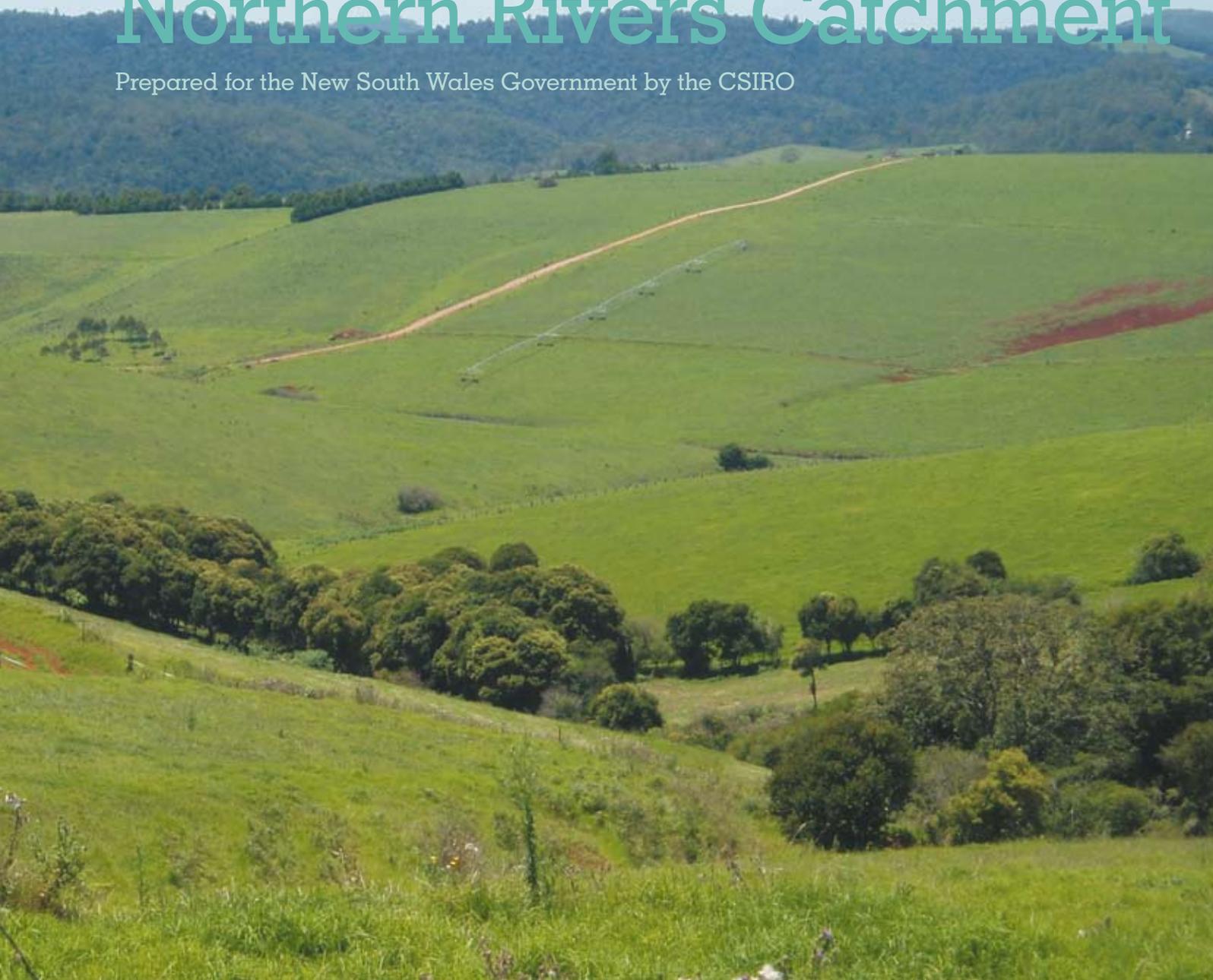




Climate Change in the Northern Rivers Catchment

Prepared for the New South Wales Government by the CSIRO



Border Rivers-Gwydir

Central West

Hawkesbury-Nepean

Hunter-Central Rivers

Lachlan

Lower Murray-Darling

Murray

Murrumbidgee

Namoi

Northern Rivers

Southern Rivers

Sydney Metro

Western





The following brochure has been prepared by the CSIRO to provide information regarding climate change and its consequences for landowners, landusers and the general public within the Northern Rivers Catchment. The information presented here is based upon recent technical reports produced for the New South Wales Government by the CSIRO as well as data from the Australian Bureau of Meteorology and other peer-reviewed scientific studies. This brief summary provides an entry-point for raising awareness about climate change and for locating additional information.

