future could plunge Europe into a cold period over a couple of decades, with London then possibly experiencing a climate similar to that of Oslo. Melting of the ice is also accelerating in Antarctica, but the effects are less obvious than in the Arctic because the ice mass is so much bigger than in the Arctic.

Hurricanes are now about 100% more intense than they were in the 1970's, although their frequency has not changed. Based on strong scientific evidence (e.g., Webster and Curry, 2006) this is believed to be due to warmer sea temperatures to greater depth, providing an increased reservoir of energy to feed these monster storms. Hurricane Katrina was over 700 kms wide as it raced towards New Orleans in 2005. Warming of the oceans is well documented, including down to 3000 m depth, and this trend is affecting regional and local climates around the world by (a) changing the patterns of El Ninos (Tremberth, 1999 in Consequences 5); (b) increasing the acidity (Caldeira and Wickett, 2003 (Nature 425), and (c) triggering a host of negative effects on marine life (diseases, coral damage,

collapse of ecosystems e.g., plankton killed, driving fish away. e.g., Harvell *et al*. Science Sept 22, 1999).
In a recent paper in Nature the first accurate measurements of methane bubbling (ebullition) from Siberian thaw lakes was shown to be at least 5 times higher than previously estimated, and was rapidly increasing with expansion of the lakes (now occurring even in winter!). Finally, documented cases of extinctions as a direct result of global warming are increasing. These examples are all from well documented scientific data that collectively indicate global warming is occurring far faster than expected.

Geopolitical awakening to the threat of global warming
The year 2005 marked a shift in geopolitical awareness about the growing threat from global warming.
It began with ratification of the Kyoto Protocol by 161 countries, and is a dress rehearsal for much more stringent emissions' reduction being needed in the next decade or so. Then, in February a major conference in the UK identified a so called tipping point (2 ˚C above current global mean temperature) that, if crossed, could lead to a runaway greenhouse effect. This seems to have been influential in motivating Tony Blair to put climate change at the top of the agenda for the G8 meeting in July that year. Another factor was the estimated death in Europe of about 30 000 people from heat stress in the hot summer of 2004. The bombing in London in the week of the G8 achieved what George Bush failed to do, and that was to submerge this issue under the frenzied coverage of the bombing and the aftermath. Also, in July, our government announced that, contrary to widespread expectation, we were unlikely to meet our target for emissions reduction under the Kyoto Protocol. This was attributed to a combination of factors, including larger than expected transport emissions since 1990, a marked slowdown in planting rates for exotic forests, and an error in calculating the extent of our Kyoto forests. Also in July, the so called AP6 was formed. This is a consortium comprising the US, Australia, Korea, India China and Japan, formed to develop an alternative to Kyoto for reducing greenhouse gas emissions that included the major developing countries. Prominent among their proposals was a strong growth in the use of nuclear power in Asia. Then, in November, the IPCC COP 11 meeting in Montreal, where delegates from most countries admitted that their countries would find it hard to meet their targets, and acceptance that much bigger emissions reductions would be needed (e.g., 30% by 2018 and 70% by 2050). Finally, in late November, our (then) new government commissioned a report from several Ministries (including Treasury) on current New Zealand climate change policies. As well as these developments in 2005, a number of other events collectively raised the profile of climate change in the media, and therefore in the consciousness of people round the world. These included more extreme weather events that may not, by themselves, be directly attributed to global warming, but collectively they are consistent with earlier IPCC predictions. Among these weather events were: e.g., , more heat-waves in Europe, hurricanes in the US and Asia, floods in the Manawatu, landslides in Hutt Valley, Wellington, Christchurch, most severe drought in Australia in 100 years, not to mention the heaviest snow falls for decades in South Island at the start of the 2006 winter.

And then "An Inconvenient Truth" was released, which resulted in Al Gore's film gaining two Oscars, and the Stern Report in 2006, which have helped place global warming firmly at the top of the world's political agenda!

Economic implications of global change

The IPCC several years ago released an analysis of changes in the frequency and inflation- adjusted economic costs of extreme weather events since 1950. Costs (decadel averages) increased from US$4b in 1950 to over US$40b by 2000 Last year, Sir Nicholas Stern presented his report on the economic options we have to weigh up when considering our responses to global warming, and the likely consequences of inaction. This is really a very optimistic report, because it clearly spells out that, using existing technologies, we have a good chance of averting a global recession on an unprecedented scale later this century, but only if we act now. If we delay action until later this century, then the costs increase to the proportions of the Great Depression combined with the two world wars of the 20th century!

