# CHAPTER 4

# CLIMATE IMPACTS AND RESPONSES

## Introduction

Climate variability and trends impact on Australia's economy, environment and society. Australian research organisations are conducting many research projects to understand the magnitude of climate change (including natural variability and human induced climate change) and the physical drivers that underpin our ability to forecast and manage its impacts.

Australia's average temperature varies by up to 1 degree Celsius from year to year, and has experienced a warming trend of about 0.8°C since 1910, most of this since 1950. Averaged over Australia, maximum temperatures have risen 0.56°C since 1910 and minimum temperatures have risen 0.96°C, with the largest warming since about 1950. According to CSIRO projections released in mid-2001, which use as their reference point the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), annual average temperatures over most of the continent could be 0.4 to 2°C greater than 1990 by 2030. By 2070, average temperatures are projected to increase by 1 to 6°C. Warmer conditions will produce more extremely hot days and fewer cold days and frosts. Greatest warming is to be expected in spring and winter will warm the least.

Australia's current rainfall averaged over the whole continent is about 450mm a year, varying between 300-800mm in any year (with the variability much larger in specific regions). Averaged over Australia, annual total rainfall has increased slightly since 1910 and the intensity of heavy rainfall has also risen. According to the CSIRO projections, rainfall decreases are projected for the southwest of Western Australia and for parts of the southeast of the continent and Queensland. Most other locations have an even chance of wetter or drier conditions. Decreases are projected to be most pronounced in winter and spring. Some inland and eastern coastal areas are projected to become wetter in summer, and some inland areas to become wetter in autumn. These projections include the effect of simulated changes in El Niño and La Niña events.

## Impacts of climate change on Australia

### Natural systems

There is a complex inter-relationship between climate and environment, with changes in each impacting on the other, often interactively. The second comprehensive and independent national assessment of Australia's environment, the Australian State of the Environment Report 2001, concluded that while environmental protection has progressed significantly, there are still threats to natural systems. In 2001, the Commonwealth Government declared land clearance as a key threatening process to the environment and biodiversity, observing that the rate of land clearance has accelerated with as much land cleared in the last 50 years as in the 150 years prior to 1945. Only four other countries exceeded the estimated rate of clearance of native vegetation in Australia in 1999. Greenhouse gas emissions associated with changes in land use have been a key contributor to global warming, albeit at a lower level than fossil fuel emissions.

The wetlands of Australia are already under threat from dams, irrigation, coastal urban development, and pollution of waterways. The Murray-Darling Basin Commission has reported that the quality of wetlands has been significantly reduced in the Murray-Darling Basin, particularly between the Hume Dam and Mildura. Climate change and sea level rise would add to the vulnerability of wetlands. If sea levels rise significantly, the vast freshwater floodplains of northern Australia will be subject to significant saltwater inundation (CSIRO, 2002).

Researchers at the Cooperative Research Centre for Freshwater Ecology surveyed the health of the Murray-Darling River Basin and found the environment and biology to be degraded throughout the river system, particularly at the river mouth. This is supported by other research finding the Murray-Darling River is degraded, with vegetation, fish and macro-invertebrate populations in poor condition. A wider survey of 14,000 reaches of rivers by the National Land and Water Audit in 2002 found one third of the reaches have impaired aquatic life and substantially modified nutrient and sediment loads, and 80% of them are affected by catchment disturbance.

Macquarie University researchers reported on the current distribution of 77 species of Australian native butterflies, and the potential changes in distribution of 24 species in response to climate change. They found that even species with currently wide climatic ranges may still be vulnerable to climate change – under a very conservative climate change scenario of a temperature increase of 0.8-1.4°C by 2050, the distribution of 88% of species would decrease and 54% of species distributions would decrease by at least 20%. Under an extreme scenario (temperature increase of 2.1-3.9°C by 2050)

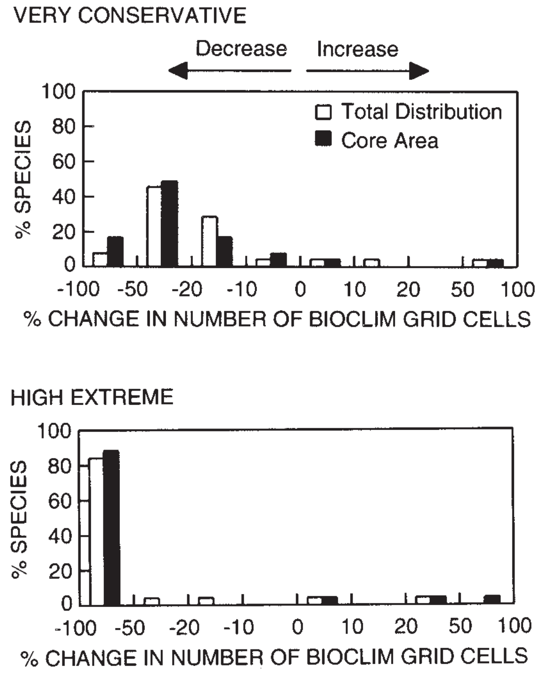


*Figure 4.1 Change in 24 butterfly species distributions in response to a very conservative (top) and extreme (bottom) climate change scenario. (From Beaumont and Hughes, Global Change Biology).*

92% of species distributions decreased, and 83% of species distributions decreased by at least 50% (Figure 4.1). Other research at Macquarie University found a moth introduced to Australia to control the Paterson's curse weed, Dialectica scalariella, showed longer development times, higher mortality and reduced adult weight when fed foliage grown under elevated carbon dioxide conditions.

## The marine environment

Evidence of a global rise in sea level over the past 100 years of between 10 and 20 cm comes from measurements around the world, corrected for land movements. The rise is primarily a result of increasing water temperatures and consequent expansion, with some contribution from melting land ice. Additional evidence of sea level rise in Australia has come to light following the discovery of 160 year old records of observations taken at Port Arthur, Tasmania. The observations, compared with data from a modern tide gauge, indicate an average sea level rise of about 1mm a year, consistent with other Australian observations and the lower end of estimates from the IPCC. The project, by researchers at the University of Tasmania and the UK's Southampton Oceanography Centre, follow the investigation of a benchmark cut into a vertical rock face at the Isle of the Dead, Port Arthur, long before any effect of global warming was apparent.

Another consequence of rising water temperatures is coral bleaching. Coral reefs around the world are becoming stressed by a number of factors: bleaching due to warmer oceans, occasional reductions in salinity due to extreme river outflows, increased cloudiness of water, chemical pollutants, local fishing practices and damage from tropical cyclones. The frequency of occurrence of mass coral bleaching (when reef-building corals lose their symbiotic algae and associated pigments) have increased globally since the late 1970s. During 1997-98 coral bleaching was reported on many of the world's coral reefs and also affected coral reefs in parts of Australia's Great Barrier Reef (GBR) and northwest shelf. Mass coral bleaching was again observed on the GBR in early 2002. Daily monitoring of water temperatures from the Australian Institute of Marine Science's (AIMS) Automatic Weather Station network during the 2001-02 summer season, combined with previously determined coral bleaching thresholds, led to early warning of conditions conducive to coral bleaching to the Great Barrier Reef Marine Park Authority. This enabled a coral bleaching strategy to be quickly implemented and this bleaching event was observed and documented in great detail. Water temperatures were again regularly monitored during the summer of 2002-2003 and regular updates of bleaching potential posted online (www.gbrmpa.gov.au/corp_site/info_services/science/bleaching/conditions_report.html). Fortunately, water temperatures did not reach coral bleaching thresholds.

Coral bleaching as severe as the event that occurred in 1998 may become common by 2020 due to projected global warming (CSIRO, 2002). The effect of higher carbon dioxide levels results in more acidic ocean waters and may lead to reduced coral growth rates. Natural adaptation will probably be too slow to avert a decline in the quality of the coral reefs. AIMS has several research activities assessing the threat to coral reefs posed by global warming. These include: determining the thermal tolerance levels of corals; determining the capacity of corals to adapt or acclimatise to new thermal regimes; determining the historical frequency of coral bleaching events; and determining whether there are spatial variations in the risk of coral bleaching along the GBR. These projects involve field and laboratory experiments of thermal thresholds, analysis of bleaching signals in massive coral skeletons, as well as application of in situ measurements of water temperature, weather conditions observed on reefs and satellite sea temperature observations.

