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Potential effects of climate change on forests and forestry **in Australia**

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Key Points

one.	Climate modelling shows that compared with 2005 most production forest areas in Australia are likely to receive lower rainfall and experience an increase in temperature by 2030 and 2050.
two.	The effects of climate change on forest productivity will vary across regions and subregions of Australia. This study used a range of models with varying reliability and many inputs and assumptions. These factors need to be considered when interpreting the results.
three.	Forest growth and wood production is highly sensitive to changes in climate; some tree species (such as radiata pine) may become less productive under projected warmer and drier conditions.
four.	The projected climate change may not overly affect some tree species such as maritime pine.
five.	Uncertainty remains around the interaction of high carbon dioxide and tree growth. However, the carbon dioxide fertilisation effect may partially or fully offset modelled declines in tree growth with future warmer and drier climates.
six.	Modelled declines in log supply may result in reduced investment in harvesting, haulage and log-processing capacity and could lead to reductions in the value of production and levels of employment. The estimates presented in this report do not take into account any measures that could be used to adapt to the new environment.
seven.	Assessment of the relative vulnerability of forest and forestry-dependent communities indicated that 17 of 73 communities assessed across the six forest regions exhibit high to very high vulnerability, even in the absence of climate change.
eight.	Due to high dependence on the location of native forests and plantations, communities with a greater dependence on employment in the growing, managing and harvesting of native forests and plantations are potentially more vulnerable than those dependent on processing industries.
nine.	Communities with a greater dependence on plantation forests are potentially most vulnerable due the projected decrease in wood flow from these forests compared to native forests.
ten.	This integrated study drawing together climate modelling, forest growth, economic analysis and community vulnerability assessments is an important step toward understanding the effects of climate change on forest industries at a regional and subregional level. It allows an assessment of multiple risks and provides a framework to investigate potential responses to climate change.

Contents

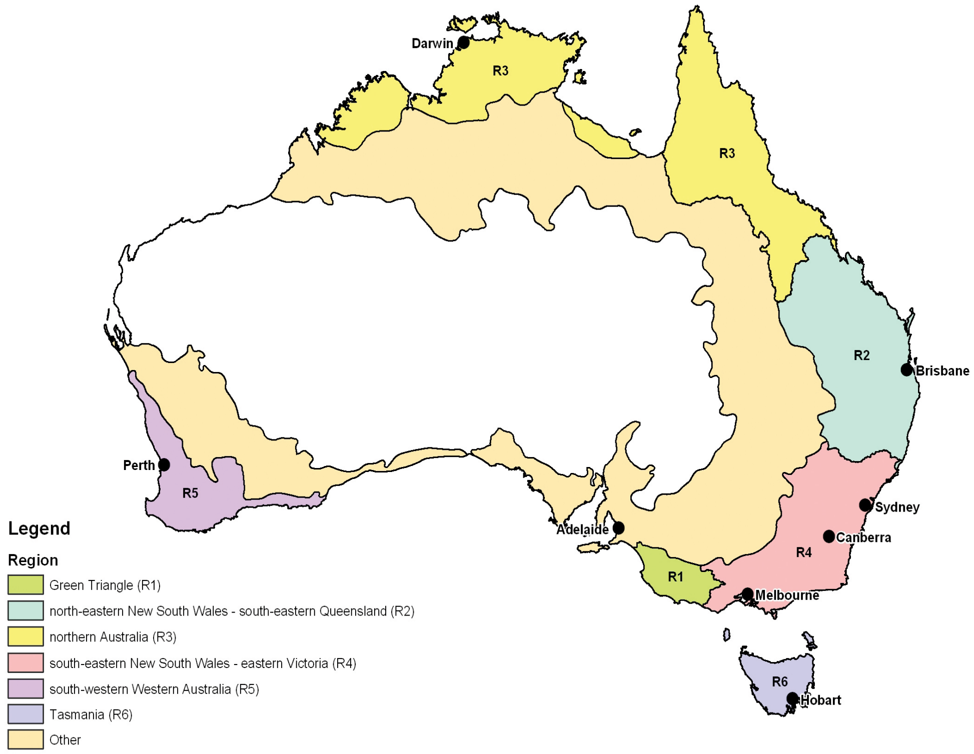
1. Introduction

This is a summary of six regional reports on the potential effects of climate change on forests and forestry in Australia. The assessments describe the possible effects of climate change on forest growth in six regions across Australia (map 1) and estimate the resulting effects of those changes on wood production, the forestry and forest products industries and the communities that depend on those industries.

The six study regions are:

- Green Triangle
- north-eastern New South Wales – south-eastern Queensland
- northern Australia
- south-eastern New South Wales – eastern Victoria
- south-western Western Australia
- Tasmania.