Environmental change in New Zealand

A consideration of environmental change in New Zealand needs to be seen in the context of our relationships with the rest of the world. The two are inextricably linked, principally through trade and tourism.

In 2004, the office of the Parliamentary Commissioner for the Environment published a report focussing on the impacts on our environment of intensification of agriculture, principally dairying. It was entitled "Growing for Good", and focused particularly on water quality. The report concluded that water quality was declining in farming areas that, if left unchecked, will mean most New Zealanders will lose access to clean fresh water.

Two aspects deserve mention here, namely the impact of increased nitrogen (N) use on water quality, and erosion. Together they illustrate why urgent action is needed to protect our waning global image as a relatively "clean and green" country.

Globally, it is well known that forests are "damaged" and ecosystems have reduced biodiversity from increased reactive N in atmosphere. The extent of this problem globally can be illustrated by the fact that each year, an area the size of Waikato in the Gulf of Mexico dies from land-derived reactive N.

Since 1998, the annual use of fertiliser N in New Zealand has increased from about 30 000 t to 400 000 t. A major current issue in New Zealand involving reactive N is the deteriorating water quality of Lake Taupo. Other New Zealand lakes, including those in Rotorua and the South Island (e.g., Lake Hays), and many of our rivers and streams, are showing clear evidence of deteriorating water quality. In the summer of 2006, the Manawatu River was plagued by green slime, and recently Lake Hays was afflicted with a toxic algal bloom, endangering fish populations, not to mention tourism!

Lake Taupo is our largest lake, and 85 % of the land in its catchment is owned by Ngati Tuwharetoa. Consequently, it has important cultural value as well as being an iconic tourist destination. The potential annual economic cost in reduced tourism alone from the impact of declining water quality due to N leakage from farms is estimated to be $97M. Animal urine has been identified as a major source of this N. Government announced in March that the RMA was to be used as regulatory tool to control farming practice. The

problem of nitrogen reaching Lake Taupo could have been anticipated from research conducted over the past few decades in Europe and North America. Early research indicated that N can build up in soil (50-100 kg N/ha/y) with intensification of land use (e.g., after conversion of land from native forests to pastoral use), and then leak out over many years, a process aided in the case of Lake Taupo by the freely-draining pumice soils that characterise the catchment.

The second issue is soil erosion, which continues to be a chronic problem in New Zealand. Over the past century we have failed to properly grapple with the need to match land use to the limitations of terrain, geology, soil type, and climate.

The global context of this chronic problem is very easy to demonstrate. New Zealand represents just 0.01% of the global land area, but contributes about 1% of the total terrestrial sediment reaching the oceans each year.

Research we have conducted over many years has shown how sedimentation rates in lakes has increased from a 1–2 mms prior to the arrival of the first humans about 1000 years ago, to about 4 mm during Maori occupation, and then to 12 mm per year since European arrival. In a paper we published in 2006 (Scott et al 2006), soil erosion is clearly shown to represent a massive loss of the life-sustaining capacity of our soils, as well as having serious impacts on both land and water. About 4 Mt C is lost to the ocean around New Zealand each year, which is equivalent to about two thirds of the C sequestered each year by photosynthesis in our Kyoto forests during the 1990's.

An added threat to tourism has recently been highlighted by Air NZ Chief Executive Rob Fyfe, who has said 'Rising environmental awareness overseas poses a real threat to New Zealand's tourist industry and economy" Some environmentalists have labelled airlines as "the new tobacco companies" because of the industry's high fuel use (even though this contributes just 1.6% to all carbon emissions". Rarely mentioned in this debate is the fact that airline emissions are delivered to the bottom of the stratosphere, where long lived species including oxides of N can persist for a very long time.

New Zealand's response to climate change

New Zealand has a markedly different greenhouse gas profile to that of the rest of the world. The main reason is that agriculture contributes a disproportionately greater amount to our total emissions. Currently, methane contributes about 37% to our total emissions, nitrous oxide 17% and carbon dioxide comprises most of the balance

Under the Kyoto Protocol, we are required to reduce a group of 6 greenhouse gases, including these three and three synthetic compounds based on chloroflurocarbons. New Zealand has contracted to reduce this "basket" of gases to 1990 levels by the commitment period 2008–2012. Currently, we are expecting to fall short by about 44 Mt CO_{2e} (CO_{2e} means that the global warming potential of all these gases is adjusted to a carbon dioxide basis), and will need to buy C credits on a rising international market to achieve this. Our transport emissions have risen over 60% since 1990, and when this is combined with the sharp fall off in exotic forest planting rates (active deforestation is now occurring!), and continued intensification of agriculture, we can understand why we face a shortfall.