AIMS researchers studied the relationship between patterns of coral bleaching impacts and patchiness in heat stress in GBR waters during the 2001-02 summer. A moderately strong relationship was found with impacts generally highest in the hottest areas. There were, however, some hot areas with low bleaching impacts, apparently due to lesser sensitivities among some coral community types and favourable acclimatisation regimes and local oceanography. In a collaborative study with CSIRO and US National Oceanic and Atmospheric Administration - National Environmental Satellite, Data and

Information Service (NOAA-NESDIS), AIMS investigated the implications of high and low rates of global warming and high and low rates of autonomous adaptation in coral communities projected to 2050. All combinations saw some setbacks in reef ecology compared to a future without bleaching impacts. For high climate change and no adaptation, the modelled index of coral state fell below the 1990 baseline before 2050. To maintain the index above the 1990 baseline required a low rate of climate change combined with high rates of autonomous adaptation. The latter scenario was, nevertheless, setback relative to the no bleaching scenario.

AIMS researchers are also investigating whether the Great Barrier Reef will survive global warming. A rise of 1°C, predicted to occur within 50 years, could cause mass bleaching of coral reefs when combined with seasonal fluctuations. AIMS researchers heated to various temperatures tanks containing different corals. They found some corals bleached or even died, while others coped under the same conditions. They conclude global warming will not destroy the Great Barrier Reef, but there may be a reduction in species of coral, leaving only those species with a special protein that protects them from prolonged temperature rises. However, CSIRO research has shown an increase of 2°C is likely to change the tropical near-shore marine life from coral to algal dominated communities.

## Coastal communities and infrastructure

More than 80% of Australia's population live within 50km of the coast, which is also used for recreation, industry, agriculture and mariculture. Growing coastal population adds to the exposure of the community to extreme events such as tropical cyclones, storm surges and river flooding. CSIRO (2002) reports that coastal communities and urban infrastructure will be affected by changes in sea level and extreme weather. Torrential rainfall over cities and surrounding catchments can produce severe runoff and flooding. Damage to buildings is caused by both the depth of floodwaters and by the force of the water flow. Both contribute to structural fatigue. Gales and strong winds directly damage buildings and also generate waves and storm surges that can contribute to coastal flooding. More frequent high-intensity rain in some areas could also be expected to increase the risks of landslides and erosion, particularly in the urbanised catchments on Australia's east coast.

As sea level rises, sediment from sandy shorelines is eroded from the beach and the shoreline recedes. It is generally accepted that the coastline will retreat horizontally 50 to 100 times the vertical sea level rise. Hence global sea level rise of between 9 and 88 cm as projected to occur by 2100 under the IPCC range of emission scenarios would cause a coastal recession of sandy beaches by 5.5 to 88 metres.

A decrease in tropical cyclone numbers occurred in the Australian region between 1969 and 1996, but there has been an increase in the number of intense tropical cyclones with pressures of less than 970hPa. Recent decades have also seen a reduction in the number of mid-latitude storms to the south of Australia, but the intensity of these storms has on average increased. Climate models suggest a future decrease in the number of storm centres over southern Australia but an increase in their intensity (CSIRO, 2002). By 2050, sea level may rise 0.1 to 0.4 metres and tropical cyclone intensity around Cairns in northern Queensland could increase by up to 20%. This would increase the flood level associated with a 1-in-100 year flood in Cairns from the present height of 2.3 to 2.6 metres to 2.7 to 3.0 metres. This equates to floods occurring over an area about twice that historically affected.

Sediment transport and deposition following heavy rainfall can smother extensive areas of estuarine habitat, killing trees and resulting in loss of breeding habitat essential to many coastal fish species, dugong and turtles. Any increase in extreme rainfall events and sedimentation would be likely to have major impacts on river, lake, estuarine and coastal waters and lead to reduced ecosystem health and reduced recreational and tourist use. There may be impacts on commercially important fisheries such as prawns and barramundi but the economic impacts are unclear (CSIRO, 2002).

Mangroves occur on low-energy, sedimentary shorelines and are the nursery areas for many commercially important fish, prawns and mudcrabs. They are highly vulnerable but could be adaptable to climate change, migrating shorewards in response to gradual sea level rise. However, in many locations this adaptation will now be inhibited by human infrastructure such as causeways, flood protection levees and urban and tourist developments, leading to a reduction in the area of wetland or mangrove (CSIRO, 2002).

Warmer temperatures favour pathogen survival and extreme rainfall events may increase nutrient levels. As Australian coastal waters are sometimes contaminated with untreated sewage, it is possible these combined effects may favour the production of harmful algal toxins, resulting in fish and shellfish food poisoning.

The Bureau of Transport and Regional Economics (formerly the Bureau of Transport Economics) estimates that between 1967 and 1999, 112 storms occurred in Australia, each causing damage of more than $10 million. The total cost of damage from severe local storms over this period was A$9.4 billion. The data show a statistically significant increase in the damage due to severe storms over time, but this is due largely to increased population in the storm-prone coastal regions of Queensland and New South Wales.

Estimates of the economic costs of natural disasters can be uncertain due to the difficulty of quantifying indirect costs. However, the Bureau of Transport and Regional Economics reports that the total estimated costs of all natural disasters exceeding $10 million each for the period

*Table 4.1. Average annual cost (in millions of dollars) of Australian natural disasters by State and Territory for the period 1967 to 1999, excluding death and injury costs (from Economic Costs of Natural Disasters in Australia. Bureau of Transport Economics, Canberra 2001).*

| State | Flood | Severe storms | Cyclones | Earthquakes | Bushfires | Landslide | Total |
|---|---|---|---|---|---|---|---|
| NSW | 128.4 | 195.8 | 0.5 | 141.2 | 16.8 | 1.2 | 484.1 |
| QLD | 111.7 | 37.3 | 89.8 | 0.0 | 0.4 | 0.0 | 239.2 |
| NT | 8.1 | 0.0 | 134.2 | 0.3 | 0.0 | 0.0 | 142.6 |
| VIC | 38.5 | 22.8 | 0.0 | 0.0 | 32.4 | 0.0 | 93.6 |
| WA | 2.6 | 11.1 | 41.6 | 3.0 | 4.5 | 0.0 | 62.7 |
| SA | 18.1 | 16.2 | 0.0 | 0.0 | 11.9 | 0.0 | 46.2 |
| TAS | 6.7 | 1.1 | 0.0 | 0.0 | 11.2 | 0.0 | 18.9 |
| ACT | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| Total | 314.0 | 284.4 | 266.2 | 144.5 | 77.2 | 1.2 | 1087.5 |
| Proportion (%) of total | 28.9 | 26.2 | 24.5 | 13.3 | 7.1 | 0.1 | 100 |

1967-99 was $37.8 billion (see Table 4.1). Of this, only $5 billion was not due to climate-related events. Floods were the most costly: for the past three decades, the total cost of floods has been about $10 billion. It has been estimated that more than 80% of the buildings at risk from flooding are located within Queensland and New South Wales. In Queensland, the Gold Coast City Council area has the greatest number of buildings at risk from a 100-year return period flood. Increases in population in risk-prone areas, combined with increases in storm intensities and rising sea levels, mean that the cost of flood damage to the built environment will increase. Severe storms and tropical cyclones have cost about $9 billion each over the past 30 years, while the cost of bushfires has been about $2 billion over the same period. The annual number of events shows an increasing trend in Australia as it has globally, but this is partly due to better reporting, increasing population and investment in vulnerable areas.

The Queensland Government, the Bureau of Meteorology and other agencies are undertaking a major project to look at the threat from storm tide flooding resulting from tropical cyclones, to improve the capability for real-time forecasts of storm tide heights, wave climate and flooding. They recommend allowance should be made for the estimated rise in sea level due to the enhanced greenhouse effect and a 10-20% increase in the maximum intensity of tropical cyclones.