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1.0 The Problem of Climate Change



The Earth's plants and animals depend on the climate to which they are exposed – they benefit when conditions are favourable, and they suffer when conditions become extreme. Humans are no exception.

The crops and water resources that we use to sustain our communities are linked to the climate, and the economic as well as human losses that we experience from hail, cyclones, floods, droughts and bushfires are a reminder of our ever-present vulnerability to the climate system.

It is increasingly clear that our climate is changing. Whereas in the past humans have learned to cope with climatic variability and change that was natural in origin, we are now living in a climate of our own making. The rate at which our climate is being transformed is unprecedented throughout much of human history.

Evidence of a Changing Global Climate

- Temperatures in the northern hemisphere at the end of the 20th century are believed to have been warmer than they have been at any time in the previous 1,000 to 2,000 years.
- The average global temperature in 2005 was the warmest on record, and eight of the ten warmest years have occurred since 1997.
- The Earth's average surface temperature has risen 0.7°C since 1900.
- Heatwaves and extreme rainfall have become more common in many regions.
- The sea level has risen 1.8 mm per year since 1950 and that rate is accelerating.
- There have been fewer frosts and the ice sheets of Antarctica and Greenland are shrinking.
- The timing of physiological processes in plants and animals is changing throughout the world, and populations are shifting their distributions.

Evidence of Australian Climate Change

- Average temperatures in Australia rose 0.9°C from 1910 to 2004. There have been more heatwaves and fewer frosts.
- Since 1950, annual rainfall has declined on the eastern seaboard and in the south of the continent, but increased in the northwest.
- Since 1973, droughts have become more intense, and extreme rainfall events have increased in the northeast and southwest.

According to the United Nations' Intergovernmental Panel on Climate Change "most of the warming observed over the last 50 years is attributable to human activities." These activities – mainly the burning of fossil fuels such as coal, oil, and natural gas – have released vast quantities of greenhouse gases into the atmosphere.

Most greenhouse gases have a long lifetime in the atmosphere. This means that even with reductions in greenhouse gas emissions, there would be a delay of several decades before those reductions have a significant effect on greenhouse gas levels in the atmosphere. Recent studies indicate that no matter how quickly we act, we are already committed to additional global warming during the 21st century of around 0.5°C and the subsequent impacts that are likely to follow.

1.1 What is Causing Climate Change?

Much of the energy that drives the Earth's natural processes comes directly from the Sun. Around half of the Sun's energy that reaches the Earth breaks through the atmosphere, warming the surface of the planet. The land and oceans then radiate that heat, some of which is trapped by greenhouse gases in the atmosphere. The principal greenhouse gases are water vapour, carbon dioxide, methane and nitrous oxide.

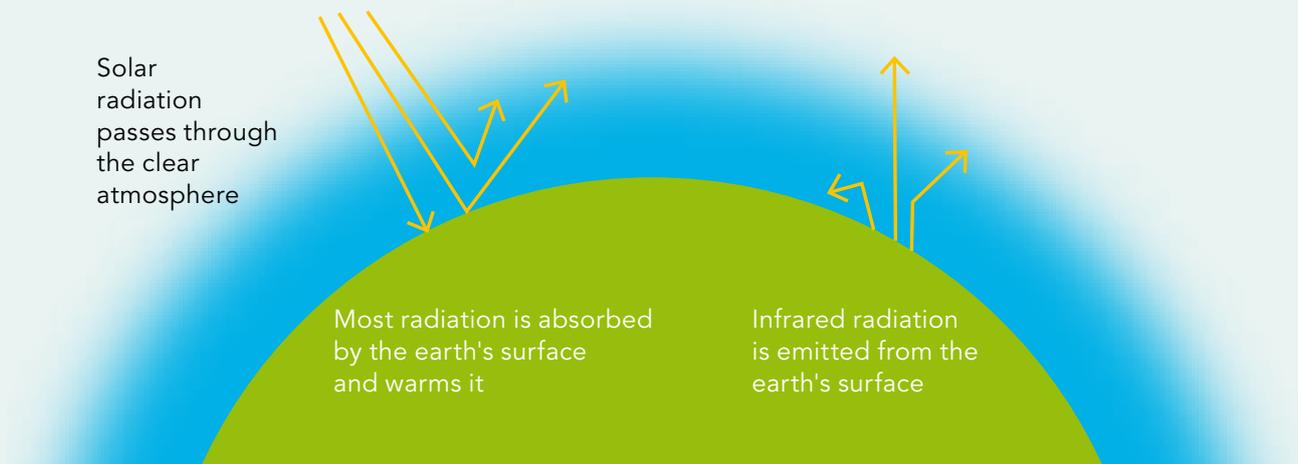
This trapping of heat energy is known as the 'greenhouse effect' – keeping temperatures higher than they otherwise would be, just like a glass greenhouse keeps plants warm (Figure 1). Without this process, the global average surface temperature would be closer to minus 18°C, instead of the current 15°C.