MAP 1: STUDY REGIONS



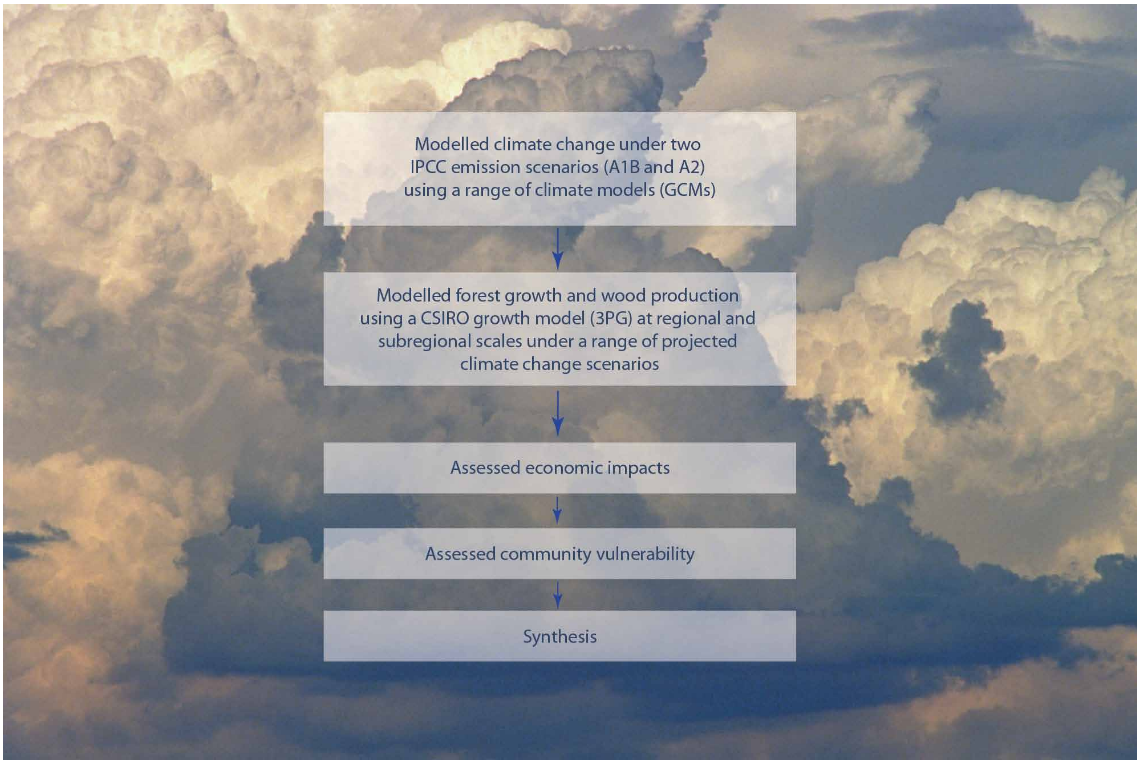
The 'other forest region' shown in map 1 is a broad climatic area with low rainfall; the main forest species that have adapted to the environment include acacias and mallee eucalypts. The native production forests in the region include eucalypts and cypress pine. Native forest wood harvest from parts of this region is included in assessments of three forestry regions, they are:

- south-western Western Australia
- north-eastern New South Wales – south-eastern Queensland
- south-eastern New South Wales – eastern Victoria.

Also, about 9000 hectares of **hardwood plantations** (mainly blue gum) and 19 000 hectares of **softwood plantations** (mainly radiata pine) in South Australia's Kangaroo Island and Mount Lofty Ranges are located in the 'other forest region'. Climate effects on these plantations were not specifically assessed but are expected to be similar to those in the Green Triangle study region.

Figure 1 shows how the study was done, and box 1 (page 12) sets out some of the assumptions the researchers used when producing the results presented here and in the regional reports. More information on how the climate change, tree-growth, economic and social effects were assessed is provided in separate regional reports.

FIGURE 1: OVERVIEW OF METHODS USED IN THE STUDY



Notes: IPCC = Intergovernmental Panel on Climate Change; GCMs = general circulation models; CSIRO = Commonwealth Scientific and Industrial Research Organisation; 3PG = Physiological Processes Predicting Growth – a CSIRO tree-growth model