A study of flood damage along the Hawkesbury-Nepean corridor of New South Wales has shown that, by about 2070, average annual direct damage could increase from the current value of $6.10 million to $23.2 million for the worst-case scenario. At present, the 1-in-100 year flood would cause failure of about 70 weatherboard dwellings and for the 2070 worst case scenario this rises to 1200 dwellings. These estimates do not include intangible losses such as illness and death, nor do they account for indirect losses including alternative accommodation in the residential sector or loss of trading profit in the commercial sector (CSIRO, 2002).

## Water resources

Efficient management of water will become increasingly important as we enter times of increasing water use and shrinking sources of supply. This is particularly true for Australia, whose high rainfall variability from year to year and decade to decade necessitates large dams and results in low stream flows in the south. Hence irrigation is extensive for agriculture and summer water restrictions are common in towns and cities even by the coast.

Researchers from the University of Melbourne and CSIRO have found signs that recent warming is affecting evaporation from crater lakes in western Victoria. The lakes have no streams flowing in or out, so their levels are dominated by rainfall and evaporation. In 1841 Lake Bullenmerri, Victoria's deepest natural lake, was recorded as overflowing into its twin crater. Since then, water levels of this and other lakes have continued to fall, with some now remaining only as dry lake beds. The researchers have found that rainfall is currently 80% of lake evaporation, whereas to maintain the historic lake levels rainfall would have had to have been 95% of lake evaporation. The falling lake levels could be explained by decreases in rainfall and cloud cover, and increases in temperature, but the exact combination is unknown.

Globally, pan evaporation data have shown a decrease in evaporation rates over the past 50 years. Researchers at the Australian National University and Cooperative Research Centre for Greenhouse Accounting concluded that air pollution and cloud increases are diffusing sunlight, blocking some direct sunlight reaching the ground and reducing evaporation rates, despite rising temperatures.

The Cooperative Research Centre for Catchment Hydrology (CRCCH) is investigating the lag relationship between streamflow and El Niño-Southern Oscillation (ENSO), and the serial correlation in streamflow. The streamflow-ENSO connection is strongest in late spring and summer in most parts of Australia, while the streamflow serial correlation is significant for most parts of the year, particularly in southwest and southeast Australia (Figure 4.2). The CRCCH has developed a nonparametric model for forecasting streamflow. The forecasts are expressed as exceedance probabilities so that they can be used to assess the operation of conservative low risk water resources systems. These forecasts can be used to help make decisions on water allocation for competing uses, and to provide a probabilistic indication of likely water allocation in the coming months.

Research is currently underway at the University of New South Wales to develop approaches for predicting hydro-climate variables with the potential to improve the current efficiency of water storage and distribution networks, particularly in the water-scarce regions of the world. The approach involves the use of probabilistic forecasts that allow water managers to predict both the expected input into a water storage system, and the uncertainty associated with each predicted value. The main contribution of the research is the development of an ensemble averaging approach that makes use of multiple model outputs to reduce the chance of model misspecification. The model averaging approach has been developed to make predictions on a seasonal basis, which are then disaggregated in both space and time to each site of interest. Trials of the procedure indicate that the consideration of uncertainty in climatological observations and the use of an ensemble of model outputs result in more reliable and accurate probabilistic forecasts of the Southern Oscillation Index (SOI).

## The drying trend, drought and fire

The significant rainfall deficiencies in the period since the publication of *Climate*

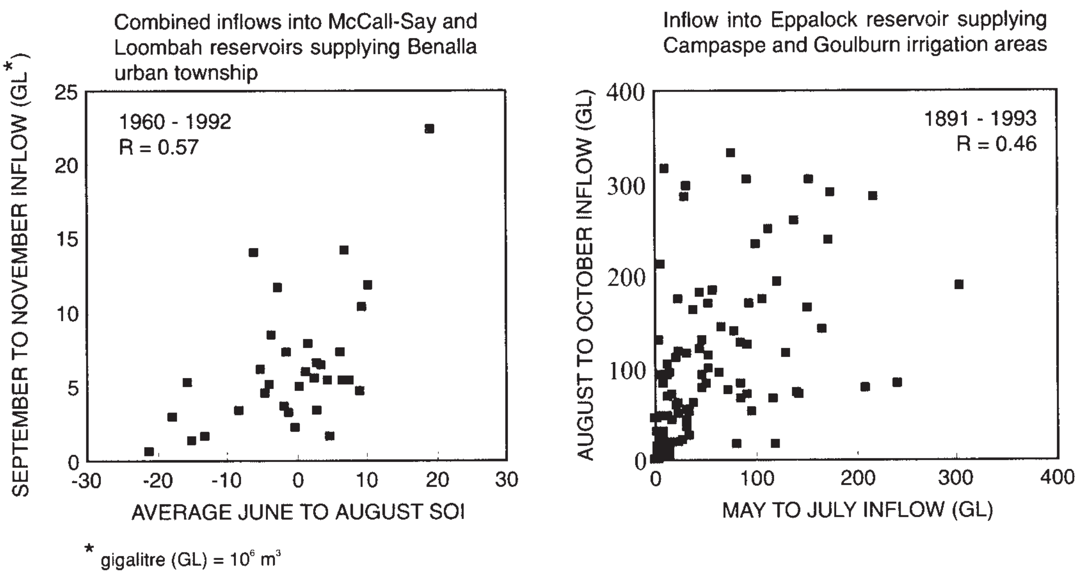


*Figure 4.2 Typical streamflow-ENSO relationship and streamflow serial correlation in southeast Australia. (From Chiew et. al. 2003, Journal of Hydrology).*

*Activities in Australia 2001* warrants separate consideration to the more general research on water resources. By November 2002, almost 62% of Australia had serious or severe 9-month rainfall deficiencies, making it the most widespread 9-month drought on record (Figure 4.3).

High temperatures were also a feature of this drought, with Australian-average maximum temperature the highest on record. On an annual basis, maximum temperature and rainfall are negatively correlated, i.e. droughts tend to have anomalously high temperatures. However, since about 1973, temperatures have tended to be higher for a given rainfall amount, i.e. droughts have become hotter, consistent with simulations of climate change due to increasing greenhouse gases. Australian researchers concluded that the drought of 2002 and the associated impacts on agriculture, water resources and fire were made more severe than past droughts due to the high temperatures and evaporation which may be partly due to human-induced global warming (Karoly et al 2003, Nicholls 2003).

Impacts of the 2002-2003 drought have been summarised by Australian Bureau of Agricultural and Resource Economics (ABARE), Bureau of Rural Sciences (BRS), Murray Darling Basin Commission (MDBC), Monash University and the Bureau of Meteorology. Key findings are:

- 62% of Australia with serious rainfall deficiency from March to December 2002 (most widespread 9-month deficiency on record);
- Australian average maximum temperature in 2002 hottest on record, especially in the Murray-Darling Basin where evaporation was also exceptionally high;
- Large dust storms over inland regions,