Figure 1. The Greenhouse Effect



Some solar radiation is reflected by the earth and the atmosphere

Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the earth's surface and the lower atmosphere.



The problem we now face is that human actions - particularly burning fossil fuels, agriculture and land clearing - are increasing concentrations of greenhouse gases in the atmosphere. Since 1750, the amount of carbon dioxide in the atmosphere has risen 35%, and the current concentration is higher than at any time in at least the past 650,000 years. The level of nitrous oxide has also risen 17% and methane 151%.

Scientists assert that there will be continued warming and increases in sea levels with significant impacts on natural and human systems. Globally, these impacts include

coastal flooding; more heatwaves storms and droughts; less frost, snow and polar ice; more people at risk of food and water shortage; reduced habitat for many plant and animal species and more people exposed to infectious diseases such as malaria.

In response to this challenge, we need to do two things: start planning adaptation strategies to minimise the negative consequences, and reduce greenhouse gas emissions to slow the rate of global climate change.



2.0 Climate Change in New South Wales

In 2004, the CSIRO and the Bureau of Meteorology released a report on behalf of the NSW Government which looked at past and likely future changes to NSW's climate.

The report found that between 1950–2003, NSW became 0.9°C warmer, with more hot days/nights and fewer cold days/nights. Annual total rainfall declined by an average of 14 mm per decade, with the largest declines in rainfall near the coast due to an increase in El Niño years since the mid-1970s. Extreme daily rainfall intensity and frequency have also decreased throughout much of the State.

The report predicted that by the year 2030:

- NSW is likely to become warmer than it was in around 1990.
- There will be more hot days over 35°C and fewer frosts below 0°C.
- Annual rainfall is likely to decline.
- Rainfall runoff and stream flows will be reduced.
- Droughts are likely to become more severe.
- The risk of bushfires is likely to increase.
- Extreme rainfall may become more intense in central and southeast NSW.

More detailed findings of the report are listed in Table 1 (below).

Season	2030	2070
Annual	<ul style="list-style-type: none"> • Warmer by +0.2– +2.1°C • Rainfall change of -13 – +7% 	<ul style="list-style-type: none"> • Warmer by +0.7– +6.4°C • Rainfall change of -40 – +20%
Summer	<ul style="list-style-type: none"> • Warmer by +0.2 – +2.3°C • Rainfall change of -13 – +13% 	<ul style="list-style-type: none"> • Warmer by +0.7– +7.1°C • Rainfall change of -40 – +40%
Autumn	<ul style="list-style-type: none"> • Warmer by +0.2 – +1.9°C • Rainfall change of -13 – +13% 	<ul style="list-style-type: none"> • Warmer by +0.7 – +5.6°C • Rainfall change of -40 – +40%
Winter	<ul style="list-style-type: none"> • Warmer by +0.2 – +2.3°C • Rainfall change of -13 – +7% 	<ul style="list-style-type: none"> • Warmer by +0.7 – +5.6°C • Rainfall change of -40 – +20%
Spring	<ul style="list-style-type: none"> • Warmer by +0.2 – +2.1°C • Rainfall change of -20 – +7% 	<ul style="list-style-type: none"> • Warmer by +0.7 – +7.1°C • Rainfall change of -60 – +20%

3.0 The Northern Rivers Catchment

The Northern Rivers Catchment covers an area of approximately 50,000 square kilometres, from the Camden Haven River in the south, to the Queensland border, and 160 kilometres inland. The region has over 450,000 people with significant population growth along the coast of over two percent per year, mainly due to retirement by 'baby boomers'. Major population growth centres are around Port Macquarie, Coffs Harbour, Ballina/Lismore and Tweed Heads, with steady to slight growth in the inland towns of Kempsey, Grafton, Casino and Murwillumbah.

