NCCARF Synthesis and Integrative Research Program

NCCARF
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Climate Change Adaptation
Research Facility

An assessment of the vulnerability of Australian forests to the impacts of climate change

I. Establishing the need and consultation with key stakeholders in forest policy and management under climate change

Image: CFA

Kathleen Wood, Anne Roiko, Peter Waterman, Helen Wallace and Richard Warrick

FOREST VULNERABILITY ASSESSMENT

Establishing the need and consultation with key stakeholders in forest policy and management under climate change

Contribution of Work Package 1 to the Forest Vulnerability Assessment

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

The research team would like to acknowledge the generous support provided by interviewed participants, workshop attendees and stakeholders. We thank them for their willingness to offer their time and considered responses to our questions. We would also like to acknowledge the peer reviewers, both invited and anonymous, who offered valuable insights and suggestions which have strengthened the document. Finally we would also like to acknowledge the assistance of Shireen Fahey with the development of the survey and her administrative role in the early stages of the project.

Table of Contents

Executive summary

The assessment of the vulnerability of Australian forests to climate change is an initiative of the Natural Resource Management Ministerial Council (NRMMC). The National Climate Change Adaptation Research Facility (NCCARF) was approached to carry out such a comprehensive Forest Vulnerability Assessment (FVA). NCCARF engaged four research groups to investigate distinct aspects in relation to the vulnerability of forests, each of which has produced a report. In addition a fifth group was engaged to create a summary and synthesis report of the project.

This report – *Establishing the need and consultation with key stakeholders in forest policy and management* - is the first in the series. Through stakeholder engagement this part of the FVA project was charged with:

- identifying key issues to be addressed by the Forest Vulnerability Assessment;
- determining to what extent climate change adaptation is being considered in current forest planning and management; and
- determining the type of information that is needed by forest managers and policy makers to adapt to the impacts of climate change.

In addition, the FVA project utilised climate change scenario modelling to generate possible medium- and long-term climate futures for 2030 and 2070. These scenarios of temperature and precipitation change across Australia provided the backdrop to the Forest Vulnerability Assessment allowing all investigators to gauge the likely impacts on the biophysical and socio-economic components of forest systems. The scenarios generated for the project are reported here.

Stakeholder interviews

In the study of stakeholder views, qualitative research methods were used that involved a combination of telephone interviews, a stakeholder social learning workshop and meetings with selected stakeholders. A semi-structured and open-ended instrument was used for the telephone interviews. Thirty four questionnaires were administered and 27 hours of recorded responses were transcribed and analysed. The participants categorised themselves as follows: 10 with a policy focus; 18 as forest managers and 6 with combined roles. The survey was undertaken on a jurisdictional basis and the respondents surveyed were drawn from the following groups: Native forest managers, national parks and conservation reserves managers, forestry researchers and policy analysts, private plantation industry managers/managed investment schemes, government plantation industry managers, private farm forestry representatives and private landholders with significant forest estates not managed for timber (freehold and leasehold), NGO's managing environmental plantings and restoration forests (freehold and leasehold), and other NGO's.

Stakeholder engagement provided valuable insights. Participants raised many concerns with regard to biophysical impacts on forests in general, including consequences for biodiversity, and more specific impacts on individual forest trees and forest productivity.

Participants raised many socio-economic issues including those in relation to: economic viability of forest production, land availability and competition, skilled labour shortage and shortcomings in research, development and extension. The impact of policy and legislative uncertainty on decision-making in forest management was an issue that emerged strongly from the interviews. The potential impact of the proposed Carbon Pollution Reduction Scheme on both plantation and conservation forests was raised repeatedly. Across all groups there was a consistent call for clarity on carbon pricing policy and legislation.

The need for adaptation was recognised. Forest managers are beginning to assess potential threats and opportunities. Responses from stakeholders indicate that some form of climate change adaptation is being considered by most, both in terms of planning and management, but implementation is inconsistent. However, there are still organisations with minimal or no plans to develop adaptation measures and adaptation is not yet widely incorporated into regular decision making processes.

Participants identified key information needs in the areas of modelling for decision-making, research and appropriate dissemination of knowledge.

The results of the interviews demonstrated that climate change impacts and adaptation are of concern to many forest managers. However, implementation of adaptation actions and adaptive management is limited because, first, stakeholders consider there is little useful and forest-relevant climate change information available and, second, the legislative and policy environment does not support adaptive management. Our research revealed that progress toward climate change adaptation in the Australian forest sector could be enhanced through a suite of measures that address the needs raised by participants:

- Investment in projects and services that meet the information needs of forest managers and policy-makers.
- Increase in the applied research effort for forest and climate science.
- Investment in the management of existing threats such as weeds, pests, disease, fire, and drought.
- Identification of climate change refugia and investment in ex-situ conservation efforts.

- Implementation of broadscale and finescale monitoring programs for climate change impacts and responses.
- Development of land-use management systems that recognise the value of forest ecosystem services and reward landowners for the ongoing provision of ecosystem services.
- Legislative clarity at all governance levels to provide stability for investment and decision-making and to minimise perverse policy outcomes at all scales.
- Regional Forest Agreements that consider climate change vulnerability and facilitate adaptive management.
- Development of adaptive governance cycles at all governance scales.
- Central management of carbon credit accreditation from bio-sequestration.
- Carbon credit accreditation for environmental and biodiversity plantings.

Scenarios of climate change for Australia's forests

Climate scenario modelling was undertaken using SimCLIM (developed from CLIMPACTS, University of Waikato; and OzCLIM, CSIRO), a software modelling system used to link and integrate complex arrays of data and models in order to simulate biophysical and socio-economic effects of climate variability and change. SimCLIM provides considerable scope for tailoring emissions scenarios and climate model sensitivity values, and in the selection of climate models, regions, seasonal aggregations and future time horizons. It therefore allows the user to explore the range of uncertainties involved in future greenhouse gas emissions. For the FVA project, the following specifications were selected: Climate sensitivity – HIGH; Emissions scenario - SRES A1FI (highest); Climate model - the median value of an ensemble of equally weighted 21 climate models. The scenarios are presented as maps illustrating changes in temperature and precipitation parameters across Australia.

The following summarises the modelled future climate scenario selected as the context against which the FVA was carried out:

- Annual rainfall increases in the tropical north and decreases elsewhere.
- In northern Australia the wet season gets wetter, the dry season gets drier.
- In southern Australia, widespread decreases in rainfall occur during winter and spring. The western and southern coasts show decreases in rainfall in all seasons.
- Mean maximum temperature in February increases by 3.5 – 4.5°C over much of Australia.

- The increase in number of days exceeding thresholds of 35°C and 40°C is greatest in the interiors of Northern Territory and northern Western Australia.

These patterns of climatic change, if realised, will have significant impacts on forest systems and emphasise the need for better understanding of the sensitivity of forests to climate change impacts, the available adaptation options and, consequently, the vulnerability of forests to climate change.