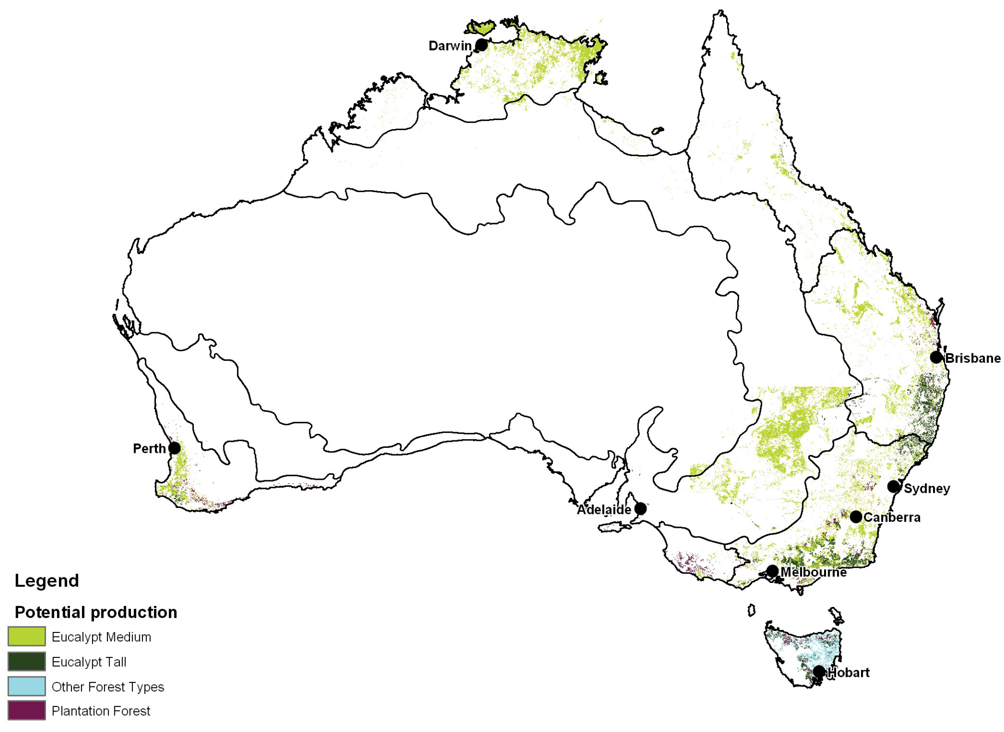
2. National overview

Timber production is regionally important industry in Australia, particularly in the study regions where commercial forest production supports many forest-based industries.

Many native forests in Australia are of suitable structure, forest type and land tenure to be potentially available for commercial timber production (map 2). The total area of these native forests is approximately 28 million hectares of which 25.5 million hectares are eucalypts. Some of these forests are managed for timber production and timber is harvested from them periodically.

Timber is also harvested from about 2 million hectares of plantations specifically established for timber production (map 2). These plantations are comprised of approximately equal areas of hardwood and softwood species. The major timber plantation species include blue gum, shining gum, flooded gum, radiata pine, maritime pine, Caribbean pine and pine hybrids.

MAP 2: FORESTS CURRENTLY POTENTIALLY AVAILABLE FOR WOOD PRODUCTION, AUSTRALIA



Note: This map does not include forest types occupying relatively small areas

3. Climate change projections

The global temperature has risen over the past century. It is likely to keep increasing because of continuing release of human-induced greenhouse gases into the atmosphere.

This study used two greenhouse gas emission scenarios (A1B and A2) developed by the Intergovernmental Panel on Climate Change (IPCC) to estimate climate change in 2030 and 2050. The first scenario (A1B) assumes a moderate increase in atmospheric greenhouse gas levels, while the A2 scenario assumes a greater increase in greenhouse gas levels by the end of the century.

The global mean annual temperature is expected to increase by 2030 and 2050 under both the A1B and A2 scenarios (table 1) when compared with the 1990 baseline.

TABLE 1: ESTIMATES OF GLOBAL CHANGE IN MEAN ANNUAL TEMPERATURE (AND RANGES) RELATIVE TO 1990 UNDER TWO EMISSION SCENARIOS, 2030 AND 2050

Emission scenario	2030 (°C)	2050 (°C)
A1B	+0.9 (+0.54 to +1.44)	+1.5 (+0.92 to +2.45)
A2	+0.8 (+0.48 to +1.28)	+1.4 (+0.84 to +2.24)

4. Tree growth projections

CSIRO's Physiological Processes Predicting Growth model, 3-PG2 Spatial (3PG) was used to estimate forest growth in 2005, under existing climatic conditions, and to project forest growth in 2030 and 2050. The model estimates forest growth based on photosynthetic processes, soil characteristics, water availability, plant attributes and climate. A number of global circulation models were used to derive the regional climate data for 3PG.

The study shows that the reduced rainfall and increased temperatures expected to occur by 2030 and 2050 under scenarios A1B and A2 would affect the **growth rates** of most commercial forest species to varying degrees across the six study regions. Figure 2 shows the different effects on growth rates of forest species in emission scenario A1B by 2030 and 2050 on a whole-region scale. The potential effects of climate change on forest growth rates under all climate change scenarios (2030/A1B, 2050/A1B, 2030/A2 and 2050/A2) are described in the regional reports, which also include effects at subregional scales.