Two distinct environments exist within the region, the coastal environment and the eastern slopes. The river, estuaries and coastal ecosystems of the coastal zone are particularly

sensitive to the impact of urbanisation and economic growth. The catchment's major rivers are the Tweed, Brunswick, Richmond, Clarence, Bellinger, Nambucca, Macleay and Hastings. The Clarence River alone discharges approximately 3.7 million megalitres each year, the highest of all the State's coastal rivers. The region is rich in agricultural production, timber production, commercial fishing and tourism — it is estimated that over six million people visit the catchment each year. The major agricultural industries are beef production, dairying, horticulture and the nursery industry. However, new industries such as tea tree and coffee plantations have emerged in recent years. The major use of water from the unregulated rivers in the region is for town water supplies and irrigation.

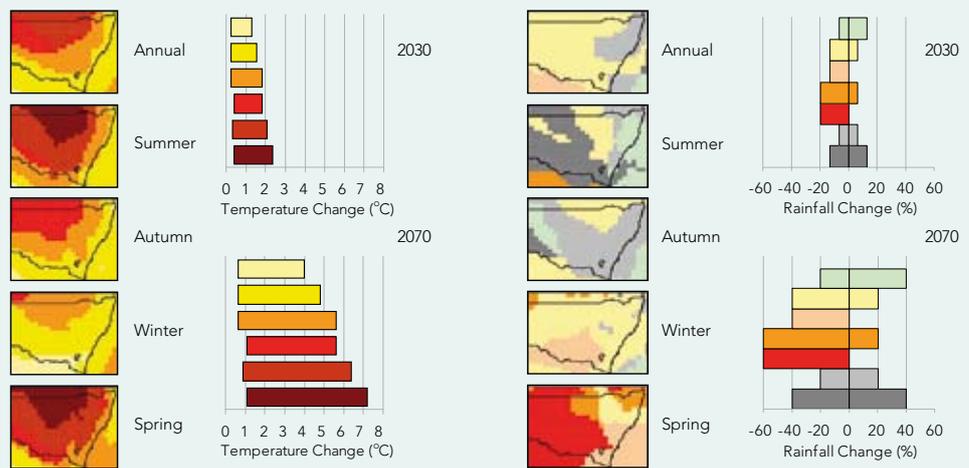
3.1 The Climate of the Northern Rivers Catchment

Summers in the Northern Rivers Catchment are relatively warm, with average maximum January temperatures of approximately 27–30°C (Table 2). On average, Yamba experiences only 1 day above 35°C each year, although warmer areas such as Lismore tend to experience more frequent summer extremes. Winters are cool to mild, with average maximum July temperatures of 19–20°C toward the coast, but only 12°C in more inland towns such as Armidale. The catchment’s coastal areas receive approximately 1,350–1,650 mm of rainfall each year, while rainfall in the interior is significantly lower, with just under 800 mm at Armidale. Peak precipitation occurs between November and April. Variability in rainfall from one year to the next is high.

A warming of 1.0°C and no change in rainfall (a moderate scenario for 2030) would make the climate of Coffs Harbour similar to the current climate of Lismore.

Figure 2. Climate Projections for New South Wales

(The coloured bars show the range of projected changes corresponding with the colours in the maps)



Since 1950, the region has experienced warming of around 0.8–1.3°C. This is likely to be partly due to human activities. The catchment has also experienced a significant drop in annual rainfall at a rate of approximately 10 mm per decade in the west and 50 mm per decade in the east. The contribution of human activities to this rainfall decline is hard to distinguish from natural variability.

The future climate of the Northern Rivers Catchment is likely to be warmer (Figure 2). Although projected changes in average rainfall are currently not clear, with projected increases in evaporation, the catchment is likely to be

drier. Such climate change would also increase heat waves, extreme winds and fire risk. Nevertheless, despite this trend toward drier conditions, there is also potential for seasonal increases in extreme rainfall events. Further details about these changes are described in the following table (Table 2), which compares average conditions for the present climate with ranges of potential change in 2030 and 2070. These projections account for a broad range of assumptions about future global greenhouse gas emissions, as well as differences in how various climate models represent the climate system.



Table 2. Current and Projected Climate Change in the Catchment Area

	Present (1990) ¹	Projected Change	
		2030	2070
Temperature			
Average	Armidale: 12 – 27°C ² Coffs Harbour: 19 – 27°C ² Lismore: 20 – 30°C ² Yamba: 19 – 27°C ²	+0.2 – +1.8°C	+0.7 – +5.6°C
No. Days below 0°C	Yamba: 0	Yamba: 0	Yamba: 0
No. Days above 35°C	Yamba: 1	Yamba: 1 – 2	Yamba: 1 – 7
No. Days above 40°C	Yamba: 0	Yamba: 0	Yamba: 0
Rainfall			
Annual Average	Armidale: 790 mm Coffs Harbour: 1,647 mm Lismore: 1,343 mm Yamba: 1,457 mm	-7 – +7%	-20 – +20%
Extreme Rainfall³		-10 – +5%	+5 – +10%
Evaporation		+1 – +13%	+4 – +40%
No. Droughts per decade⁴	2	2 – 4	1 – 9
Extreme Winds		-5 – +8%	-16 – +24%
No. Fire Days⁵	Coffs Harbour: 4	Coffs Harbour: 5 – 6	Coffs Harbour: 5 – 8