1 Introduction

1.1 Introduction to the Forest Vulnerability Assessment project

The Natural Resource Management Ministerial Council (NRMMC) identified the need for a national assessment of the vulnerability of Australia's forests to climate change and a framework for adaptation to the potential impacts. The National Climate Change Adaptation Research Facility (NCCARF) through the Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) was approached to carry out such a comprehensive assessment of the vulnerability of Australia's forests. This Forest Vulnerability Assessment (FVA) has been carried out by four research groups each of which has produced a report. In addition a Synthesis Report (Boulter et al. 2011) has been produced which summarises and synthesises the outcomes from the four narrowly focussed reports. A summary for policy makers for the whole project has also been prepared..

A Steering Committee of federal and state government and university stakeholders involved in forest management, policy and research was engaged to adopt the NRMMC brief and set the parameters for this study. Here we scope the FVA and introduce the general terms of reference for the project.

1.1.1 Purpose and approach

The primary aim of the Forest Vulnerability Assessment project is to provide forestry policy makers and forest managers in Australia with information that assists the sector to adapt to climate change. In particular, the project sought to provide governments, natural resource managers and the business sector with:

- *an improved understanding of current knowledge of the likely biophysical and socio-economic consequences of climate change for Australia's native and planted forest regions;*
- *an assessment of the vulnerability of Australian forests from the perspectives of both resource use and ecosystem services - identifying particularly vulnerable forests and communities in major forest areas;*
- *an understanding of what is already being done in Australia in relation to understanding and managing climate related risk in relation to forests; and*
- *guidance on key gaps to assist climate change adaptation.*

The project has sought to enhance awareness of forest managers and policy makers to climate change risk by providing up-to-date information about likely climate change impacts on forests and vulnerability to these impacts. As outlined above, the project was undertaken by a consortium of research groups with specific aspects of the project allocated to five separate Work Packages (WP) based on four major research themes and a synthesis. Work Packages 1 to 4, through an extensive review of literature and policy from a range of sources (including peer reviewed journals and technical reports) and through engaging with stakeholders, provide a critical analysis of the vulnerability of Australia's forests to climate change impacts. (see Table 1 for a list of reports).

A fifth Work Package (Boulter et al. 2011) summarises and synthesises all Work Packages, draws some broader conclusions on regional variability and vulnerabilities, and provides a review of the legal issues surrounding forest management under climate change.

1.1.2 Definition of forests and forest uses for the purpose of the project

The scope of the project is largely set by the definition of forests used. We adopted the definition in the 2008 *Australia's State of the Forests Report* (SOFR) (Montreal Process Implementation Group for Australia, 2008). This definition includes both native forests and plantations:

> *A FOREST is an area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding two metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20%. This includes Australia's diverse native forests and plantations, regardless of age. It is also sufficiently broad to encompass areas of trees that are sometimes described as woodlands.*

Based on this definition, the assessment includes a large part of Australia's mallee ecosystems (defined as dominated by multi-stemmed eucalypts - any one of about 25 species depending upon location) and encompasses very large areas of tropical savannah and woodland (also referred to as rangelands), where trees are spread out in a more open landscape and grazing is the predominant landuse. Inter-tidal, salt tolerant forests, often referred to as mangroves, also fall within this definition of forests. What many people would traditionally regard as forests – expanses of tall, closely spaced trees – are a relatively small part of the country's total forest estate.

Australia's forests are dominated by eucalypt forests (including the genera *Eucalyptus, Corymbia* and *Angophora*) and acacia forests making up about 89% of all native forest types (see Table 3). Both these forest types support an enormous diversity of species with over 700 eucalypt species and almost 1000 *Acacia* species (Montreal Process Implementation Group for Australia, 2008) as well as other plant species. Other important forest types cover smaller areas. These include rainforest, as well as *Melaleuca* wetlands and mangroves.

Table 1 The Work Package reports delivered as part of the forest vulnerability assessment (Abbreviations: JCU – James Cook University, Macquarie – Macquarie University, Murdoch – Murdoch University, QUT – Queensland University of Technology, USC – University of the Sunshine Coast, USQ – University of Southern Queensland, GU - Griffith University and NCCARF, National Climate Change Adaptation Research Facility).

WP	Report title	Authors and affiliations
1	Establishing the need and consultation with key stakeholders in forest policy and management under climate change. Contribution of Work Package 1 to the Forest Vulnerability Assessment (This report)	Helen Wallace, Kathleen Wood, Anne Roiko and Peter Waterman (USC)
1	The scenarios of climate change: Tools, methods, data and outputs. Supplementary Materials of Work Package 1 to the Forest Vulnerability Assessment	Richard Warrick (USC and CLIMsystems Ltd)
2	Biophysical impacts of climate change on Australia's forests. Contribution of Work Package 2 to the Forest Vulnerability Assessment (Medlyn et al. 2011)	Belinda Medlyn and Melanie Zeppel (Macquarie), Tom Lyons, Giles Hardy Niels Brouwers, Kay Howard, Emer O'Gara, Li Li and Bradley Evans (Murdoch)
3	Socio-economic implications of climate change with regard to forests and forest management. Contribution of Work Package 3 to the Forest Vulnerability Assessment (Cockfield et al. 2011)	Geoff Cockfield and Tek Maraseni (USQ), Laurie Buys and Jeffrey Sommerfeld (QUT), Clevo Wilson and Wasantha Athukorala (QUT)
4	Climate change adaptation options, tools and vulnerability. Contribution of Work Package 4 to the Forest Vulnerability Assessment (Wilson and Turton 2011)	Steve Turton and Robyn Wilson (JCU)
5	An assessment of the vulnerability of Australian forests to the impacts of climate change (Boulter et al. 2011)	Sarah Boulter (GU & NCCARF), Roger Kitching (GU), Frank Stadler (NCCARF)
5	An assessment of the vulnerability of Australian forests to the impacts of climate Change. Supplementary Material: Forest resources, climate change and the law	Douglas E. Fisher (QUT)

The SOFR 2008 report also used the National Forest Policy Statement (Commonwealth of Australia 1992) definition of plantations:

> *Intensively managed stands of trees of either native or exotic species created by the regular placement of seedlings or seeds*

which has also been adopted for the Forest Vulnerability Assessment.

In summary, Australia's forests are a continuum of large-scale industrial plantations at one extreme and native forests (including mallee, savannah, woodland and mangroves) at the other. In order to place the Australian forest estate firmly into a management context, we superimpose a set of forest type categories, reflecting the way forests are used:

- Plantation or farm forests
- Productive native forests
- Conservation native forests
- Environmental plantings

Table 2 Total area ('000 hectares) under three of the four categories of forest type used in this report including the percentage of Australia's total area under each type. The coverage of environmental plantings has not been quantified. Source: Montreal Process Implementation Group for Australia (2008)

Forest Type	ACT	NSW	NT	QLD	SA	Tas	Vic	WA	Aus	% of forest area
Plantation/farm forests	10	345	26	233	172	248	396	389	1818	1
Productive native forests	5	21060	30994	48005	4826	1996	4332	13797	125052	83
Conservation native forests	108	5148	16	4576	4029	1121	3505	3868	22371	16
Total forest	133	26553	31036	52814	9024	3364	8233	18054	149215	100

Table 3 Important vegetation types and their representation in the Australian forest conservation estate.