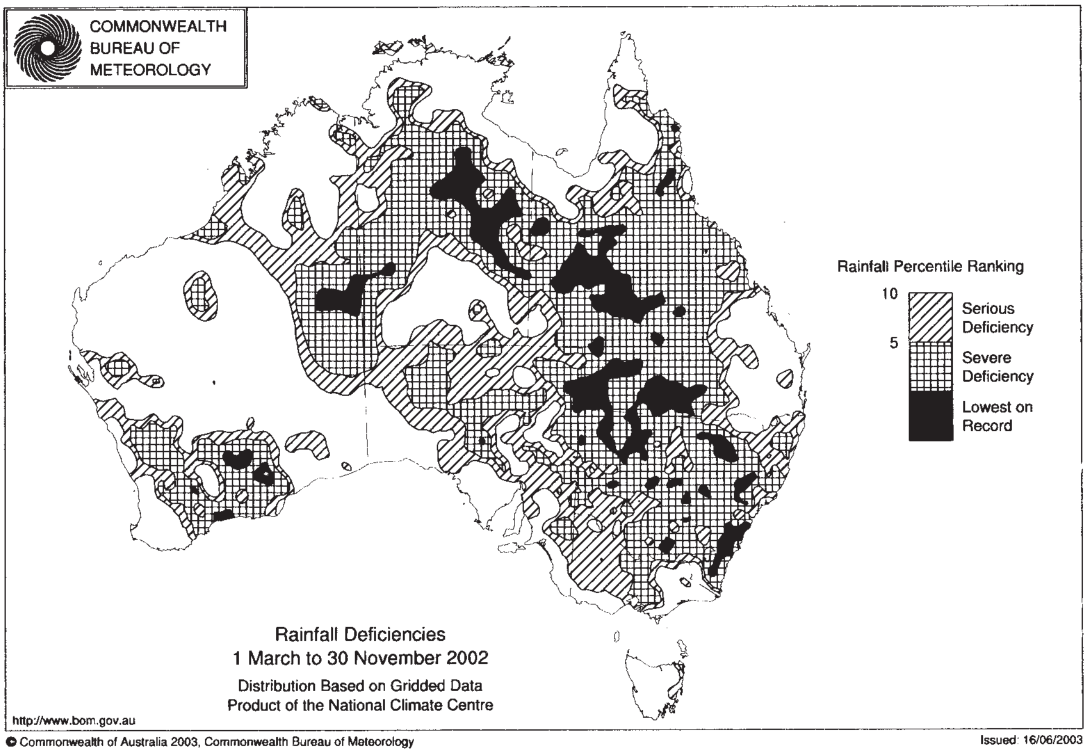


*Figure 4.3 Rainfall anomalies for April 2002 to January 2003 compared with records back to 1900.*

one measuring 1500 by 400 km reaching Sydney and Brisbane on 23 October 2002, another affecting Griffith and Sydney on 13 November 2002, and another affecting Griffith again on 29 November 2002 reducing visibility to less than 300 metres;

- 30% reduction in 2002-03 agricultural output, equivalent to 1% of GDP;
- Net effect on 2002-03 GDP expected to be a loss of 1.6%;
- Loss of 70,000 jobs likely, mainly in wholesale, retailing and repairs, transport, business services, agricultural services, and food processing and beverages;
- Government drought relief package totalling $728 million over three years for farmers and businesses affected in rural regions;
- Depleted water storages in the Murray-Darling Basin, e.g. Burrendong Dam at 18% of capacity in December 2002, Copeton Dam 23%, Burrinjuck Dam 28%, Hume Dam 14%, Dartmouth Dam 54%, Lake Eildon 20% and expected to decrease further;
- No net flow past the Barrages at the Murray River mouth for more than 15 months; and
- Water restrictions in Melbourne (first time since 1982) and Canberra (first time since 1966), reduced water allocations in many rural areas, and water carting needed in 21 NSW towns (9 having exhausted dam supplies).

CSIRO analysed the output of nine climate models driven by projected increases in greenhouse gases over the 21st century. Results suggest a tendency for increased summer-autumn rainfall, especially in the north where human water use is low, but decreased rainfall in southern and eastern Australia, especially in winter and spring, with increased potential evaporation. This would exacerbate the existing moisture deficit across most of the country (Figure 4.4). For example, in western NSW, the average water balance is -1500 to -2000 mm (net moisture deficit) and the average change by 2030 is -40 to -160 mm (greater moisture deficit). These estimates could be a reflection of possible changes in ENSO, which affects the frequency of severe weather such as hailstorms. Over the past decade, El Niño conditions have been observed to increase and climate variability is expected to continue under enhanced greenhouse conditions, possibly with more intense rainfall in La Niña years and more intense drought in El Niño years.

CSIRO researchers input the above estimated changes in rainfall and potential evaporation into a rainfall-runoff model for the Macquarie River, to find the decrease in

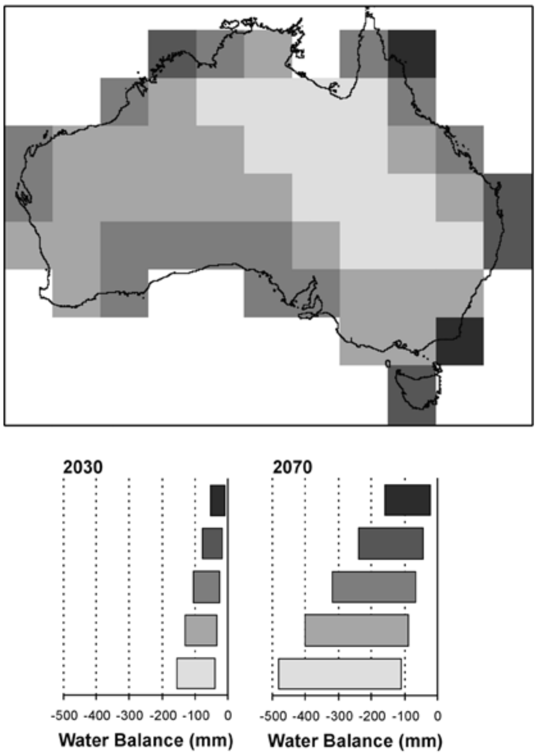


*Figure 4.4 Annual average Australian water balance (rainfall minus evaporation) for 1961-90 (a) and projected changes for 2030 and 2070 relative to 1990 (b).*

average streamflow was up to 20%. Critical thresholds, defined as missed bird breeding cycles and economic failure on farms, were exceeded in 2030 by 20-30% in a drought-dominated climate and much less than 1% in a flood-dominated climate. However, by 2070 these risks were 70-80% and 10-20%, respectively. These reduced flows were increased by afforestation, seen as a method of addressing salinity and carbon sequestration. For example, BRS researchers found an increase of 10% in tree cover led to a decrease of 17% of river flow. Flow reductions have also been found by other researchers using different methods, and in different catchments.

The Indian Ocean Climate Initiative (IOCI) is a climate research program established by the Western Australian Government in collaboration with the BMRC and CSIRO to identify the causes of the serious rainfall decreases and the consequential impact on water resources experienced in southwest Western Australia since the 1970s (Figure 4.5). The strategic research program undertaken by IOCI over the last 5 years has improved the understanding of climate variability and trends for south-western Australia. Research directed at developing inter-seasonal forecasting and better understanding climate variability on longer time-scales became progressively focussed on issues of decadal variability and longer term change because of the dominance of these issues in any analyses of the observed record.

Key findings include (IOCI 2002):

- Winter rainfall has decreased sharply and suddenly in the region since the mid 1970s;
- The decline was not gradual but more of a switching to an alternative rainfall regime;
- The rainfall decrease accompanied and was apparently associated with documented change in large scale atmospheric circulation at the time;
- The decrease in rainfall and associated circulation changes bear some resemblance to model projections for an

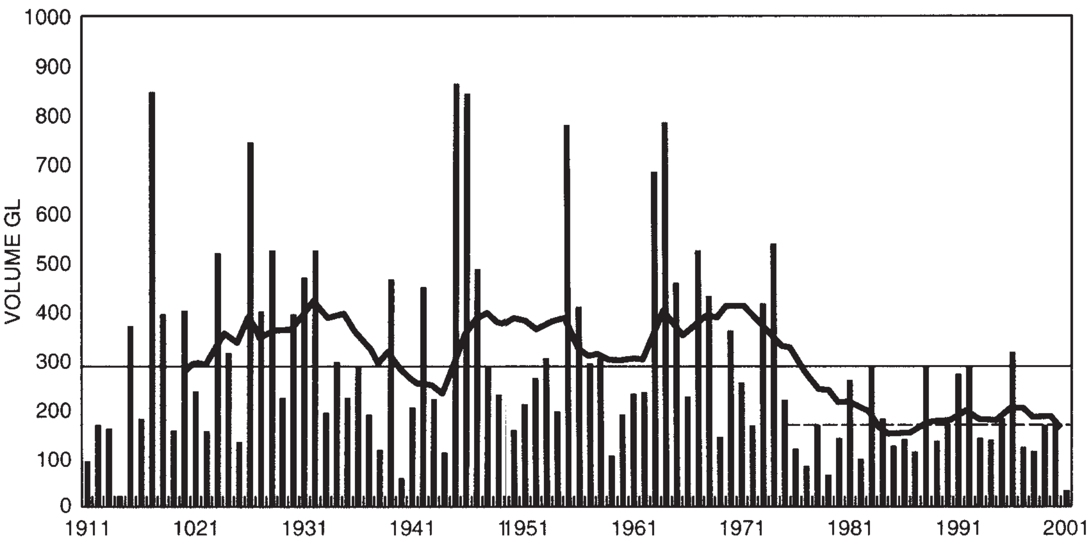


*Figure 4.5 Yearly inflow to Perth water supply (columns), showing 10-year moving average, 1911-2001 average (287GL) and 1975-2001 average (167GL). From Climate variability and seasonal change in south west Western Australia, Perth, September 2002 (www.wrc.wa.gov.au/ioci).*

enhanced greenhouse effect (EGE) but are not sufficiently similar to indicate, beyond doubt, that the EGE is responsible. Most likely both natural variability and the EGE have contributed to the rainfall decrease;

- The climatic shifts, which include warming, have resulted in an even sharper fall in regional streamflows;
- The changing climate will exhibit wetter and drier periods throughout the 21st century due to natural variability, overlaid on trends of continued warming and of probable decline in mean rainfall consequent on the EGE; and
- Decision-makers need to alter their decision base-lines to reflect observed and projected changes and also to include increased levels of uncertainty.