Surrogate species were used to simulate effects of projected climate change on a number of native forests and plantation species for which growth rate data were not available to calibrate 3PG (table 2). The surrogate species used for native forests or plantation were chosen because, of the species for which 3PG is calibrated, they were considered similar to the native forest or plantation species occurring in a study region.

Actual species were used when data were available for 3PG including: blue gum in Green Triangle and south-western Western Australia; Caribbean pine in northern Australia; maritime pine in south-western Western Australia; and radiata pine in Green Triangle, south-western Western Australia and Tasmania.

TABLE 2: SURROGATE TREE SPECIES USED FOR MODELLING EFFECTS OF CLIMATE CHANGE ON NATIVE FOREST AND PLANTATIONS ACROSS STUDY REGIONS

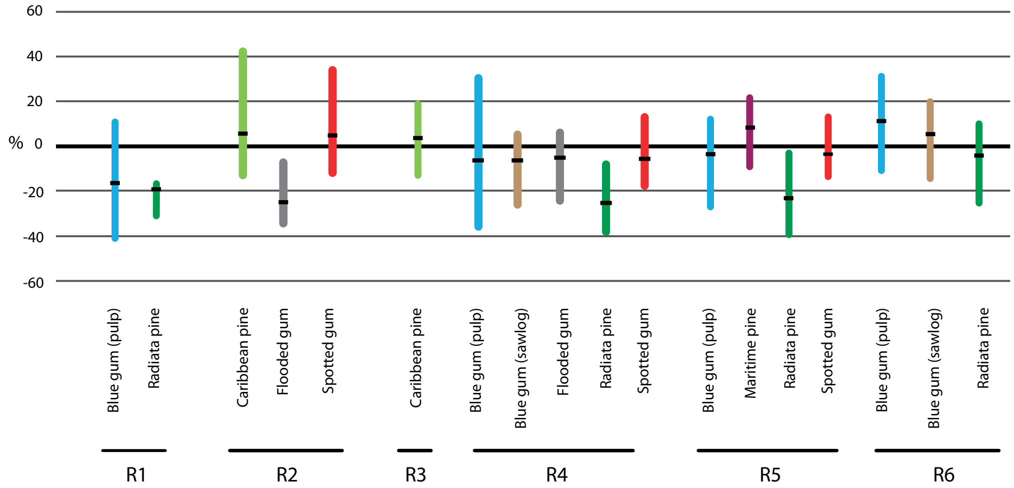
Surrogate	Surrogate used for	Region
Blue gum	Native forest Shining gum plantations Hardwood plantations	R2, R4 R6 R4
Caribbean pine	Softwood plantations	R2
Flooded gum	Native forest	R2, R4
Radiata pine	Softwood plantations	R4
Spotted gum	Jarrah/karri native forest Native forest	R5 R2, R4

Notes: 1. R1 to R6 are the study regions: R1 = Green Triangle; R2 = north-eastern New South Wales – south-eastern Queensland; R3 = northern Australia; R4 = south-eastern New South Wales – eastern Victoria; R5 = south-western Western Australia; and R6 = Tasmania. **2.** Surrogates used for native forests in different parts of the study regions R2 and R4 were as follows: blue gum in moist tableland areas; flooded gum in warm humid areas; and spotted gum in drier areas.

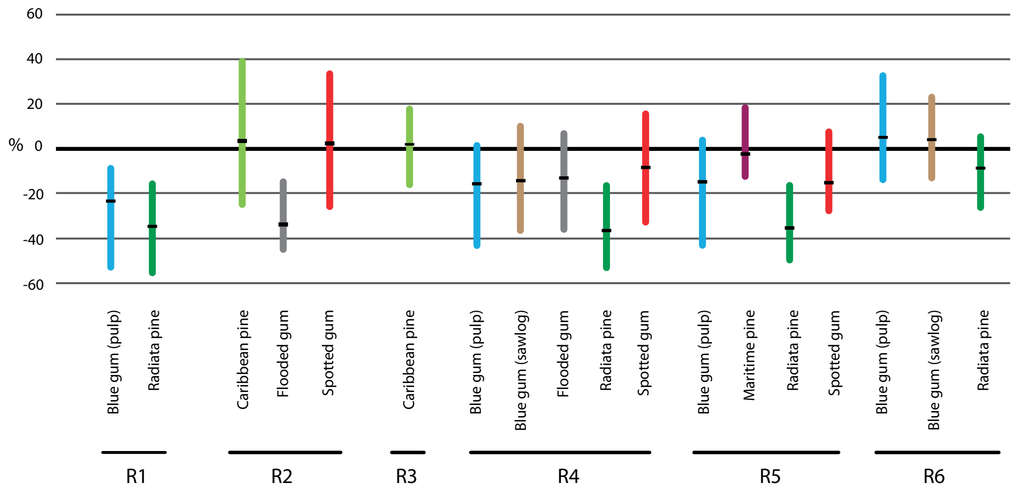
Projected increases in atmospheric **carbon dioxide** in all scenarios may offset modelled declines in tree growth. Increases in pests, diseases, weeds, and fire and drought risks in a changing climate may impact negatively on tree growth.