Achievement of our emissions' reduction target was predicated on the success of a combination of measures, including the National Energy Efficiency and Conservation Strategy (NGA, projects e.g., wind farms), the NZ Waste Strategy (this is on target), **and** continued planting of new Kyoto forests-these are forests planted since 1990-from which

substantial C credits were expected The government of the day had claimed these C credits, and also took responsibility for liabilities if these forests were removed prior to the commitment period 2008–2012. The misleading spectre of deforestation liabilities under Kyoto has recently hastened the rates of deforestation (in the mistaken belief by the forestry sector that forests removed after December 2007 will attract a $1300/ha penalty; this is only one option floated by MAF in their recent discussion document, March 31 2007. According to Rod Oram (Sunday Star Times, April 1, 2007) the forest owners have two choices: (a), continue to try to grab the Kyoto credits for themselves (ca. NZ$1b), as we all wrestle with the impacts of climate change and attempt to achieve a higher value economy, or (b), return to negotiations (after two walkouts) with the government to secure a future for themselves and the wider economy

Our research has identified an additional reservoir of Kyoto forest carbon, namely, reverting shrubland on marginal pastoral land. This regenerating native forest forms the basis of the Permanent Forest Sinks (PFS) policy, which is now being implemented, mainly to reduce erosion of hill country. In this policy initiative, landowners can retain the carbon credits and trade these on an emerging carbon market, provided they agree to leave the forest for at least 30 years. These permanent forests have other benefits including increased water quality, biodiversity, etc.

The PFS policy has been launched after the devastating storms in the Manawatu-Wanganui region in 2004 and 2005 that caused large-scale erosion and damage to ca. 100 000 ha of hill country.

The carboNZero initiative of Landcare Research also grew out of this research, and now is a high profile brand for e.g., Grove Mill winery, Toyota, MacPac, with many food producers now lining up to join as the "Food Miles" threat looms. Businesses and individuals can have their emissions assessed, and then purchase C credits from registered landowners who undertake to offset their emissions by encouraging the planting of native trees. This initiative is a prelude to a possible cap-in-trade scheme currently under discussion by Government.

Dairying is the main land use being developed on land being deforested. This will result in greatly increased greenhouse gas emissions, because a valuable carbon reservoir (Kyoto forest) is being replaced with a major source of agricultural methane and nitrous oxide emissions. Both these gases are much more potent greenhouse gases than carbon dioxide.

Research is continuing to try to find ways to reduce our emissions of methane and nitrous oxide from agriculture (49 % of our total emissions), but there are no magic bullets. Clearly, any technology that could effectively reduce emissions of either gas, and that would be acceptable for adoption by farmers, would be a major step towards meeting our Kyoto target. The Pastoral Greenhouse Gas Consortium was established to achieve this. It is led by AgResearch, and includes a consortium made up of agribusinesses from the pastoral industry.

Livestock accounts for 9% of our carbon dioxide emissions (more than cars), 65% of nitrous oxide and 37% of methane. Put another way, of all our greenhouse gas emissions from New Zealand, 49% are methane and nitrous oxide from livestock!

Although there are no major mitigation strategies yet available for agricultural emissions, there is an expectation that if (when) ruminant methane emissions can be reduced, there may be a corresponding increase in production. This is based on an expectation that the

hydrogen and carbon producing methane could instead be diverted into producing more protein (meat, milk, wool). If realised, this could represent an increase in production of *ca*. 6%. This has yet to be demonstrated. More progress has been made to reduce nitrous oxide emissions. One fertiliser company currently sells an N fertiliser with a nitrification inhibitor incorporated in the formulation aimed at reducing nitrous oxide emissions. Its efficacy has yet to be proven on the farm.

Threat to our food exports

New Zealand lamb can be shipped to the UK for about 25% of the energy and "emissions" costs of UK-produced lamb, according to a recent report from Lincoln University (Saunders et al., 2006). Total energy use was not considered by the UK supermarket that introduced the 'food miles" labelling, only the distance travelled to market (17 700km to Britain)! This debate is likely to continue, as another supermarket chain has joined in, and shoppers could quickly adopt country of origin as a simple criterion for buying their imported food. For this reason New Zealand has to be squeaky clean in terms of its position on the environment. Central to this is reducing our greenhouse gas emissions. The UK is apparently on track to exceed their Kyoto target for emissions reduction, and have just passed legislation to enforce emissions reduction through a 5 yearly audit, with the aim of 60% reduction by 2050! In New Zealand, by contrast, we are likely to overshoot our Kyoto target by at least 44M t carbon dioxide, with increasing agricultural production estimated to exceed 1990 baseline by 38 M t carbon dioxide equivalent by 2012!