There is a strong link between interannual climate variability – particularly that associated with ENSO – and the intensity of the subsequent fire season. Bushfires were a major emergency in Australia over the 2002-03 summer. Fires raged in southeast Queensland in October 2002, in Western Australia in November 2002 (124,000 ha burnt), in eastern NSW in early December 2002 ($100 million damage), in northeast Victoria in mid-December (180,000 ha burnt), in ACT in mid-January 2003 (4 deaths, 520 buildings destroyed, $250 million damage) and in the Great Dividing Range in January-February 2003 (over 1 million ha burnt, $60 million firefighting costs).

In July 2003 the Cooperative Research Centre for Bushfire Research will commence operation, with seven years of funding. The research centre includes participants from Emergency Management Australia, CSIRO, the Bureau of Meteorology, State and Territory fire authorities and emergency service departments, and forestry organisations from NSW, Queensland, Tasmania, Western Australia, Victoria and New Zealand. Existing climate prediction and monitoring systems will be adapted and extended to provide advance warning of conditions likely to affect the level of fire danger.

## Agriculture and Forestry

Approximately 40% of the 70 million hectares of forest existing in Australia at the time of European settlement has been cleared, and a similar amount has been logged.

CSIRO Plant Industry researchers are applying their knowledge about the impacts of drought on availability of soil nutrients for crops. Nitrogen and phosphorous concentrations are generally high following a drought. Careful nutrient management can assist in reducing drought recovery times. Underestimating nitrogen levels can lead to growers sowing an inappropriate crop. Calculations of nitrogen need to include residual nitrogen from fertiliser applied the previous year, subsoil and topsoil nitrogen mineralisation – which can be accelerated after a drought – and nitrogen removed by the previous year's crops.

Climate change is already affecting Australian cropping systems and the way they are managed, according to scientists from the Queensland Department of Primary Industries. Continuing increases in the concentration of atmospheric carbon dioxide will affect growth patterns of crops, trees and pastures while changes in rainfall patterns will influence production. Temperature increases are already leading to changes such as the planting dates for wheat. For example, in Emerald, in Central Queensland, there are around three weeks each year of frost, compared with 10 weeks each year in 1900 (Figure 4.6). Further temperature increases will also affect rotations, limiting canola's spread north into Queensland, or supporting cotton production further south than it is grown today. Farmers in marginal regions now might need to switch from their current grain/grazing mixed operations to grazing or even plantation forestry. Management changes recommended to farmers could include changes in varieties and planting dates, changes in crop species, erosion and salinity management, pest and disease management, and greater use of seasonal forecast information.

CSIRO researchers have shown that under climate change in Australian viticultural regions – likely warming with drier conditions particularly in winter and spring – earlier ripening and possible reductions in grape quality are expected. In cooler, southern regions higher temperatures may allow for new varieties. Higher carbon dioxide concentrations may lead to more canopy growth and shading, leading to decreased fruitfulness. Water supplies for irrigation may decrease.

Researchers at Queensland Department of Natural Resources and Mines (Crimp et al 2002) used the pasture production model GRASP to explore the impact of climate change on native grasses. With a small increase in temperature and a decrease in rainfall, pasture growth was reduced by 10-50%, with larger reductions by 2070. With a small increase in temperature and an increase in rainfall, pasture growth increased. With larger increases in temperature and increases in rainfall pasture production increased by 2030 in the north, but not in the south, and results were not as positive by 2070. With large increases in temperature and decreased rainfall, average pasture growth across Australia was reduced by between 30-70% by 2030, with reductions increasing to 30-100% by 2070.

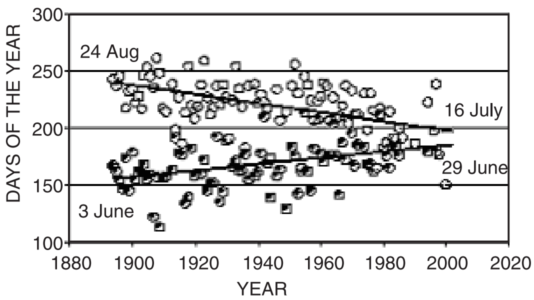


*Figure 4.6 Changes in the dates of first (black circles) and last (grey circles) frost at Emerald, Queensland, during the last century (expressed as a screen temperature of 2°C or lower). From www.grdc.com.au/whats_on/mr/north/northern_region1090.htm.*

On clear, sunny days a plant's top leaves cast strong shadows over the rest of the plant, say researchers at the Australian National University and Cooperative Research Centre for Greenhouse Accounting. Plants photosynthesise more effectively when sunlight is diffused through cloud or haze, rather than when it hits the plant canopies directly. Their research suggests that plants would respond to greater cloudiness and more pollution by growing more.

CSIRO scientists have undertaken research into the impact of increases in atmospheric concentrations of carbon dioxide and climate change (specifically increased temperature and water stress) on the Australian wheat industry. The wheat industry is particularly important as it represents Australia's major crop in terms of both value and volume. Yields and areas cropped are strongly influenced by climate. The scientists employed a statistical method to build likelihoods and ranges of future grain yields, value of production and value of exports. They found that by 2030, there is an 88% chance of production being above current levels. By 2070, there is a 64% chance that average national grain production will be higher than current levels. Markedly different regional climate changes are likely to result in large differences in regional production, particularly by the year 2070. Climate variation causes change in long-term yields by about + 10% for Queensland and +6% or lower for the other states. In cropping regions of Western Australia, there is a strong chance that productivity and value will be below current levels in both 2030 and 2070.

Pragmatic adaptation strategies such as

changing varieties and planting times can offset some of the negative impacts, especially in Western Australia, while enhancing the positive impacts. Changing wheat varieties and planting dates alone for example could save the industry between $100M and $500M each year (in current dollar terms) by maintaining productivity in the face of change. An overview of the adaptive capacity of the Australian agricultural sector to climate change (options, costs and benefits) was undertaken for the Australian Greenhouse Office. CSIRO researchers worked with industry groups to deal effectively with their key concerns, draw on their valuable expertise and also contribute to enhanced knowledge in the agricultural community. A clear conclusion from this overview was that investment in adaptation is extremely worthwhile for the agricultural sector.

## Pests and weeds

Australia's crops, horticulture and forestry are vulnerable to introduced pests that have no local biological controls. Climate change may increase the chance that such pests will become established. Researchers at the CRC for Australian Weed Management Systems have found that the moths, weevils and beetles that play a vital role in biocontrol of weeds are suffering severely in the current drought. The latest bitou biocontrol agent, the leaf rolling moth Tortrix, has not established as well as predicted in the two years since initial release. Bitou bush is a native of southern Africa. It is rated as the worst pest plant in the Australian coastal environment, restricting access to beaches and destroying native bushland. This invasive species is being affected by the dry conditions, in turn affecting the biocontrol agents that attack it. The leaves of bitou bush become tough and lose nutritional value. This makes it very difficult for the young larvae to get a niche amongst the growth tips. Ants and spiders, short of their normal food, are also devastating the control agents. In the north of the state, Agriculture NSW has been rearing and releasing agents.