Forest vegetation type	Area (‘000 ha)	Portion of forest type in conservation area (%)	Description
Acacia	10,365	5	Australia’s second most common forest type; predominantly woodlands (average annual rainfall <750mm); can form open forests in wetter areas; found in all states and the Northern Territory; Mulga (*Acacia aneura*) dominant species in arid and semi-arid zone; Brigalow (*A. harpophylla*) widespread in Queensland and northern New South Wales.
Callitris	2,597	8	Found in a wide variety of climates; tolerant of temperatures ranging from below 0°C to more than 40°C; areas of annual rainfall > 300 mm, but can be as low as 200 mm; wide range of soil types, but commonly nutrient-poor soils associated with mycorrhiza.
Casuarina	2,229	39	Woodlands or open forests; all states and territories of Australia; semi-arid zone; coastal areas; Belah (*Casuarina cristata*) forests have the widest distribution; Belah and river she-oak (*C. cunninghamiana*) common inland; Coast she-oak (*C. equisetifolia)*, rock she-oak (*Allocasuarina huegeliana*) and drooping she-oak (*A. verticillata*) form pure stands.
Eucalypt	116,449	18	Three genera – *Eucalyptus*, *Corymbia* and *Angophora* – are usually referred to as eucalypts; found throughout Australia except in the most arid regions; variety of dominant structures.
Mangroves	980	18	Mangroves are important and widespread coastal ecosystems in the intertidal zone of tropical, subtropical and protected temperate coastal rivers, estuaries and bays. Can form dense, almost impenetrable stands of closed forests providing coastal protection from storm and wave action.
Melaleuca	7,556	11	There are hundreds of species in the genus *Melaleuca* and many other species in closely related genera, such as *Callistemon.* About 75% of Australia’s melaleuca forest occurs in Queensland, particularly on Cape York Peninsula.
Rainforest	3,280	55	‘Rainforest’ is a general term for a range of broad-leaved forest communities with closed canopies; do not depend on fire for their regeneration; account for most (77%) of Australia’s closed crown cover forest; extend across the top of northern Australia from the Kimberley to Cape York and down the east coast to the cool temperate zone in Tasmania.

Plantation/farm forests

In this category are those planted forests which are destined to be harvested for economic benefit at some time in the future. They include major broad-acre plantings of exotic species such as pines as well as smaller farm forestry plantings utilising a variety of species from construction to cabinet timbers.

In the 2010 National Forest Inventory update (Gavran and Parsons 2010), there were a reported 2.02 million hectares of plantations of which 1.02 million hectares was pine (softwood) and 0.99 million hectares of hardwoods of various species and mixtures. This is an increase of 49 658 hectares of new plantations from that reported in the 2008 State of the Forests Report (Montreal Process Implementation Group for Australia 2008). The area of plantation estate in Australia has continued to expand, with planting of hardwoods the greatest area of expansion (from 29% of all plantations in 1999 to 49% in 2009). There are several regions of plantation activity (Figure 1) with the largest proportion of the national estate being in Victoria and Western Australia. The majority of plantations are privately owned (62%). One-third are publicly owned and a further 5% are jointly owned (Gavran and Parsons 2010).

Productive native forests

Under this category we include those naturally occurring forests which may be periodically harvested for timber or other forest products or used for other agricultural purposes while retaining the essential ecological characteristics of their undisturbed predecessor forests. Therefore, ‘productive’ refers to the narrow economic use of forest resources such as timber, for example. In contrast, the much broader ecological understanding of productivitiy is applied to all ecological systems.

Of the 149 million hectares of forest in Australia, 147 million hectares are native forest (Montreal Process Implementation Group for Australia 2008). Under the Montreal Process definition, native forests available for harvesting (wood and non-wood products) are defined as “those native forests in which harvesting is not illegal” and some 112 million hectares or three-quarters of Australia’s native forests were classified as not legally (in a strict sense) excluded from timber harvesting or tree clearing in the 2008 State of the Forests Report, (Montreal Process Implementation Group for Australia 2008). Only forests in nature conservation reserves are specifically excluded from tree removal.

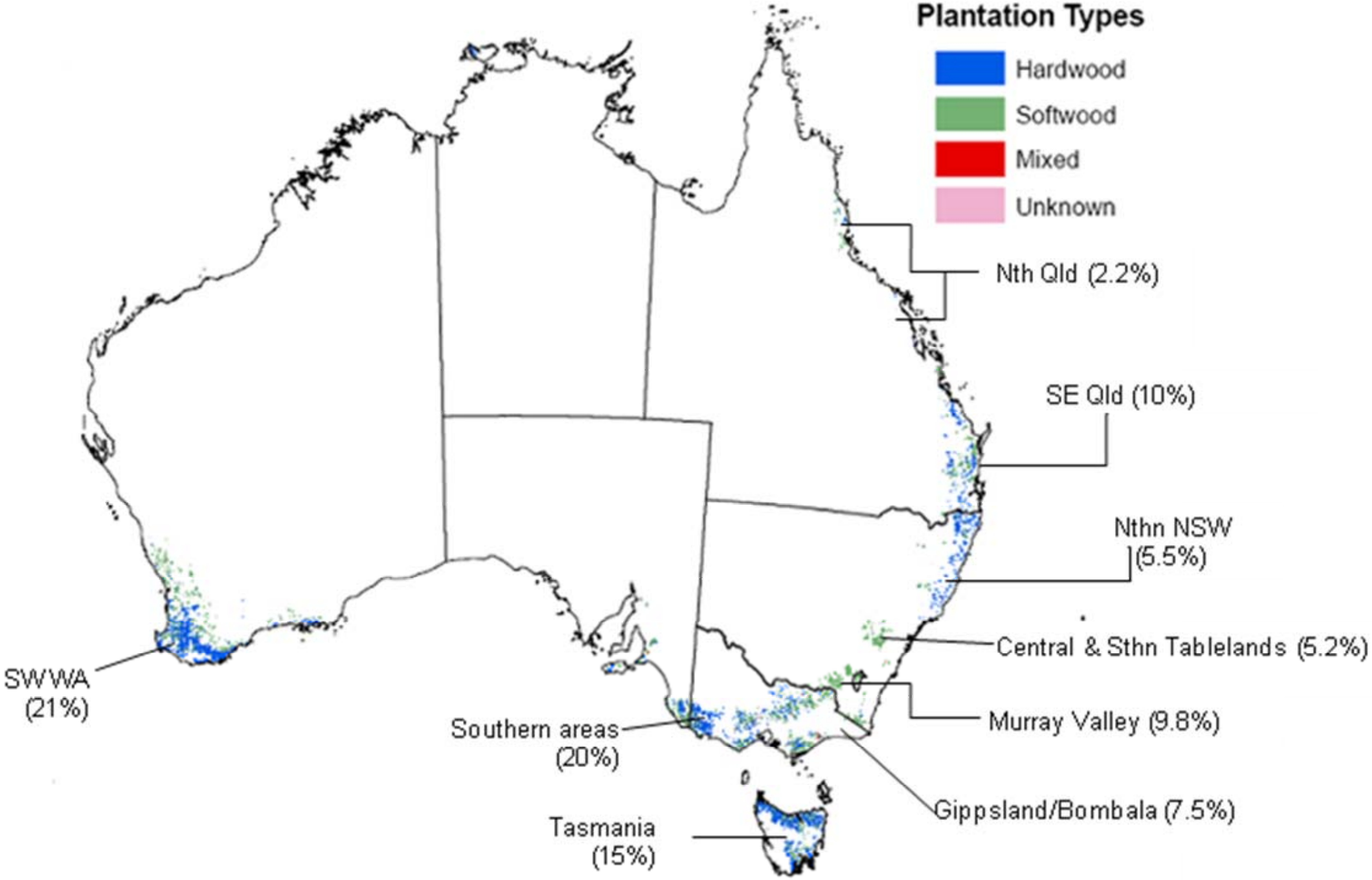


Figure 1 Major Australian plantation regions. The percentage area each region makes up of the national estate is shown in brackets. Source: Bureau of Rural Sciences