In her Statement to Parliament in February 2007, Helen Clarke said "More than any other developed nation. New Zealand needs to go the extra mile to lower greenhouse gas emissions and increase sustainability ….we face increasing pressure on our trade and tourism…..

In the recently released once-in-a decade report on our environmental performance, the OECD noted that our economy had grown by 30% since their last report; passenger car traffic had increased by 28%, agricultural production by 23% and industrial production by 13%. But they also concluded that our municipal waste generation is likely to have grown at the same rate as our GDP, and our carbon dioxide emissions have certainly grown by 24%. They concluded that "There is increasing public concern that New Zealand's clean and green image is waning: nevertheless, surveys show that this concern is not matched by a willingness to take personal action or accept the costs of measures to improve the environment"

The Government recently announced that New Zealand would move to a position of Carbon Neutrality, but no timeframe or milestones for monitoring achievement have yet been given. This cannot happen in New Zealand without Government taking a firm lead; this will have to involve all political parties in a non partisan effort **and** willingness by each of us to make changes where possible in our lives. This is becoming an imperative not only for the reasons I have outlined, but also for reasons of intergenerational equity, and to ease the disproportionately large burden that global change is having on the developing world-and **time is running out!**

Conclusions

There are a number of ways that we can adopt cleaner, healthier and ultimately cheaper alternatives to dependence on fossil-fuels. What will it take to make these things happen? Firstly, we need to have a very clear understanding of the costs (economic, social) of inaction. Secondly, at individual, institutional, corporate and government levels we need to appreciate the enormous opportunities that are available if we act now. These opportunities encompass economic (e.g., lower energy bills), social (e.g., lower future health risks) and environmental. Thirdly, we need a large ambition and resolve to create the right environment for the necessary changes to happen. This is where local, regional and national governments can provide leadership to facilitate change.

Here are some things we can do now without much effort to reduce energy consumption, while at the same time bringing other benefits, including the household budget, and (often) improved health.

In the home

- Ensure your home is well insulated, particularly in the ceiling space and below the floor.
- Remove un-flued gas heaters that produce large amounts of water in winter.
- If you have pre-teenage children, consider installing solar water heating. .As the kids hit the teenage years, and discover the shower, power bills can soar. Solar water heating in many areas of New Zealand can save up to 40% of your annual power bills.
- Make sure your hot water cylinder is well insulated.
- At dusk close the curtains. Replace conventional incandescent bulbs with energy efficient ones wherever possible
- Eat less meat and grow at least some of your own vegetables

Out and about

- Walk, cycle and take public transport wherever possible.
- Keep your car well tuned and the tyres inflated correctly.
- Limit the number of journeys you take by car to essential trips only and, wherever possible, offer someone a lift.
- When next replacing your car, make energy efficiency your top criterion for choice. It's a sobering fact that over the past decade or so New Zealand family sizes have fallen but the engine size of our cars has on average more than doubled.
- Drive carefully, avoiding rapid acceleration or braking.
- If you are travelling overseas consider offsetting your emissions using e.g., www.carboNZero.co.nz

Waste

Each New Zealander produces over a tonne of waste each year.

The catch words here are: reduce, reuse and recycle.

- Use cloth bags for supermarket shopping rather than plastic ones.
- Compost organic waste rather than use municipal collection.

- Purchase goods wherever possible that are energy efficient, locally made, last longer and that have minimal packaging

Community initiatives

- Lobby your local representatives in regional and national government to provide responsible leadership by making decisions that facilitate emissions reduction and lessening environmental impacts. This might include e.g., shifting the emphasis from building more roads to increasing investment in public transport, future-proofing the built and peri urban environments against increases in storm intensities, flooding, and droughts.
- Encourage ethical investment, where the effects of these investments don't enhance environmental degradation or increase greenhouse gas emissions.

All these examples are within our power to implement now. While these changes will greatly help if we all contribute, other measures will also be necessary to achieve the cuts in emissions that are needed to avoid a climate catastrophe later this century. These include: planting more forests and stopping deforestation in tropical and boreal regions, accessing a much greater proportion of our total energy needs from renewable resources, and changes in current policy, institutions and practices,

The final word is paraphrased from the movie "An Inconvenient Truth".

Pray that we can all find the strength to change