Researchers at the University of Queensland and CSIRO (White et al. in press) investigated the vulnerability of the Australian beef industry to the cattle tick Boophilus microplus under climate change. Compared to current estimated losses of 6000 tonnes per year, they found potential losses in live weight gain from 7800 tonnes per year by 2030 to 21,600 tonnes per year by 2100. These figures are in the absence of adaptation measures such as changing to tick-resistant breeds or increasing tick control treatment.

## Disease and human health

Climate change can affect human health directly through, for example, heat stress or the consequence of natural disasters, and indirectly through, for example, disrupted agriculture. Several of the health impacts of climate change identified by the IPCC (McCarthy, 2001) are relevant to Australia, including an increase in vector-, food- and water-borne infectious diseases; a decrease in winter deaths but an increase in heat-related deaths and illness; and an increased risk of drowning, diarrhoeal and respiratory diseases related to any increased flooding.

Australian studies are shedding new light on the likely impact of climate change on human health. The Federal Government has funded a formal assessment of the effects of climate change on health in Australia over the coming decades, entitled *Human Health and Climate Change in Oceania: A Risk Assessment* (McMichael et al., 2002). Each year, 1100 people aged over 65 die from temperature-related causes (summed in 10 major Australian cities). The projected rise in temperature for the next 50 years is predicted to result in a total of three to five thousand additional heat-related deaths a year (in the absence of adaptive measures, including the effect of population growth and aging, and with heat-related deaths defined as deaths estimated from the overall relationship between temperature and mortality rates from any cause that are in excess of the average for that time of year). Temperate cities show higher rates of deaths due to greater temperature extremes than tropical cities. The estimated increases in heat-related deaths were predicted to be far greater than the decreases in cold-related deaths. Canberra may experience positive effects from a reduced number of cold winter days in the short-term, but in the medium- to long-term these health gains are predicted to be outnumbered by additional heat-related deaths. The Risk Assessment report also found that 1 in 10 year extreme rainfall events are expected to increase in almost all Australian states and territories by 2020, changing the number of flood-related deaths and injuries to between an increase of 240% (in the southern areas of New South Wales near the Murray River) and a decrease of 35% (in north-eastern Tasmania).

*Table 4.2 Australian populations estimated to be living in a region suitable for dengue transmission (from McMichael et al., 2003).*

| Baseline (million) | Scenario | 2020 (million) | 2050) (million) |
|---|---|---|---|
| 0.17 | Low: | | |
| | CSIRO Mark 2 | 0.30 | 0.78 |
| | ECHAM4 | 0.29 | 0.75 |
| 0.17 | Mid: | | |
| | CSIRO Mark 2 | 0.33 | 0.77 |
| | ECHAM4 | 0.34 | 1.16 |
| 0.17 | High: | | |
| | CSIRO Mark 2 | 0.51 | 1.24 |
| | ECHAM4 | 0.49 | 1.61 |

Malaria is not endemic in Australia, with eradication achieved in the 1960s (only a handful of cases having been reported since then). The likelihood of malaria being reintroduced into Australia is very low – however model results in the health risk assessment report (McMichael et al., 2003) indicate that under climate change there is a hypothetical risk of the zone where Australia's only malaria vector could exist, expanding as far south as Rockhampton, Gladstone and Bundaberg if adaptive measures are not taken. The tourism threat from an outbreak of vivax malaria in far north Queensland in 2002 and the recent high incidence of malaria among the Australian defence forces in East Timor underlines the priority that needs to be placed on prevention.

From 1991, when national reporting began, to 2002, 2595 cases of dengue had been recorded. The health risk assessment report (McMichael et al., 2003) estimated the region climatically suitable for dengue transmission, accounting for projected population change but not for the likely adaptive strategies that would reduce the risk of transmission. The model's current risk region, including Broome, Darwin and Katherine in northern Australia and some coastline between Townsville and Mackay, is acknowledged as a slight underestimation. The model's future risk regions were shown to increase in the simulations, as given in Table 4.2, although as noted above this does not account for adaptive measures.

Australian National University researchers have examined whether climate variables could be used to accurately predict epidemics of Ross River virus disease. Between 1991 and 2002 in Australia there were 51,761 notifications of the disease, which has no treatment (prevention remains the sole public health strategy). It is well recognised that weather directly affects the breeding, abundance, and survival of mosquitoes, the principal vector of many arboviruses. Using weather data from two regions in southeastern Australia, the scientists assessed Ross River virus disease data for the period 1991 to 1999. Two predictable epidemic patterns emerged, after either high summer rainfalls or high winter rainfalls. Lower than average spring rainfall in the pre-epidemic year turned out to be a prerequisite. The research findings are likely to be valuable to health authorities, as early warning of weather conditions conducive to Ross River virus disease outbreaks is possible with a high degree of accuracy in particular regions.

Researchers from Australian National University and Food Safety Australia have assessed the potential impact of climate change on food borne disease in the coming century. A link between climate and microbial food borne disease remains speculative. However, data show that Salmonella infections increase in summer, while Campylobacter infections increase in spring, similar to patterns seen overseas. In eastern Australia, rates of Salmonella notifications increase with decreasing latitude and consequently with increasing average yearly temperature. Food poisoning outbreaks may also be linked to unusually hot weather which can enhance bacterial replication. Reports of food poisoning outbreaks are higher during unusually hot summers in Australia. Assuming that a sustained temperature rise has a similar effect to monthly temperature variations, then the incidence of salmonellosis may rise in future decades, and, by extrapolation, the incidence of diseases caused by other food borne pathogens and toxins could also rise. Higher global temperatures could increase human exposure to toxins produced by cyanobacteria (blue-green algae) in water supplies and recreational water bodies, which can cause gastrointestinal and dermatological symptoms. Similarly, production of mycotoxins in agricultural produce could increase.

# Responses to climate change

## Commonwealth response

The principal focus of the Commonwealth Government's $1 billion climate change package is to reduce Australia's greenhouse gas emissions resulting from human activities. In August 2002 the Government announced its Climate Change Forward Strategy, which included a commitment to undertaking research to better understand potential impacts of climate change and develop adaptation strategies.

The Government is also pursuing bilateral partnership with other countries to address priority climate change matters, for example the Climate Action Partnership with the United States, announced in February 2002. The Partnership will work on practical approaches to deal with climate change and involves the US Environmental Protection Agency and the US Departments of Commerce, Energy and State, and the Australian counterpart agencies. They are focussing on emissions measurement and accounting, climate change science and monitoring, energy technologies, agriculture and land management, and business engagement to create economically-efficient solutions. They are also collaborating with developing countries to build capacity to deal with climate change.

The Australian Greenhouse Office (AGO) was established in 1998 as an agency to provide a whole-of-government approach to greenhouse matters, and to lead Australia's greenhouse action to achieve effective and sustainable results. The AGO is responsible for coordination of domestic climate change policy and delivery of greenhouse response programs, and functions as a central point of contact for stakeholder groups. Programs such as the National Greenhouse Gas Inventory and

National Carbon Accounting System, have a research focus. Through the Australian Greenhouse Science Program (AGSP), administered and coordinated by the AGO, the Commonwealth Government supports a broad base of greenhouse science research advancing the understanding of global and regional climate change, and its possible effects on Australia's natural and managed systems.

The AGSP supports greenhouse science research in the CSIRO, Bureau of Meteorology Research Centre, and the National Tidal Facility Australia, as well as contributions through the Australian Academy of Science to the international programs of the International Geosphere-Biosphere Programme and its Global Change and Terrestrial Ecosystems project, and the World Climate Research Programme. Research conducted through CSIRO and BMRC focuses on:

- Monitoring greenhouse gases in the atmosphere;
- Developing and evaluating climate models at the global and regional scale;
- Integrating ocean and terrestrial carbon and energy cycles into climate models; and
- Providing projections of future climate change in regions across Australia.

This work is essential to support other research on climate change impacts and responses.

With support from the AGO, the Cooperative Research Centre for Greenhouse Accounting undertakes research to:

- Increase understanding of the Australian terrestrial carbon cycle and the forces driving change;
- Predict biophysical responses to global change;
- Develop methods for accurately measuring terrestrial carbon fluxes, sources and sinks; and
- Develop innovative ways to manage the Australian carbon cycle to lower greenhouse gas emissions.