For the purposes of the FVA, we have categorised those forests in which “harvesting is not illegal” as productive native forests. In practice, however, very little of this area is currently used for timber supply, with more than half (65 million hectares) being leasehold land used for grazing. In addition, in Queensland and New South Wales the clearing of vegetation is controlled legislatively (Vegetation Management Act Qld 1999 and Native Vegetation Act NSW 2003) with permits required for tree clearing and areas under remnant vegetation in “endangered” or “of concern” or “threatened” categories prohibited from tree clearing but available for other land uses such as grazing. Productive native forests, as defined here, are represented by three tenure types – multiple-use public forests, leasehold and freehold (private) lands.

Harvesting of native forests is largely restricted to multiple-use public forests with some contribution from leasehold and private lands. There is relatively limited commercial harvesting of native forests in the Northern Territory and none in South Australia or the Australian Capital Territory (Montreal Process Implementation Group for Australia 2008). The Queensland government has signalled its intention to phase out native forest harvesting in favour of hardwood plantation development (Montreal Process Implementation Group for Australia 2008) with the South-East Queensland Forests Agreement providing for the ending of timber harvesting in native State forests and timber reserves in the South East Queensland Bioregion by 2024. Although wood products can be harvested from native forests on private land, this is distinguished from farm forestry, in which seed or seedlings are purposefully planted for future harvest.

Much of the land that can be classified as productive native forests makes up the arid area of Australia commonly referred to as “the rangelands”. The rangelands are those areas where the rainfall is too low or unreliable and the soils too poor to support regular cropping (Bastin and ACRIS Management Committee 2008). The area traditionally defined as rangelands includes savannah, woodlands, shrublands and wetlands that fall under the definition of forest used in this assessment. The primary use of these areas is grazing, with the trees or forests providing services such as shade and shelter, nutrient input, salinity control, biodiversity and amenity rather than any harvestable product.

Conservation native forests

Native forests on which no harvesting is legally permitted and over which conservation controls are in force are defined here as conservation native forests. This includes the many categories of forest reserves designated to serve as areas for the maintenance of environmental quality, biodiversity conservation and/or tourism. In some states this also includes forests designated as ‘wilderness’. Forests in nature conservation reserves are located around Australia and cover a broad range of vegetation types. Australia has 22.37 million hectares of nature conservation reserve (Montreal Process Implementation Group for Australia 2008).

Environmental plantings

This last category encompasses artificially constructed forests with a diverse set of roles from restoration and maintenance of environmental health to provision of shelter belts, biodiversity corridors, erosion control or amenity.

Amenity plantings are for human enjoyment and comfort and seek to provide shade, screening and windbreaks. Amenity plantings may also be used along roadsides.

Ecological plantings use species local to an area (indigenous species) and provide habitat to native animals. The use of locally indigenous species conserves the character of a region both biologically and visually.

Environmental plantings may also be established for the purpose of carbon sequestration (carbon offsets) and the management of soil salinity. Environmental plantings can serve a number of these purposes simultaneously.

1.1.3 Classifying Australia's forests

In addition to the forest use classification introduced earlier, the FVA applied a second layer of landscape classification using the 10 zones (Figure 2) proposed by Hobbs and McIntyre (2005). These zones were developed using both climate and vegetation. Climate was based on an agro-climatic classification incorporating a moisture index, growth index and seasonality. The climate classes were aligned to the existing Interim Biogeographical Regionalisation for Australia (IBRA) bioregions (Environment Australia 2000). Vegetation was broadly classified on the presence or absence of a tree layer and whether the understorey was grassy or shrub-dominated. A more extended discussion of these overlapping concepts of forest classification and their role in evaluating likely impacts and adaptation strategies is given in the FVA Synthesis.

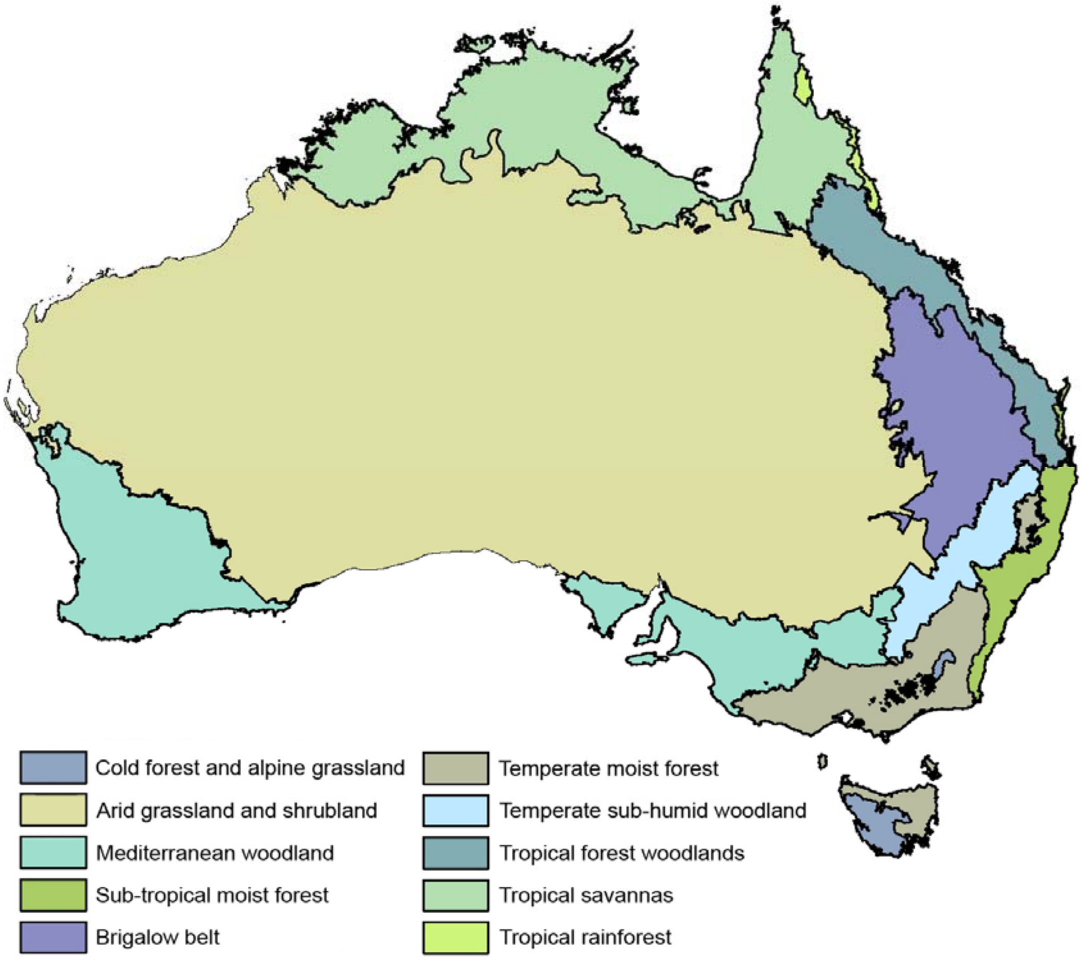


Figure 2 Agro-climatic biomes developed by Hobbs and McIntyre (2005) and used here as a framework to assess the regional impact of climate change on Australia's forests