FIGURE 2: PROJECTED PERCENTAGE CHANGE IN GROWTH RATES DUE TO CLIMATE CHANGE, WHOLE REGIONS

(a) 2030/A1B



(b) 2050/A1B



Notes: 1. The solid dashes across the coloured bars show the effects on the forest growth rate due to median model effect of climate change and the bars above and below the dashes show the range. **2.** R1 to R6 are the study regions: R1 = Green Triangle; R2 = north-eastern New South Wales – south-eastern Queensland; R3 = northern Australia; R4 = south-eastern New South Wales – eastern Victoria; R5 = south-western Western Australia; and R6 = Tasmania. **3.** 2005 baseline growth rates for the forest species are available in the regional summary reports.

5. Sensitivity analysis

A sensitivity analysis was conducted to explore the effect on tree growth of changes in temperature, rainfall and atmospheric carbon dioxide concentrations. The extent of these effects may vary across regions and forest species.

Growth rates for all tree species decrease as temperatures increase, although the extent of the effect varies between species. Most tree species grow faster with higher annual rainfall and growth of all species slows as rainfall decreases.

The 3PG model has an algorithm to estimate the effect of increasing carbon dioxide on forest growth reducing canopy conductance and increasing canopy quantum efficiency. However, to better calibrate the carbon dioxide function in the 3PG model, it would be necessary to obtain data from empirical studies where trees have been grown under artificially increased levels of carbon dioxide. Such studies are much more common for grasses and crops, as these are easy to enclose in carbon dioxide enhanced chambers, and their life spans are short enough to complete the experiment in a reasonable time period. Similar experiments for trees are much more problematic, both in the length of time required to run the experiment and the ability to mimic altered carbon dioxide conditions for the duration of the experiment, and such experiments are more frequent in the Northern Hemisphere. Consequently very few tree studies have been undertaken. Therefore, the carbon dioxide function in 3PG is based on best estimates of what is most likely to happen under carbon dioxide fertilisation, based on empirical data from pine species growing in different regions. A sensitivity analysis was undertaken as a preferred method in this study to test the potential effects of carbon dioxide fertilisation.

This study did not consider the effects of increasing carbon dioxide on forest growth by 2030 and 2050. The results are conservative estimates because potential increases in carbon dioxide fertilisation in these timeframes may enhance growth, although the extent of this enhancement is uncertain.

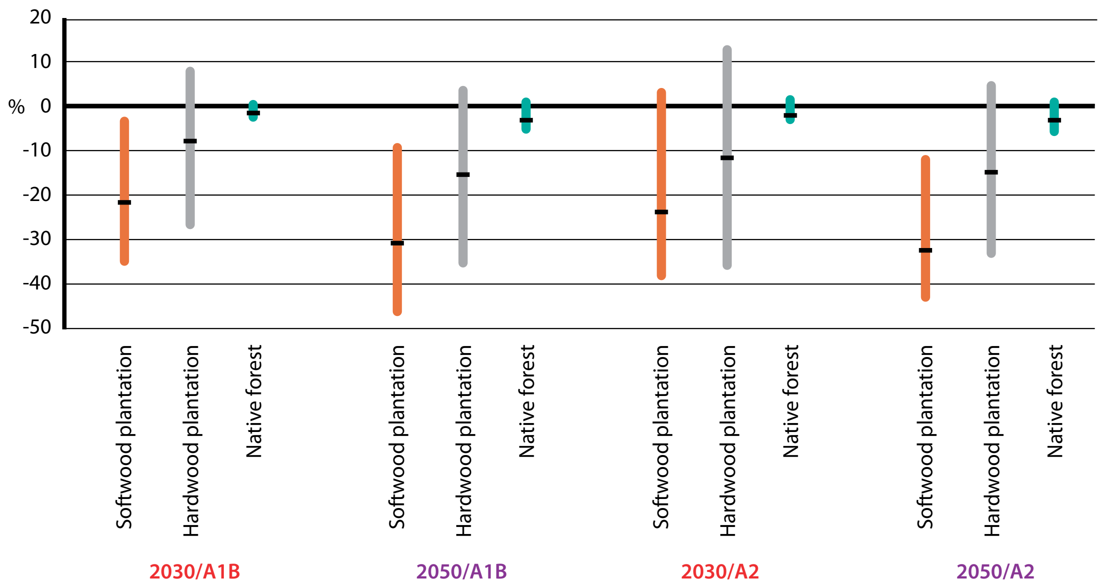
The sensitivity analysis shows that growth for all species increases with higher concentrations of carbon dioxide. The extent of this effect varies between species and study regions. Enhanced growth rates as a result of higher carbon dioxide may partially or fully offset projected declines in growth resulting from increased temperatures and decreased rainfall. The extent to which this occurs would depend on both the species and the interactions between carbon dioxide fertilisation and other growth parameters (box 1).