¹ Present day conditions for temperature and rainfall represent long-term averages from the Bureau of Meteorology. For other variables, present day temperatures are represented as approximately 1990 conditions.
² Range represents average July and January maximum temperature.
³ Defined as 1 in 40 year 1-day rainfall event.
⁴ The values for drought represent average monthly drought frequencies, based upon the Bureau of Meteorology's criteria for serious rainfall deficiency.
⁵ Number of days annually with a "very high" or "extreme" fire danger index. Changes are for 2020 and 2050, respectively, as in Hennessy et al. (2005).

3.2 Impacts of Climate Change in the Northern Rivers Catchment

Although changes in average temperature, rainfall and evaporation will have long-term consequences for the catchment, the impacts of climate change are more likely to be felt through extreme weather events. Projections suggest there will be more hot days, bushfires, droughts and intense storms. These can all place human life, property and natural ecosystems at increased risk. Additional details regarding climate change impacts on various activities and assets in the catchment are discussed on the following pages.

Water

Changes in rainfall and higher evaporation rates are likely to lead to less water for streams and rivers in the Northern Rivers Catchment, which will have downstream consequences for storages and place strains on the catchment's water resources. However, given increases in extreme rainfall events that periodically deliver large volumes to storages, the effects of long-term reductions in average rainfall on storages may be moderate. Water storages in the region are currently relatively secure. For example, as of August, 2006, Toonumbar Dam on Iron Pot Creek was almost completely full¹.

¹ Data obtained from the Water Observation Network: <http://wron.net.au/DemosII/DamData/DamMap.aspx>

However, the potential for declines in average rainfall in the region indicate that future water security in the catchment may be undermined by climate change.

Various studies of stream flows in NSW indicate that climate change is likely to further reduce flows in the future (Hassall and Associates, 1998; Jones and Page, 2001; Beare and Heaney, 2002; Bates et al., 2003). Under the National Water Initiative, the Commonwealth, State and Territory Governments have agreed that water users should bear the risk of such reductions in water availability. As a consequence, water users within the catchment may face long-term reductions in allocations and higher prices for water.

Lower flows and higher temperatures may also reduce water quality within the catchment. For example, low flows, higher temperatures and elevated nutrients create a more favourable environment for potentially harmful algal blooms. Greater fire activity could contaminate water catchments with sediment and ash. Salinity problems in the catchment may be exacerbated by changes in rainfall, temperature and stream flows (Beare and Heaney, 2002). In addition to effects on surface water, the quality of coastal groundwater aquifers may be adversely affected by rising sea levels and salt-water infiltration. In addition, decreases in runoff due to climate change may reduce the extent and function of wetlands, such as the internationally recognised Little Llangothlin Lagoon as well as the Clarence River Estuary, Bunyip Swamp and the New England Wetlands.

Farms

The farmers of NSW have developed useful adaptation skills that stand them in good stead for dealing with climate change, but they will need to plan for new climatic challenges and opportunities.

Climate change will have both positive and negative impacts on the types of crops that can be grown and on agricultural productivity. For example, higher levels of carbon dioxide in the atmosphere are likely to increase plant growth, but the protein content of those plants is expected to be lower. Low to moderate warming will also help plant growth and extend growing seasons, but a rise in the number of very hot days or droughts could damage crops. Dry land grazing (sheep and beef cattle) and broad acre cropping are also likely to benefit from higher carbon dioxide levels, but this may be offset by the effect of higher temperatures (Hassall and Associates, 1998). For example, warmer temperatures will increase heat stress on livestock (Howden et al., 1999a; Jones and Hennessy, 2000), which may affect growth and productivity and, subsequently, livestock management.

Irrigated agriculture is very significant in the region, including dairy and horticulture, with emerging tea tree and coffee industries. These industries are likely to be affected by reductions in water availability meaning that water efficiency will be increasingly important. Warmer temperatures will

increase heat stress on dairy cattle, reducing milk production unless management measures such as shade sheds and sprinklers are adopted (Jones and Hennessy, 2000).