1.1.4 Governance frameworks for Australian forests

Under Australian constitutional arrangements, the Commonwealth Government controls land use and management on land that it owns. Pursuant to the residual powers under the Constitution, primary oversight of the bulk of the national forest estate rests with the states and territories. This responsibility reflects state obligations for land use decisions as well as the ownership of a large portion of the national forest estate (Commonwealth of Australia 1995). The governance structure for forests differs in every state and territory and this affects the way policy and management decisions are made. In turn this has an impact on the way climate change adaptation is currently being perceived and managed. Furthermore, the differences in governance approaches impact on the capacity of commercial operators and conservation estate managers to adapt their plans and operational procedures to changing climatic and associated environmental conditions.

The Australian Government influences forest management through legislative power associated with foreign affairs, export licensing, taxation and spending programs (Howell et al. 2008). All jurisdictions are involved in planning, assessment and policy reviews through key intergovernmental cooperative arrangements. Key bodies include the Primary Industries Ministerial Council, the Natural Resource Ministerial Council, the Forestry and Forest Products Committee and the Natural Resource Policies and Programs Committee. The Forestry and Forest Products Committee provides the major forum for agencies to consider national forest policy issues (Montreal Process Implementation Group for Australia 2008). In this context, local government has an operational role determined by state and territory Governments. Arguably, it is through local government controls over local land use planning and rating systems that public and private forest management is affected (Commonwealth of Australia 1995).

COAG is one of the key intergovernmental forums for the negotiation of coordinated policy and the shaping of agreements. Recent national climate change action plans for commercial forestry, agriculture and biodiversity are products of these intergovernmental networks. A key Memorandum of Understanding (MOU) exists at a federal inter-departmental level between the Department of Environment, Water, Heritage and Arts and the Department of Agriculture, Fisheries and Forestry specifically setting out the departmental obligations for aspects of compliance monitoring of the Regional Forest Agreements (Hawke 2009). The governance framework for Australian forests includes multiple governance layers from global and international entities and initiatives through to local associations and networks all of which have an influence over the way forest policy is developed and forests are being managed. Forest governance is achieved through a complex array of interacting networks, formal and statutory arrangements.

A large body of legislation is applied by all jurisdictions to the forest estate as a whole. A number of reviews and documents have surveyed existing legislation and its importance to the forest estate. These include the following:

- Australia's State of the Forests Report 2008;
- Establishing Plantations in Australia: A Review of Legislative and Regulatory Frameworks 2007 (Plantations for Australia: The 2020 Vision, 2007);
- Independent Review of the Environment Protection and Biodiversity Conservation Act 1999-2009.

These reviews were silent with respect to specific statutory provisions to guide the forestry sector in adapting to climatic changes. Arguably, this reflects the situation that climate change in general and climate change adaptation in particular are new areas of legislative challenge. This situation could change at national and jurisdictional levels as a result of new policy drivers relating to climate change vulnerabilities, impacts and adaptation such as the 2004 policy on biodiversity and the 2009 inter-governmentally endorsed policy on commercial forests. The FVA has the potential to provide further impetus towards an integrated focus on climate change adaptation.

1.1.5 Climate change projections and scenario modelling

Actions to mitigate and adapt to ongoing climate change rely on modelling to predict how the climate will respond to changing atmospheric levels of greenhouse gases. There are four main areas of uncertainty in climate models (Steffen et al. 2009):

- The projected rate of production of greenhouse gases (emissions scenarios, see below)
- The relationship between the rate of greenhouse gas emissions and their atmospheric concentrations
- The rate and magnitude of the global warming for a given change in concentration in greenhouse gases
- Identifying region to region differences within global climate change scenarios.

It is difficult, if not impossible, to predict the amount of greenhouse gases that will be emitted in the future. The IPCC, the principal organisation assessing, synthesising and reporting on climate change literature, have developed four major emission scenarios (Box 1).

Economic Emphasis

Global Integration (left) / **Regional Emphasis** (right)

A1 storyline	A2 storyline
World: market-oriented **Economy:** fastest per capita growth **Population:** 2050 peak, then decline Governance: strong regional interactions; income convergence **Technology:** three scenario groups: **A1FI:** fossil intensive **A1T:** non-fossil energy sources **A1B:** balanced across all sources	**World:** differentiated **Economy:** regionally oriented; lowest per capita growth **Population:** continuously increasing **Governance:** self-reliance with preservation of local identities **Technology:** slowest and most fragmented development
B1 storyline	B2 storyline
World: convergent **Economy:** service and information based; lower growth than A1 **Population:** same as A1 **Governance:** global solutions to economic, social and environmental sustainability **Technology:** clean and resource-efficient	**World:** local solutions **Economy:** intermediate growth **Population:** continuously increasing at lower rate than A2 **Governance:** local and regional solutions to environmental protection and social equity **Technology:** more rapid than A2; less rapid, more diverse than A1/B1

Environmental Emphasis

Box 1 Summary characteristics of the four IPCC SRES emissions scenarios (from Carter et al. 2007)

Projections of climate change vary among models. For the purpose of the Forest Vulnerability Assessment project, it was determined that the working groups would use a single set of climate change projections. The “worst case” A1FI emissions scenario was chosen because current emission trends and climate observations closely track this scenario (Allison et al. 2009). Climate modelling was carried out using the SimCLIM modelling software (Warrick 2009).

To provide the present day baseline, the SimCLIM Model uses observed monthly-mean values of precipitation and mean, maximum and minimum temperature derived from the 1961-1990 baseline period (source: Australian Bureau of Meteorology), interpolated to a 0.25 lat/long grid. For future projections, it includes spatial patterns of change for these same variables from general circulation models (GCMs). In order to capture the four areas of uncertainty already discussed, there are three points within the SimCLIM model where different ranges of data can be selected to capture different levels of uncertainty. They are:

- **Climate sensitivity** which determines the *magnitude* of global warming in response to a given change in greenhouse gas concentrations.
- **Greenhouse gas emissions** which determine the *rate* of change of greenhouse gas concentrations and associated radiative forcing (capturing uncertainties 2 and 3 from the Steffen et al., 2009, list – see above).
- **Spatial patterns of change from general circulation models (GCMs)** which determine the *regional differences* in changes in temperature, precipitation and other climate variables.
- For this project the following specifications were applied for all projections:
    - Climate sensitivity – **high**
    - Emission scenario – **A1FI** (highest future emissions)
    - General circulation model – **the median value of an ensemble of 21 equally weighted GCMs**

Two time horizons were selected for the project, 2030 and 2070, to provide a mid- and long-term scenario in each case. Projections were made for annual rainfall, seasonal rainfall (all seasons for the southern half of Australia and wet and dry seasons for northern Australia), February maximum temperatures, days over 35ºC and days over 40ºC and frost days (days with minimums less than 0ºC).