6. Socioeconomic effects

Log availability from Australia's softwood and hardwood plantations and native forests is projected to decline due to climate change, relative to baseline projections in the absence of climate change. This would have consequences for production and employment in forest industries.

Log availability from softwood plantations is expected to be more affected than from hardwood plantations, while log availability from native forests is not expected to be overly affected. Effects of climate change on log availability from plantations and native forests are projected to vary across the study regions and subregions. Under the median estimates of both emission scenarios, log supply is projected to be lower in both 2030 and 2050 (figure 3). Reduced log supply is likely to result in reduced investment in harvesting, haulage and log processing capacity and could reduce the value of production and level of employment in the industry. Due to the regional and subregional variations in projected log availability, these effects will also vary across regions and subregions of Australia. These estimates do not take into account any adaptation measures that could be used.

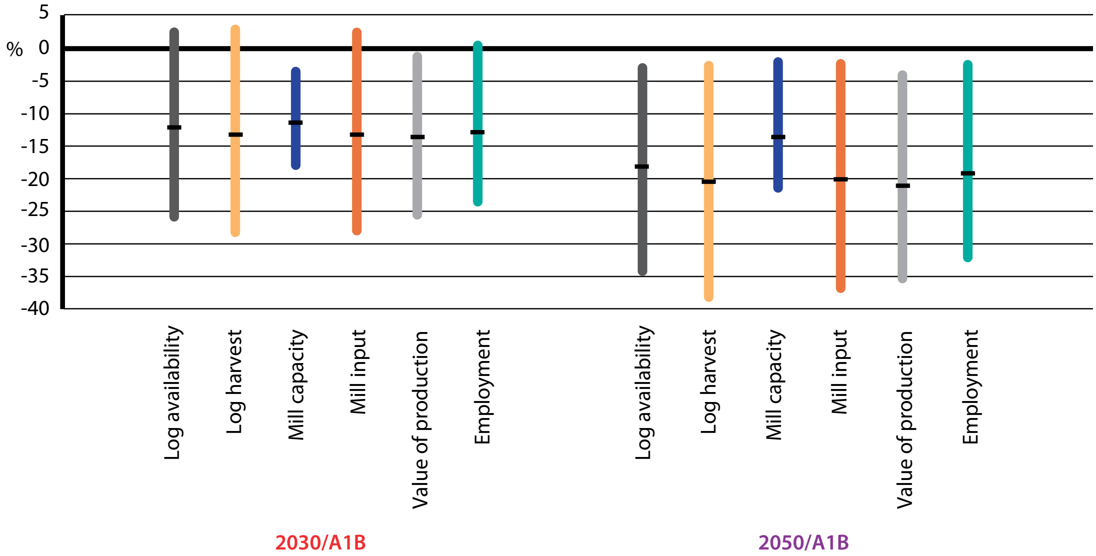
FIGURE 3: PROJECTED CHANGES IN LOG AVAILABILITY DUE TO EFFECTS OF CLIMATE CHANGE



Notes: 1. The solid dashes in the coloured bars show the effects on log availability due to median model effect of climate change; the bars above and below the dashes show the range. **2.** For 2030 and 2050, the national estimated baseline log supply from softwood and hardwood plantations was about 16 million cubic metres (each) and from native forests was about 8 million cubic metres.

Figure 4 shows the median and range of projected climate change effects on several economic factors, relative to the baseline. These data came from combining the results presented in the six regional reports.

FIGURE 4: PROJECTED CHANGES IN SOCIOECONOMIC FACTORS DUE TO MEDIAN AND RANGE OF EFFECTS OF CLIMATE CHANGE ON LOG SUPPLY UNDER THE A1B EMISSION SCENARIO BY 2030 AND 2050



Notes: 1. The solid dashes in the coloured bars show the effects on socioeconomic factors due to median model effect of climate change on log supply; the bars above and below the dashes show the range. **2.** Baseline employment figures are 13 895 for 2030 and 13 854 for 2050.

According to Australian Bureau of Statistics data, in 2006 the forest industries in the six study regions employed about 75 472 people (both full-time and part-time); that was less than 1 per cent of the estimated 8.31 million people employed in those regions that year. In 2010, about 12 129 (16 per cent) of those jobs were in wood harvesting, log haulage and primary wood products manufacturing; the rest were in forest establishment and management, secondary wood products manufacturing, and other support activities.