Higher temperatures will lead to inadequate winter chilling for some fruit trees, which may reduce fruit yield and quality (Hennessy and Clayton-Greene, 1995). It may become necessary to consider low chill varieties and alternative management options. However, higher temperatures are also likely to reduce the risk of damaging winter frosts. As a result, growing conditions in the catchment are likely to increasingly favour subtropical and tropical species.

Sea-level rise will also impact on drainage and groundwater in low-lying coastal floodplains leading to potential increases in the duration of floods, water logging of soils, and soil salination. These impacts may be exacerbated by the infiltration of saline water into coastal aquifers, reducing the quality and viability of groundwater for irrigation.

However, the key consequence of climate change on farming will clearly be rainfall. Any reduction in rainfall will place most farms under stress, particularly when linked to higher temperatures. For dryland cropping, reductions in rainfall directly contribute to reductions in soil moisture. Meanwhile, irrigated agriculture is likely to be affected by tighter constraints on water allocations and higher prices (see above). In this sense, the unusually hot droughts of 2002/03 and 2005/06 may be a sign of things to come. Furthermore, heavy rains and winds from storm events also contribute to crop damage and soil erosion. Indirect impacts due to changes in weeds, pests and international markets may also place farms under stress.

Biodiversity

Changes to the climate will have significant effects on the catchment's plants and animals. Currently, 380 species, five populations and 13 ecological communities (i.e., collections of species or habitat) in the catchment are classified as threatened or endangered (DEC, 2006). Although current threats to the catchment's biodiversity are largely a product of historical land clearing, alterations of river flows and water extraction, climate change is likely to heighten the need for conservation efforts.

The geographic distribution of a species is often defined by its 'climate envelope,' reflecting species-specific tolerances to extremes of temperature and moisture. Climate change is likely to drive changes in the distribution of some plant and animal species, driving some species out of the catchment or enabling invaders to move in. Meanwhile, even those species capable of coping with climate change alone may succumb to the cumulative effects of multiple stressors. Despite such impacts, little is actually known regarding how climate change may affect some of the catchment's endangered iconic species such as the Double-Eyed Fig Parrot, one of Australia's most endangered birds, as well as the ecologically important coastal freshwater wetlands and salt marshes.



Other risks to biodiversity in the Northern Rivers Catchment include:

- Reductions in streamflows are likely to have a negative impact on aquatic biodiversity and wetland ecosystems.
- Plants and animals may become 'stranded' in isolated remnants of vegetation due to changing climate and continued development within the catchment.
- More frequent droughts and fires are likely to increase stress on plants and animals.
- Sea-level rise is likely to inundate coastal wetlands and alter the discharge of freshwater into estuaries, with potential adverse effects on coastal wetland habitat.

Forests

The forests of the Northern Rivers Catchment are a significant asset that is managed for timber production, biodiversity conservation, recreation and other purposes. The forestry industry contributes roughly \$90 million per year to the economy of northeast NSW as well as over 3,000 jobs, and it is the dominant industry in a number of small communities (DAFF, 1998). Substantial native forests are located on both private and public lands in the catchment, and a private forest plantation industry has been rapidly growing since the late 1990s (NNSW Forestry Service, 2005).

Preliminary research suggests that temperate forests in Australia may increase in productivity with higher temperatures and increased concentrations of atmospheric carbon dioxide. However, these benefits may be offset by decreased rainfall, increased bushfires and changes in pests. Also the benefit of higher carbon dioxide concentrations may be limited in the longer term by the availability of nutrients (Howden et al., 1999c).

Climate change is likely to lead to changes in the distributions of tree species, possible increased invasion by pests, and changes to the habitat that these areas provide for local plants and animals. This will raise new challenges in managing forest areas for biodiversity conservation.

Climate change may also create challenges and opportunities for the forest plantation industry. Given appropriate selection of tree species and the availability of suitable land, it may be possible to expand plantation forestry within the catchment. The region's relatively low fire risk and high average annual rainfall may help insulate it from some of the threat that climate change may pose to forestry, particularly when compared with more arid regions. Nevertheless, fire and drought risk are projected to increase.

Communities

Warmer winters are likely to reduce cold-related illnesses, but warmer summers are likely to increase the risk of heat-related health problems, especially in the elderly (McMichael, 2003). Warmer temperatures may also contribute to the spread of infectious diseases, although the spread of tropical diseases such as dengue fever into the Northern Rivers Catchment remains unlikely.