The AGO is working with other Commonwealth agencies to develop a national framework for addressing climate change impacts and development of adaptation strategies across all sectors and systems. The AGO is also coordinating a cross-jurisdictional Adaptation Working Group, formed by the High Level Group on Greenhouse (HLGG) to develop options for a potential national approach to climate change impacts and adaptation as part of the national greenhouse response. Throughout 2002, the HLGG Adaptation Working Group undertook a review of the knowledge base for climate change impacts and adaptation. The Working Group identified many key knowledge gaps and future research priorities that will need to be addressed.

A national approach will provide a framework for collaboration and partnerships in climate change impacts research and identification of adaptation options, and on sharing that information across jurisdictions and sectors.

The framework is to be developed through the implementation of a national assessment of climate change impacts, and identification and implementation of targeted adaptation strategies.

A national assessment will assess Australia's vulnerability to existing climate variability and climate change, current adaptive capacity, and lead to the development of the tools to enable integrated assessments (biophysical, social and economic dimensions of climate change) of adaptation options.

Identification of adaptation options will involve evaluating the costs and benefits of potential adaptation options, priority setting, and identification of appropriate jurisdictions and mechanisms to implement adaptation strategies.

The Commonwealth has commenced working with the States and Territories to address climate change impacts on key systems. The Natural Resource Management Ministerial Council, for example, has established a task group addressing climate change impacts on biodiversity.

More information on specific responses to climate change are included in Chapter 3, Climate Services and Applications.

## National Greenhouse Strategy

The National Greenhouse Strategy (NGS) provides the strategic framework for advancing Australia's domestic greenhouse response. Launched in 1998, it extended substantially the program of action begun by the 1992 National Greenhouse Response Strategy and includes the Prime Minister's package of measures. The NGS was developed by Commonwealth, State and Territory governments, with input from the Australian Local Government Association (ALGA), industry and the community.

The NGS articulates the framework for a coordinated and collaborative approach by all levels of government in Australia and is directed toward the achievement of three overarching goals:

- fostering knowledge and understanding of greenhouse issues;
- imiting greenhouse gas emissions; and
- laying the foundations for adaptation for climate change.

Implementation of the NGS has required considerable coordination both at the Commonwealth level and among the Commonwealth, States and Territories. At the Commonwealth level, the Ministers for the Environment and Industry jointly oversee the implementation of the NGS. The Council of Australian Governments (COAG) High Level Group on Greenhouse, comprising senior officials from the Commonwealth, States and Territories, is responsible for managing the implementation, monitoring, review and further development of the NGS.

The priority in the first five years of the NGS has been on emissions abatement. The Commonwealth Government, through the framework of the NGS and an additional package in 1999, Measures for a Better Environment, committed almost $1 billion over five years to greenhouse response. The Government is committed to meeting Australia's target agreed under the Kyoto Protocol, of limiting greenhouse gas emissions to 108% of 1990 levels over the period 2008-12. The strategy features a range of initiatives, including:

- Boosting renewable energy actions and pursuing greater energy efficiency in electricity generation and in the household and commercial/industrial sectors;
- Addressing transport systems emissions through technology development, uptake of alternative fuels, fuel efficiency and travel demand management;
- Investing significant resources into greenhouse research and monitoring Australia's progress towards its Kyoto target through the National Greenhouse Gas Inventory;
- Investigating the possibility of a domestic emissions trading scheme;
- Encouraging industry, business and the community to use less greenhouse intensive transport; and
- Providing impetus for greenhouse action through the Greenhouse Gas Abatement program.

In August 2002, the Commonwealth announced its intention to develop a climate change forward agenda that will focus upon the longer term, while working to meet its commitment to the Kyoto target of 108%. Such a forward strategy on climate change is intended to ensure that Australia can reduce its greenhouse signature, while maintaining a strong, competitive economy. The Commonwealth is currently working with all levels of government, business and the community, in the development of the strategy.

# Estimates of Greenhouse Gas Emissions

As part of commitments under the UNFCCC, Australia has produced an inventory of national greenhouse gas emissions every year since 1990. These inventories provide a baseline for monitoring and reviewing response actions and for developing projections of greenhouse gas emissions.

Periodic State and Territory inventories, in addition to the National Greenhouse Gas Inventory (NGGI), are also produced. Each inventory is essentially a database of human-induced greenhouse gas emissions sources and sinks, categorised into six sectors: energy, land use change and forestry, agriculture, industrial processes, solvent and other product use, and waste.

The National Greenhouse Gas Inventory 2000 (AGO, 2002) provides the latest report on Australia's greenhouse gas emissions. This inventory incorporates improvements in data collection methods that have been used to update emission estimates for the previous years. The NGGI aims to provide robust estimates of greenhouse gas emissions and sinks that are neither overestimates or underestimates of the true emissions. A continuous improvement program ensures that methodologies and data sources are periodically reviewed, that uncertainty is progressively reduced to acceptable levels and that the report is subject to rigorous quality control and quality assurance procedures.

The Australian Government has established the National Carbon Accounting System (NCAS) to improve inventory control in the land sector. The NCAS tracks production and removal of greenhouse gases arising from human-induced changes to the forests, plant cover and agricultural and grazing lands across Australian land systems.

The NCAS is a single highly integrated digital map-based information system. It couples remotely sensed land cover change, land management, climate and soils data, with greenhouse accounting and ecosystem modelling to provide a dynamic 30-year perspective on the nature and extent of human-induced change in Australian land systems over the period since 1970. The NCAS is progressively providing state-of-the-art methodological capability for international reporting of greenhouse sources and sinks, including accounting for all relevant pools of carbon (above and below ground), all greenhouse gases and relevant activities since 1972 associated with Land Use Change, Land Use Change and Forestry (as required under the Kyoto Protocol).

The credible and verifiable data and methods developed under NCAS now fully replace those used previously in the preparation of Australia's Land Use Change emissions estimates. With continued refinement, NCAS methodologies will also be used for calculating emissions from other land sectors, including commercial forestry (plantations and native forest management) and non-$CO_2$ sources.

The AGO, the Commonwealth Department of Agriculture, Fisheries and Forestry and a range of research organisations across Australia are working towards more accurate estimates of greenhouse gas emissions from agriculture and methods to quantify emission reduction opportunities for agricultural land uses.

Scientists at CSIRO Atmospheric Research are investigating new ways to measure the concentration of carbon dioxide in the atmosphere, particularly over the Australian continent and Southern Ocean. They have developed an instrument that is both less expensive and much more precise to operate than previous methods of measuring $CO_2$. The LOFLOTM $CO_2$ analyser can potentially operate unattended for five months and is 90% less costly to run than conventional measurement systems. This makes them ideal to fill gaps in the current observation network over land, or to detect subtle changes in $CO_2$ sources and sinks from remote locations around the Southern Ocean. The devices are around 10-times more precise in detecting the minute differences in atmospheric $CO_2$ concentrations needed to identify greenhouse gas sources and sinks. The research will lead to ways to monitor the effectiveness of international actions to limit future $CO_2$ emissions.

# Emissions Reduction Strategies

Australian research into options for mitigating climate change is proceeding on a broad front, with investigations into reducing greenhouse gas emissions as well as research into the impacts of various domestic policy options.

Australia has developed a balanced mix of policy responses to reduce emissions – targeting industry, households, governments and communities. Australia is also currently developing a climate change forward agenda to cover the next 20-30 years.

## *Greenhouse Gas Abatement Program*

The Greenhouse Gas Abatement Program (GGAP) is a major Australian Government initiative to assist Australia in meeting its Kyoto Protocol target. The objective of GGAP is to reduce Australia's net greenhouse gas emissions by supporting activities that are likely to result in substantial emission reductions or substantial sink enhancement, particularly in the first commitment period under the Kyoto Protocol (2008-12). $400 million has been allocated to the Program.

To date, approximately $165 million has been offered to successful proponents, to support projects with a total value of $836 million. These projects include a Regional Renewable Energy Project in the Douglas Shire; Efficient Calcination in Alumina Refining in Gladstone; Lignite Predrying using Mechanical Thermal Expression by Latrobe Valley generators; and CargoSprinter – a new concept in moving freight by rail in regional Victoria.