The employees involved in wood products manufacturing did not necessarily depend on timber from within the study regions. However, the economic modelling generally did not take into account inter-regional transport of wood. As this study considered only jobs in wood harvesting, log haulage and primary wood products manufacturing, the implications of climate change for regional forest industry employment were estimated for only around 16 per cent of the necessary workforce. Flow-on effects in other parts of the industry (such as forest establishment and management, secondary wood products manufacturing, and other support activities) would therefore be additional to those assessed in this study.

7. Regional community vulnerability assessment

If governments and decision-makers understand a community's dependence on the forestry and forest products industries and its ability and capacity to adapt, they can plan and implement strategies to minimise those effects on that community.

An assessment of community vulnerability was used to assess the relative vulnerability of forest and forestry–dependent communities The assessment provides an index of general vulnerability to change in the forestry sector. The index is not specifically related to climate change, but climate change and any factor that influences employment will affect the vulnerability index rating.

The **vulnerability index** ratings are for the local areas of interest within a region and are not comparable across the study regions. Seventeen of 73 communities assessed across the six study regions exhibited a high to very high vulnerability (table 3).

Communities with a greater dependence on employment in growing, managing and harvesting native forests and plantations are potentially more vulnerable than those dependent on processing industries due to a high spatial dependence on the location of native forests and plantations.

Communities with a greater dependence on plantation forests are potentially more vulnerable due to the projected decrease in wood supply from these forests compared to native forests by 2050.

TABLE 3: THE 17 MOST VULNERABLE COMMUNITIES IDENTIFIED ACROSS SIX FORESTRY REGIONS IN AUSTRALIA"

Statistical Local Area[1]	Proportion of labour force (%)[2]	Socioeconomic disadvantage index[3]	Economic diversity[4]	Remoteness[5]	Vulnerability index[6]
Green Triangle					
Wattle Range (DC) – West	16.7	3	0.5	2	Very high
Glenelg (S) – North	5.8	2	0.2	2	Very high
Wattle Range (DC) – East	10.6	5	0.2	2	High
North-eastern New South Wales – south-eastern Queensland					
Eidsvold (S)	7.60	2	0.2	2	Very high
Clarence Valley (A) Bal	7.20	1	0.5	2	Very high
Northern Australia					
Tablelands (R) – Herberton	3.14	2	0.6	2/3	Very high
Tiwi Islands (CGC)	0.93	3	0.4	4	High
South-eastern New South Wales – eastern Victoria					
Bombala (A)	13.8	4	0.2	2	Very high
Tumbarumba (A)	13.1	4	0.3	2	Very high
Alpine (S) – West	13.0	2	0.6	2	Very high
Oberon (A)	18.1	7	0.5	1/2	High
Tumut Shire (A)	15.6	4	0.6	1/2	High
South-western Western Australia					
Nannup (S)	11.1	4	0.4	2	Very high
Manjimup (S)	8.4	3	0.5	3	Very high
Bridgetown – Greenbushes (S)	7.5	5	0.6	2	High
Tasmania					
Dorset (M)	15.6	3	0.4	2/3	Very high
Central Highlands (M)	6.0	2	0.2	2/3	High

Notes: 1. Statistical Local Areas are general-purpose spatial units the Australian Bureau of Statistics uses when collecting statistical data. The names are as given by the Australian Bureau of Statistics (2010). **2.** Total labour force employed in the forestry and forest products industries as a proportion of total employment, 2006. Only local areas with a dependency value of ≥ 1 per cent have been included. **3.** ABS Socio-Economic Indexes for Areas for relative disadvantage (state decile ranking), based on 2006 data, where 1 is the most disadvantaged and 10 is the least disadvantaged. Rankings between 4 and 7 are considered neutral. **4.** As calculated using the Hachman Index of Economic Diversity, based on 2006 data. The Hachman Index is a comparative measure of industry diversity; 0 indicates the lowest economic diversity and 1 the highest economic diversity. **5.** Assessed based on the distance by road to the nearest service centre with a population of >1 000 people. There are five classes: major cities, inner regional, outer regional, remote and very remote (ABS 2001). In the table: 1 = inner regional; 2 = outer regional; 3 = remote; and 4 = very remote. Neither major cities nor migratory class are included in the assessment. **6.** Vulnerability index is a comparative measure for the local areas of interest within the forestry region; the ratings are not comparable across forestry regions and are not specifically related to climate change.

8. Adaptation measures

The productivity and protection of forest plantations can be improved by a range of measures, including **silviculture**. For example, species that are more tolerant of warmer and drier climatic conditions could be planted as existing stands are harvested, and **thinning** regimes could be adjusted to reduce competition for water within stands. The choice of adaptation measures for sustainable management of plantations and native forests would need to be tested to check their ability to address the effects of climate change. Combining increasingly accurate climate and forest growth modelling with effective monitoring and surveillance systems will lead to a better appreciation of threats and adoption of anticipatory adaptation measures. Early recognition of the need to adapt to changing climatic conditions will improve the forest industry's ability to adapt.