The built environment is also vulnerable to climate change. As well as impacting on homes, climate change will effect infrastructure, commercial buildings and other physical assets. Changes in average climate will affect building design and performance, including structural standards, cooling and heating demand (PIA, 2004). Higher summer temperatures, for example, may force rethinking regarding building design and standards to ensure thermal comfort at minimal cost. In addition, a study by Austroads (2004) concluded that climate change would increase road maintenance costs in NSW by up to 25% by 2100, largely due to assumptions about the effects of climate change and population growth on traffic volumes.

Given increases in the intensity of the heaviest rainfall events, flash flooding and strains on water infrastructure such as sewerage and drainage systems may rise, particularly in urban areas. For example, a study by Minnery and Smith (1996) found that climate change may double flood-related damages in urban areas of NSW. More recent modelling suggests that extreme rainfall events along the NSW coastal margins may decline, but increase further inland (Hennessy et al., 2004b). Regardless of changes in such extremes, higher temperatures and lower average rainfall are likely to lead to increased pressure on urban water and energy supplies, unless moderated by demand management measures.

Modelling of weather patterns along the NSW coast indicates the potential for increases in the frequency of weather events that contribute to extreme winds and, subsequently, storm surges (Hennessy et al., 2004b). Such an increase in storm surges, in conjunction with future sea-level rise, will increase the risk of coastal inundation, erosion, and damage to infrastructure and property. Modelling of coastal responses to sea-level rise from various locations along the NSW coast indicates the potential for tens of metres of beach erosion over the next century, and the potential for erosion in excess of 100 metres during severe storm events (Hennecke, 2004; Cowell et al., 2006). However, the actual magnitude of beach erosion will vary significantly from one location to another.

The risk of property loss due to bushfire is also likely to increase. For example, Coffs Harbour is likely to experience 1-2 more days with a fire danger index of "very high" or "extreme" by 2020 and 1-4 more days by 2050 (Hennessy et al., 2005). As a consequence of these and other changes in extremes such as winds and floods, insurance risk assessments and premiums are likely to be affected.

Increases in the intensity of the heaviest rainfall events are likely to increase flash flooding, leading to strains on water infrastructure such as sewerage and drainage systems, particularly in population centres. For example, a study by Minnery and Smith (1996) found that climate change may double flood-related damages in urban areas of New South Wales. Despite such extremes, higher temperatures and lower average rainfall are likely to lead to increased pressure on urban water supplies, unless these impacts are moderated by demand management measures.

The risk of property loss due to bushfire is also likely to increase. As a consequence of these and other changes in extremes such as winds and floods (Table 2), insurance risk assessments and premiums are likely to be affected.

4.0 Adapting to Climate Change



Adaptation is a risk management strategy involving actions to reduce the negative impacts of climate change and take advantage of new opportunities that may arise. The types of adaptation measures adopted will vary from region-to-region. Because some of the decisions we make today will have lasting implications for future climate vulnerability, we must start planning our adaptive responses now. By doing so, we may help to lessen some of the environmental, economic and social costs of climate change.

Some examples of potential adaptation measures relevant to the Northern Rivers Catchment include:

- Improving water-use efficiency.
- Reducing dependency on surface water during low flow conditions.
- Changing to crops that are more tolerant of heat and drought.
- Changing planting times and practices for crops.
- Providing more shade and cooling for livestock.
- Providing migration corridors for vulnerable animals.
- Reviewing flood and fire management arrangements.

Making sure the catchment has the necessary capacity to implement such adaptation measures means continually expanding research, education and communication.

4.1 Adaptation in Action



Throughout much of Australia, users of the land have developed considerable experience in managing the high degree of variability that is characteristic of Australia's climate. However, many individuals and enterprises are recognising that they are contending not just with climate variability, but also climate change, and the past is no longer a reliable indicator of future conditions. In response, a broad range of adaptation actions are being implemented across Australia.

In 1999, the **Masters of the Climate** project collected information from more than 80 landholders on how they were using climate tools to better manage their land resources and farm businesses – 23 were selected as case studies. In 2004, those 23 landowners were visited again to see how they fared during the 2002/03 drought and to identify trends in the use of climate tools over the intervening five years.

Some of the observed trends included:

- Solid understanding of local climate history as the basis for greater understanding of climate variability and change.
- Growing use of weather and climate websites for both long and short-term forecasts.
- The application of sophisticated tools (such as software for tracking sub-soil moisture and wheat yields) for making full use of all available moisture.
- Shifts in the nature of crops and stock run on properties, with a movement away from riskier varieties and activities.
- Opportunistic decision-making – being ready to act on short notice to take advantage of weather conditions.
- In a few cases, deciding to leave the enterprise altogether.

All of the **Masters of the Climate** case studies from 1999 and 2004 are available over the internet at www.managingclimate.gov.au/information_resources.asp.