A full description of the SimCLIM methods and a complete set of mapped projections is provided in both Work Package 1 (Wood et al. 2011) and the FVA Synthesis Report (Boulter et al. 2011)

Projected changes in climate factors

Under current climate change projections there is a high certainty that across Australia temperatures are likely to rise in response to global increases in CO_2 (CSIRO and Bureau of Meteorology 2007; IPCC 2007; and Wood et al. 2011). Annual rainfall patterns and moisture availability are likely to change, but a general trend of increases or decreases is less clear and is mainly dependent on location.

The key climate-related changes that will most likely have an effect on forest system functioning in Australia are summarised below.

Atmospheric CO_2 concentration: The atmospheric CO_2 concentration is currently 380 ppm; estimates for the year 2099 range from 600 ppm under a low-emission scenario, up to 1100 ppm under a high-emission scenario (Sitch et al. 2008).

Temperature: Maximum and minimum temperatures are projected to increase in all regions and seasons. By 2030, increases of approximately 1ºC are projected, with the greatest increases occurring in inland Australia. By 2070, increases of as much as 4ºC could occur.

Extreme hot days: Increases in the number of extreme hot days are expected. By 2070, large areas of interior Australia in particular would be facing average daytime temperatures in February in excess of 39ºC.

Snow and frost: Duration and occurrence will likely decrease across Australia.

Precipitation: There is considerable uncertainty around future trends. Current best estimates of annual precipitation change indicate possible increases or little change in the far north and decreases of 2% to 5% elsewhere. There could also be changes in seasonality. In Northern Australia, projections indicate that the wet season will get wetter and the dry season drier. In southern Australia, widespread decreases in rainfall are likely to occur during winter and spring. The west and southern coasts are likely to show decreases in rainfall in all seasons.

Storms: More severe and/or frequent storms are projected, including an increased occurrence of damaging hail and windstorms. Rainfall intensity is also likely to increase, which may lead to more flooding.

Potential evapotranspiration: Annual potential evapotranspiration is currently projected to increase across Australia. Best estimate projections reported by CSIRO (2007) are for an increase in potential evaporation of 6% in the south and west, and 10% in the north and east, under the A1FI scenario by 2070. However, new research demonstrating non-stationarity in other climate variables affecting the process of evaporation, particularly wind speed (see Roderick and Farquhar 2004, McVicar et al., 2008, Donohue et al., 2010) suggests that these projections need to be re-modelled using all the forcing meteorological variables (net radiation, vapor pressure, wind speed and air temperature).

Droughts: With decreasing rainfall, increasing potential evapotranspiration and higher temperatures, drought occurrence is projected to increase over most areas, but particularly in southwest Australia.

1.2 Work Package 1 and the Forest Vulnerability Assessment (FVA)

This report documents the findings of *Work Package 1: establishing needs and consultation with key stakeholders* component of the Forest Vulnerability Assessment (FVA) project being undertaken by the National Climate Change Adaptation Research Facility (NCCARF).
Three key objectives framed the research project undertaken by Work Package 1:

i. To identify key issues to be addressed in the Forest Vulnerability Assessment;
ii. To determine to what extent climate change adaptation is being considered in current planning and management;
iii. To determine the type of information that is needed by forest managers and policy makers.

The outputs of Work Package 1 were designed to inform the activities of the other Work Packages as well as subsequent programs. The approach taken by Work Package 1 elicited a stakeholder view of the issues facing organisations through a series of interviews. At the same time, the project team sought to engage and build collaborative support for the project as a whole. Using this approach, Work Package 1 explored the issues that were upper-most in the minds of stakeholders at the time the interviews were conducted.

2 Stakeholder engagement methodology

Stakeholder engagement was a crucial determinant of the research methodology used. The methodological approach used complemented the needs of both participants and collaborative research partners in the other Work Packages as well as ethical demands for the maintenance of confidentiality.

Qualitative research methods were chosen for this project because they provide the potential for an in-depth approach which can combine direct engagement with data collection. Qualitative research aims to capture "*the meanings, definitions and descriptions*" offered by participants which are then analysed according to emergent themes and the data is reported using the language of participants (Minichiello et al. 1996). Researchers can maximise the possibilities of obtaining the most relevant data by talking with the most knowledgeable people and then following leads to other sources (Glaser 1978).This method allows researchers to 'purposefully select cases' or potential key informants on the basis of them being a perceived source of rich information relevant to the study. This is just one of the many 'purposeful' sampling strategies that is described in Patton (1990). Purposeful sampling was chosen because it offers an efficient means of identifying and confirming the relevance of key informants. An additional strategy was employed, that of snowball or chain sampling, in which referrals from an initial purposeful sample are selected based on relevance to the research. Snow ball sampling demonstrates sensitivity to potential participants, in that they are identified by people with a similar experience (Oliver 2006) and helps to establish improved levels of engagement through referred and inferred project legitimacy. In order to avoid the problems of insular sampling, a broad range of engagement points are necessary.

For this project the sampling was directed towards gaining an insight into sectoral knowledge about the impacts of climate change on forests as well as organisational intentions focussed towards climate change adaptation. We sought to engage with people who were able to provide a depth of industry insight based on knowledge and experience as well as an overall appreciation of the issues facing their organisation. Therefore we purposefully sought to interview people involved at a more senior level within organisations.

2.1 Selection of participants

The selection of participants involved two strategies. At the commencement of the research project forest and conservation related organisations in Australia were mapped to gain an overall picture of the types of organisations involved with forests in Australia. This was achieved through an internet survey of jurisdictional, industry and conservation group websites. The web sites of advisory bodies, local and regional representative bodies and single interest groups were also included. Organisational structures and profiles were mined for potential contacts and supplemented by contacts provided by researchers from all FVA Work Packages, the FVA steering committee and a stakeholder reference group were engaged to ensure that the FVA met stakeholder needs and addressed relevant issues. Heterogeneous groups and individuals were deliberately targeted in this initial process.

Potential key interview candidates were identified and contacted in each of the federal, state and territory jurisdictions based on the initial stakeholder mapping process undertaken. Several of the key organisations contacted chose to nominate a person or persons who were considered to be the most relevant, based on their position within the organisation. The second strategy involved these key stakeholders being asked to nominate additional potential participants who were likely to be able to contribute further rich information relevant to the project – a purposeful sampling strategy often referred to as snow-ball or chain sampling. Participants were selected from this pool with the aim of capturing people engaged in both forest policy and forest management. Multiple chains with various entry points were used to maximise potential coverage of the sector across different scales and focal points. This resulted in both a convergence and divergence of referrals.