Box 1: Assumptions

Two of several global IPCC emission scenarios were used in this study. Emission scenarios the IPCC prepared are based on greenhouse gas and sulphate aerosol emissions over the twenty-first century and incorporate assumptions about future demographic, economic and technological factors. Greenhouse gas levels inherent in these emission scenarios are one of the key variables that drive global climate models and enable observers to derive climate projections at future points in time and space. In this study, the A1B emission scenario was selected to generate climate projections that assume a moderate increase in atmospheric greenhouse gas levels over the twenty-first century whilst the A2 emission scenario was selected to generate climate projections that assume a more substantial increase in greenhouse gas levels over the same period.

Adapting those global scenarios (scale of about 125 to 400 kilometres) for regional scale analyses (scale of 25 kilometres) increases the level of uncertainty but was necessary to produce the inputs for growth modelling. The various global climate models employed in this study produced a wide range of results, the highest and lowest and median of which are reported here. The tree growth model used in this study (3PG) is one of many available models for simulating growth of forest trees and its results may differ from those of other models.

When determining baseline log supply, it was assumed that current growth rates would continue, that existing plantations would be replanted with the same species following harvesting, and that native forests currently managed for timber production would continue to be managed for timber production. Long-term historical average effects of wildfire, storms, drought and other factors were assumed; changes to incidences of those factors under climate change scenarios were not assumed.

Species' growth data are required to calibrate 3PG. For some species grown in the study regions, such as radiata pine and blue gum, considerable growth data were available; model projections for those species would therefore be more reliable than projections for other species for which fewer data were available.

Surrogate species were used to simulate the effects of projected climate change on native forests and a number of plantation species (such as shining gum); the accuracy with which those surrogate species reflect growth rates of the actual species is unknown.

Our sensitivity analysis and recently published work suggests that the effects of projected climate change reported in this study may be offset by potential increases in atmospheric carbon dioxide. This study and Almeida et al. (2009) did not consider interactions between increased levels of atmospheric carbon dioxide and soil fertility which is a known area of complexity. Projected increases in carbon dioxide fertilisation benefit are dependent on assumptions about the nature of tree species responses to increases in atmospheric carbon dioxide. The potential benefits of carbon dioxide in a changing climate must be regarded with caution because of uncertainty about its interaction with other factors, including temperature, rainfall distribution and soil fertility.

The projected effects on log supply do not take into account any adaptation measures that could be adopted.

Overall, this study used a range of models with varying reliability and many inputs and assumptions. These factors need to be considered when interpreting the results.

Glossary

carbon dioxide	A naturally occurring gas. Also, fossil fuel and biomass burning and various industrial processes, among other things, release carbon dioxide into the atmosphere that contributes to climate change. Carbon dioxide is essential for tree growth and survival.
carbon dioxide fertilisation	Increase in growth rates of trees in response to increasing concentration of carbon dioxide in the atmosphere.
climate change	Change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period of decades or longer.
climate projection	A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases, among other things, often based upon simulations by climate models.
emission scenario	A representation of the future of greenhouse gas emissions based on a range of assumptions about key drivers, including demographic and socioeconomic development and technological change. The Intergovernmental Panel on Climate Change (IPCC) has presented a number of emission scenarios, including A1B and A2 used in this study.
growth rate	Mean annual increment defined as the total log volume growth (in cubic metres) of a unit area (hectare) of plantation or forest averaged over the planned rotation (years), expressed in cubic metres per hectare per year.
hardwood	Timber from flowering trees, such as eucalyptus, irrespective of the physical hardness of the timber; also used to refer to the trees that have such timber.
plantation	Strands of trees of native or exotic species, created by the regular placement of seedlings or seeds.
silviculture	The science and technology of managing forest establishment, composition and growth.
softwood	Timber from cone-bearing trees, such as pines, irrespective of the physical softness of the timber; also used to refer to the trees that have such timber.
thinning	Removing a proportion of the trees in a stand so remaining trees have more growing space and are therefore likely to increase in diameter.
vulnerability index	A social index. Vulnerability is a function of a local area's sensitivity and adaptive capacity. sensitivity is measured through dependence on forest and forestry industries for employment while adaptive capacity is a composite measure of Socio-Economic Indexes for Areas (SEIFA) relative disadvantage, economic diversity index and remoteness score. Vulnerability index scores are rated as: very low (0.00 – 0.21); low (0.22 – 0.41); moderate 0.42–0.61); high (0.62 – 0.81); and very high (0.82 – 1.00).
yield	The volume of logs harvested, often expressed in cubic metres per hectare.

Further Information

Six regional reports on the effects of climate change on forests and forestry are available at **www.abares.gov.au**