5.0 What is the New South Wales Government Doing?

The NSW Government is taking a leadership role in responding to climate change. In late 2005 the NSW Greenhouse Plan was released, which outlines the NSW Government's response to climate change.

The NSW Greenhouse Plan outlines policies and actions in three main areas:

- Awareness Raising
- Adapting to Climate Change
- Reducing Greenhouse Gas Emissions.

Copies of the Plan can be downloaded from www.greenhouse.nsw.gov.au.



6.0 What's happening in the Northern Rivers Catchment

The following climate change activities are currently underway within the Northern Rivers Catchment:

- The NSW Government's Climate Change Impacts and Adaptation Research Program (CCIARP) is supporting a research effort into the coastal and estuarine impacts associated with the various climate change scenarios, with the Woolli River system as a case study. This work is being conducted by the NSW Department of Natural Resources, with additional cooperation from the CSIRO.
- The NSW Government's CCIARP is also supporting research within the NSW Department of Environment and Conservation on the catchment's Central Eastern Rainforest Reserves World Heritage Area.
- The Border Ranges Multi-species Recovery Plan is a project being conducted in conjunction with the University of Queensland that is investigating the effects of altitude on insect populations and how increased

temperatures associated with climate change may push species "off the top of the mountains".

- The Draft Northern Rivers Pest Animal Strategy is developing priority actions to investigate and monitor the impacts of climate change on invasive species ecology and its management in the Northern Rivers.
- The Coastal Lakes Assessment and Management program includes climate change as part of the sustainability assessment for each of the 16 coastal lakes captured by the study.
- The Catchment Education Program is working with schools to develop environmental management plans to reduce greenhouse gas emissions by implementing actions following an audit of water, energy, waste and resource use on the school grounds. In addition, through student/teacher education forums, a network of students and teachers is cooperating to develop strategies to improve natural resource conditions, specifically addressing climate change impacts.



Want to know more about Climate Change?

A number of climate change studies relevant to the Northern Rivers Catchment are listed here:

Austrroads. 2004. Impact of Climate Change on Road Infrastructure. Austrroads Incorporated, Sydney, Australia, 124 pp.

Bates, B.C. Charles, S.P. Chiew, F. Harle, K., Howden, M., Kirby, M., Peel, M., Suppiah, R., Siriwardena, L., Viney, N.R. and Whetton, P.H. 2003. Climate Change Projections and the Effects on Water Yield and Water Demand for the Australian Capital Territory. Consultancy report for ACT Electricity and Water.

Beare, S., and A. Heaney 2002. Climate Change and Water Resources in the Murray Darling Basin, Australia: Impacts and Adaptation. ABARE Conference Paper 02.11, 33 pp.

Burke, E.J., Brown, S.J., and Christidis, N. 2006. Modelling the recent evolution of global drought and projections for the twenty-first century with the Hadley Centre climate model. *Journal of Hydrometeorology* 7, 1113-1125.

Charles, S.P., B.C. Bates, and N.R. Viney 2002. Linking atmospheric circulation to daily rainfall patterns across the Murrumbidgee River Basin. Proc. 5th International River Symposium, 3-6 September 2002, Brisbane, Qld, Australia.

Cowell, P.J. Thom, B.G., Jones, R.A., Everts, C.H., and Simanovic, D. 2006. Management of uncertainty in predicting climate-change impacts on beaches. *Journal of Coastal Research* 22, 232-245.

DAFF (Department of Agriculture, Fisheries, and Forestry). 1998. Draft Social Assessment. NSW Upper North East. Forest Assessment Branch (Social Assessment Unit), Commonwealth of Australia.

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Hassall and Associates. 1998. Climatic Change Scenarios and Managing the Scarce Water Resources of the Macquarie River. Australian Greenhouse Office. Hassall and Associates, New South Wales Department of Land and Water Conservation, New South Wales National Parks and Wildlife Service, and CSIRO Atmospheric Research, Canberra, Australia, 113 pp.

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For the latest information on climate change, its consequences and tools for managing risk, visit the following web pages:

The NSW Greenhouse Office website:

www.greenhouse.nsw.gov.au

This site contains more information on what the NSW Government is doing to combat climate change, including downloadable copies of the NSW Greenhouse Plan.

The Northern Rivers Catchment Management

Authority: www.northern.cma.nsw.gov.au

This site provides the latest news on catchment management projects and programs, relevant policies, and access to brochures and publications related to management of the catchment.

The Australian Greenhouse Office's National Climate Change Adaptation Program:

www.greenhouse.gov.au/impacts/index.html#programme