Stakeholders were chosen from a broad cross section of forest management, policy and research and included the following:

- Native forest managers – State Forest, National Park and Conservation Reserve Managers;
- Private landholders with significant forest estates – farm forestry representatives were included in this group;
- Plantation industry managers – Managed Investment Schemes (MIS), State Forest plantation managers and government plantation companies;

- Non Government Organisations (NGO's) - incorporating managers of environmental plantings and restoration forests as well as industry representative bodies;
- Forestry research organisations and forest policy analysts.

These stakeholder categories ensured coverage of primary, secondary and tertiary stakeholders as identified by authors such as de Groot et al. (2008). Additionally, the categories also provide coverage of the multi-layered governance framework for forests in Australia.

2.2 Semi-structured interviews

Semi-structured interviews are an important tool for qualitative research which seeks to reveal how people attach meaning to and organise actions (Minichiello et al. 1996) .Semi-structured interviews based on a set of open-ended questions were utilised for this project because they allow a more natural conversation and therefore facilitate the establishment and maintenance of rapport during the interview. Moreover, this style of interview permits the researcher the flexibility to deviate from any proforma to follow rich veins of conversation, thereby aiding a greater depth of researcher understanding. At the same time, the interviewee has greater freedom to elaborate and return to previous topics as ideas or experiential references are triggered by later conversation. The use of a guiding proforma helps to ensure that the conversation is kept relevant to the study, reduces the potential for any premature analysis and creates a framework for comparative analysis. Use of a guiding proforma also ensures a basic level of consistency between different interviewers where this is necessary.

2.3 Literature search and document collation

A limited literature search and document review was conducted as part of the scoping of issues relevant to production forestry, forest conservation, climate change impacts and climate change adaptation. This was done to ensure that the underlying design of the research project was relevant (Minichiello et al.1996) through a review of theoretical frameworks, of current management practices, issues and broader contexts of decision making for forests in Australia, and to identify climate change adaptation initiatives being undertaken in relevant forest sectors. In addition, this review was used to enhance the verification and triangulation of data produced through the interview process. The search involved a wide range of materials including peer-reviewed journal articles, industry guidelines and manuals, reports and documents produced under the auspices of government departments, website resources and published literature. Where possible documents identified by participants were sourced and included. This review is reflected in the bibliography and a range of key documents have been identified in Annex 1.

2.4 Process

Figure 3 sets out the overall process followed by Work Package 1. The diagram identifies the major steps and relationships.

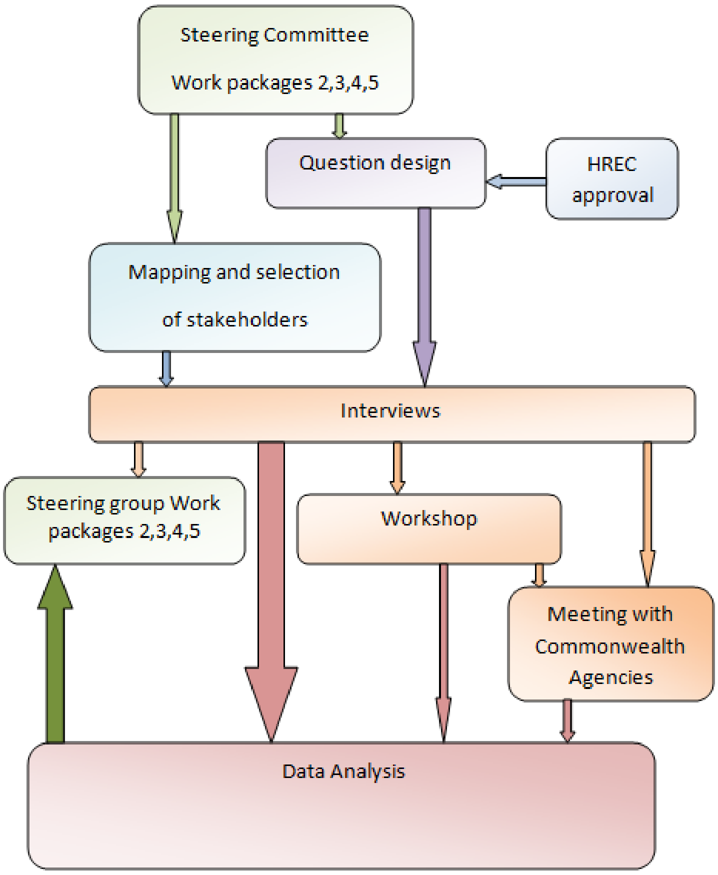


Figure 3 Flow Diagram for Work Package 1 research process.

2.5 Human ethics approval process

Ethics approval for the project was subject to a National Health and Medical Council human ethics process and was granted through the University of the Sunshine Coast's Human Research Ethics Committee (Approval: HREC A/09/198). This was later modified to permit the sharing of non-identifiable data with the principle investigators from Work Package 4: Adaptation options, tools and vulnerability (Wilson and Turton 2011).

Approval was given for the conduct of interviews and workshop. The research questions were also reviewed by the committee and approved (see Annex 2). The key ethical considerations adhered to during the project included:

- maintenance of the confidentiality of participants;
- voluntary participation, participants had the option to withdraw at any stage;
- informed consent.

2.6 Question design

The initial phase of question design was an iterative process undertaken in consultation with other Work Packages and NCCARF. Input and comments were sought and questions were incorporated and/or amended to meet the needs of each of the Work Packages, in particular, those of Work

Package 4 (Wilson and Turton 2011). Questions were designed to capture data about biophysical as well socio-economic aspects of forest management and the implications and interactions of climate change with these issues.

An assessment of the general knowledge and awareness of the biophysical impacts of climate change was one of the key themes embedded in the questions. Therefore, several questions focused on vulnerabilities and sensitivities to the impacts of climate change on forests. Others were designed to gauge adaptive capacity and to explore the extent to which planned adaptation was already being considered. A further question was included to gain an understanding of the perceived constraints to adaptation for forestry stakeholders. Consistent with the need to establish a baseline for future assessments, questions also explored current issues, forest management contexts, strategies, tools in use and the collaborative environment. One set of questions explored participants' current and proposed involvement in the carbon sequestration market. Finally a group of questions was included to obtain some general demographic and background data. Two closed-ended questions were included to probe the relative importance to participants of a set of key biophysical drivers of forest health and productivity (rainfall variability, fire frequency, drought, weather extremes, diseases, weeds and pests). Participants were asked to rank on a Likert scale of 1-5 (with 5 being very important) how important they considered each issue with respect to forest policy or management as each one was read out to them.

Comments were made by participants about the thought-provoking nature of the questions, with one subsequently asking about the possibility of using the questions within their organisation to facilitate in-house discussion about the topics covered.

2.7 How the questions were used

Two versions of the basic questionnaire were prepared for interviewers to use. At the commencement of the interview participants were asked whether they saw their predominant role as either engaged in forest management or forest policy. From this point, interviewers chose whether to use a full or abbreviated version based on how participants self identified their role. The full questionnaire was used for forest managers. The second, abbreviated version used for policy-focused participants omitted those questions pertaining to land tenure, forest use and forest type that were deemed irrelevant for those not engaged in actively managing forests (See Annex 2 for the full version. The abbreviated version omitted question 4b through to 4f). The basic questionnaire was piloted with forest sector stakeholders to remove redundancy and improve the flow.