## *Renewable Energy*

The Australian Government has made a strong commitment to increase the use of clean renewable energy in Australia. The following summary presents a selection of activities aimed at encouraging the uptake of renewable energy in Australia:

- World-first legislation that requires the generation of 9,500 gigawatt hours of extra renewable electricity per year by 2010, enough power to meet the residential electricity needs of four million people. This initiative is being achieved by establishing an innovative market in renewable energy certificates and is expected to deliver in excess of $2 billion of investment in renewable energy in Australia;
- The Photovoltaic Rebate Program enables households and community buildings to generate their own electricity from sunlight. To the end of December 2002, abatement of 4,700 tonnes of greenhouse gas abatement per year will result from the installation of 3,800 photovoltaic systems, totaling 4,000kW;
- Over $200 million has been made available through the Renewable Remote Power Generation Program to replace diesel with renewable power in Aboriginal communities, pastoral properties, remote towns, tourist and other locations. By the end of December 2002, funds have been used by remote communities to install 1,042kW of photovoltaics, 75kW of wind turbines and 17kW of micro-hyrdro and associated enabling equipment reducing green-

house gas emissions by approx 7,000 tonnes per year. In addition, many major projects are under construction such as a 3.7 MW wind farm.
- Through its Renewable Energy Commercialisation Program, the Australian Government has supported 49 projects to commercialise innovative renewable energy equipment, technologies, systems and processes, with $6 million specifically dedicated to the development of the renewable energy industry.

## *Promoting Energy Efficiency*

Commonwealth, State and Territory governments are working together to regulate the energy efficiency of equipment and many appliances used by Australian households and businesses. Recent achievements in this area include:
- Introducing Minimum Energy Performance Standards (MEPS) for six equipment types (refrigerators, freezers, electric water heaters, three phase packaged air conditioners, fluorescent lighting ballasts and electric motors);
- Updating the Mandatory Energy Rating Scheme for whitegoods for six major appliances (including refrigerators, freezers, washing machines, dryers, dishwashers and air conditioners) to allow for improvements in energy efficiency technologies;
- An agreement on a "model regulation" for national implementation;
- Development of MEPS for electricity distribution transformers, fluorescent lamps and revised MEPS for small electric storage type hot water heaters to be introduced in the next few years; and
- Development of labeling schemes for home entertainment systems, computers and other appliances.

In 1999, the Australian building and construction industry signed an historic agreement with the Australian Government to see energy efficiency measures introduced to the Building Code of Australia. To date, this agreement has resulted in the introduction of new standards of energy efficiency for residential buildings to the Building Code of Australia. These amendments came into force on 1 January 2003.

A joint initiative of the Government and the building and design industries has made a major contribution to the energy efficiency of buildings with the production of the "Your Home" consumer guide and technical manual. The guide has made substantive inroads towards informing consumers and industry professionals about energy efficient homes, with more than 100,000 copies distributed since late 2001.

Major emission reductions are expected from Australia's fossil fuel electricity generation sector, with 14 companies signed up to the Government's Generator Efficiency Standards (GES) program. Efficiency standards introduced for Australian power stations under this program are expected to cut about 4 million tonnes of carbon emission each year by 2010.

## *Local Government and Communities*

Cities for Climate Protection™ (CCP™) Australia is the Australian Government's primary mechanism for encouraging greenhouse gas abatement by local government in Australia. CCP™ Australia has 171 local governments representing over 66 per cent of Australia's population committed to achieving sustainable, long-term reductions in their greenhouse gas emissions through their participation in CCP™ Australia. CCP™ is an international campaign of the International Council for Local Environmental Initiatives (ICLEI), which now has over 500 local government members in national campaigns running in 11 countries. Australia has around 30 per cent of total world participation, with the fastest growth and more councils at the final program milestone than any other international program.

Cool Communities is an AGO initiative delivered in partnership with non-government environment organisations from each State and Territory. It is an innovative program designed to reduce the creation of greenhouse gas emissions from the community. Twenty-two Cool Communities covering all States and Territories are receiving support from the Federal Government to actively and significantly reduce greenhouse gas emissions. The communities represent a diverse range of socioeconomic, geographic and cultural demographics. As a household behaviour change program operating at a national level with multiple communities, Cool Communities is a world first. It uses a social marketing approach to change behaviour, rather than relying on increasing householder awareness alone.

## *Sustainable Transport*

The Government is working to increase the use of alternative fuels such as compressed natural gas (CNG) and liquefied petroleum gas (LPG) and to improve consumer awareness of the fuel efficiency of their motor vehicles. Key initiatives of the program include:

- a program to facilitate the uptake of CNG and LPG as an alternative to diesel in heavy vehicles such as buses and trucks;
- mandatory fuel consumption labels for all new cars sold in Australia introduced in 2001 and revised in 2002 to include all vehicles up to 3.5 tonnes. Carbon dioxide emission labeling is required on all new model vehicles from 1/7/03 and all new vehicles from 1/1/04;
- a fuel consumption guide that allows consumers to accurately compare the fuel efficiency of new passenger cars, four-wheel-drives and light commercial vehicles;
- agreement with industry to set national average fuel consumption targets for new passenger and light commercial vehicles; and
- development and implementation of a travel demand management program to provide smarter travel options for urban residents and reduce use of personal vehicles by complementing current state travel initiatives.

## *Agriculture, Forestry and the Land*

The Commonwealth is working with all States and Territories through the Natural Resource Management Working Group on Greenhouse in Agriculture and Natural Resource Systems, established in 2002, to address greenhouse in the agricultural and natural resource sectors. Initial work program priorities for this Group include development of a National Plan for Greenhouse and Agriculture. This work will be supported by the 2001 agriculture sector workshops undertaken by the former Standing Committee on Agriculture and Resource Management, and the 2002 issues paper entitled *Developing a Strategic Framework for Greenhouse and Agriculture*, prepared by the AGO in consultation with the Department of Agriculture, Fisheries and Forestry.

In December 2002, the AGO supported a joint New Zealand / Australia workshop on research priorities for abatement of non-$CO_2$ greenhouse gas emissions from agriculture.

The Department of Agriculture, Fisheries and Forestry has released a new kit to help foresters make more informed plantation management decisions concerning climate change. The Greenhouse Resource Kit for Private Forest Growers presents information on maximising carbon uptake, on carbon trading and on processes for independent verification. The kit, prepared by CSIRO, includes material on the economics of forest-based carbon sequestration projects, particularly in low-rainfall zones.

The viability of new forest plantations and on-farm forestry for timber production, the control of salinity and soil erosion, enhanced biodiversity, bioenergy production and carbon sequestration will depend partly on adequate planning for climate change and variability, control of fire and interactions with soil moisture and water supply. Considerable effort is being put towards providing advice and planning for such plantation projects.

# Conclusions

Many Commonwealth and State government agencies, and University Departments, conduct research into climate impacts and responses. Much of this research involves strong collaboration between agencies and with international colleagues, and the active involvement of stakeholders.

Climate change (including climate variability and climate change associated with the enhanced greenhouse effect) has, and will continue to have, major impacts on the Australian economy and natural systems. This has particularly been the case in 2002-03, with the large impacts of drought and fire affecting many sectors.

Numerous assessments of the likely impacts of climate change are being conducted by Australian scientists using CSIRO's climate projections, which were released in May, 2001. Recent results generally indicate negative impacts on natural systems, the marine and coastal environments, water resources and infrastructure. Some positive and negative impacts have been identified in agriculture, forestry and human health.

The Commonwealth has a substantial program of policies and measures which are reducing Australia's greenhouse gas emissions across key sectors. The full implementation of these policies and measures will contribute to the global challenge of reducing emissions and stabilising climate. The Commonwealth is developing a Climate Change Forward Strategy that will position Australia for a longer term response to climate change.

The impacts of climate change and variability are already apparent in Australia, and we are likely to experience further impacts in future due to the inertia of the earth system. Hence there is a need to consider adaptation to climate change and variability to minimise negative impacts and make the most of any positive impacts.

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