2.8 Conduct of interviews

Participants were contacted initially by telephone and invited to take part in the interview. This contact was followed up with a confirmation email providing them with a copy of the Human Ethics approved Informed Consent information. Potential participants were able to withdraw from the process at any stage.

The interviews were conducted in conjunction with a researcher from Work Package 4 (Wilson and Turton 2011), James Cook University. In all, 34 telephone interviews were undertaken. With the permission of participants, these interviews were digitally recorded and later transcribed. Interviews lasted between 30 and 90 minutes with a median length of 42 minutes and together amount to a total of 1634 minutes. A strong willingness to participate was noted, participants were pleased to be able to share their thoughts and experience. Annex 3 provides the list of interviews and corresponding code used in this document for quotations taken from transcripts.

The team of interviewers were fully briefed and participated in a professional development workshop to refresh interview skills prior to the commencement of interviews.

2.9 Scenarios for climate change

Early in the project process a need was identified by the Work Packages and stakeholders for climate change scenarios. A series of scenario outputs from CLIMsystems Ltd were commissioned, in the form of maps, for changes in rainfall (northern Australian wet and dry seasons, and southern seasonal), maximum temperature and frost for the time slices of 2030 and 2070. The scenarios produced utilised accumulated data provided by the Australian Bureau of Meteorology. A brief overview and the outputs prepared by Richard Warrick and Yinpeng Li from CLIMsystems Ltd are included in Annexes 5 and 6 respectively.

The climate change scenarios provide a ‘probable representation’ of change from climate baseline that can be used for exploration of possible worst case conditions. They should not be viewed as a prediction; rather they are projections of possible changed climate conditions. Scenario outputs can be used as a visual tool for ‘future thinking’ exercises which inform questions central to climate change adaptation. This approach was used when demonstration scenario outputs were presented at a stakeholder social learning workshop. In this context scenarios are viewed as a tool to generate discussion, not as a decision support tool.

2.10 Stakeholder social learning workshop

NCCARF held a one and half day stakeholder workshop on the 18th and 19th of November 2009 to enable Work Package teams to share preliminary findings with stakeholders, the FVA Steering Committee and each other. A key purpose of the workshop was to inform the work of Work Package 4 (Wilson and Turton 2011) by tapping into the expertise of the workshop participants. Specifically, the workshop organisers sought to be informed by the stakeholders about:

- climate change and forests;
- what climate change impacts they were observing and anticipated to observe in the future;
- their understanding of forest vulnerability to climate change;
- the available adaptation options; and,
- the barriers to adaptation.

Work Package 1 provided some input into the development of the overall agenda and facilitated the attendance of participants who had indicated their desire for further engagement during the interview process.

The discussion and observations from the workshop have informed the finalisation of the stakeholder needs analysis as a core task of Work Package 1.

2.11 Meeting with Commonwealth stakeholders

At the conclusion of the Brisbane stakeholder workshop, the need for further consultation with Commonwealth Government Agencies was identified. Subsequently, a meeting was convened in Canberra by a representative of the then Department of Climate Change (DCC). Email invitations were sent out by DCC and the meeting was attended by representatives from:

- The Department of Agriculture, Fisheries and Forestry;
- The Department of Climate Change;
- The Australian Bureau of Agriculture and Resource Economics;
- The Bureau of Rural Science;
- The Department of The Environment, Water, Heritage and Arts; and
- Two Work Package 1 researchers from the University of the Sunshine Coast.

The format for the meeting was an un-chaired round table, free flowing discussion which lasted two hours. Those attending had been provided with a list of dot points of what Work Package 1 were interested in discussing. However, this list was not used as an agenda.

The purposes of the Canberra meeting on the 3^{rd} of December 2009 (which methodologically has been treated as a group interview), were to:

- provide an opportunity to acquaint those present with the Forest Vulnerability Assessment project as a whole;
- encourage engagement with the project by Commonwealth Agencies; and
- explore the types of project outcomes that might be most useful for the Commonwealth.

The meeting provided Work Package 1 with an opportunity to explore structural and operational arrangements between agencies as well as discussing issues from a national perspective. Additionally, the meeting enabled a general discussion of relevant background material, with a focus on accessibility of information holdings. Key national holdings of forest resource information were confirmed.

2.12 Analysis of interview data

The focus of the research was on climate change adaptation within the forestry sector from a variety of perspectives and across different regions of Australia.

The taped interviews were transcribed verbatim. The transcripts were then checked for accuracy and edited where necessary to correct the spelling of technical terms and fill in words missed by the transcriber. Each interview, whether it was a single person or several people being interviewed, was treated as a separate source document and unique codes were assigned to each transcribed interview document to allow referencing in a way that would protect the identity of the informant/participants. The documents were then analysed within the computer program NVivo version 8 (QSR International Pty Ltd., Melbourne, 2009).

As the interview data were being shared by researchers from Work Package 1 and 4, there was a strong collaboration in the analysis of the interview-derived data. An initial set of codes (set up as nodes within NVivo) was derived based around the themes being explored through the semi-structured interviews and the specific objectives related to WP1 and WP4. One of the more 'information-rich' interview transcripts was coded independently by two members of the research team to trial the utility of the basic coding system, which was fine-tuned in the process to ensure consistent coding. Key attributes of the interviewees were set up within the Casebook feature of NVivo to capture the characteristics of those being interviewed in the 34 interviews and to facilitate some degree of stratified analysis across the sub-groups of stakeholders represented. Each 'interview' was assigned values of each attribute where they were applicable, based on who or what they represented and some personal details. Attributes included: jurisdiction (specific state, territory or 'national'), types of forests (native, plantation, a combination of native and plantation and other), 'forest use' (extraction, conservation only, both), role (policy, management or both) and 'climate zone' (north, south). Participants from Queensland and the Northern Territory were classified as "north" and all others as "south" due to the geographic location of interviewees. Age category, years of forestry experience and gender was also noted.

The sharing of the NVivo project between WP1 and WP4 was facilitated by one researcher from each group working closely together on the analysis. Essentially, different sets of codes (nodes) were pertinent to each Work Package, although some codes that represented generic themes were utilised by both. For WP1, the following themes were explored in the analysis of the interview data:

- Key forestry issues of concern to the stakeholder (irrespective of climate change adaptation);
- The extent to which climate change adaptation was incorporated into their current planning/practice;
- Information needs expressed by the stakeholders.

In the process of exploring these central themes above, new issues emerged from the data and were coded as either sub-nodes within a tree structure or as free nodes. The tools built into NVivo allowed bits of information-rich text to be indexed at one or more nodes and for memos to be created around the developing ideas on possible relationships between various issues. Matrix queries built around cross-tabulating information coded at selected nodes and attributes supported the aim of exploring the range of perspectives expressed by different groupings of the stakeholders. These functions and the mechanics of renaming and collapsing overlapping categories and shifting nodes to reflect a growing understanding of the data were supported efficiently within NVivo 8.

2.12.1 Analysis of categorical data

The results from the closed-ended questions about the importance of biophysical drivers (rainfall variability, fire frequency, drought, extreme weather, diseases and weeds and pests) were calculated for climate zone, forest type, and forest use. In each case the responses to the Likert scale questions, with 1 representing *not important* and 5 *very important* were entered into SPSS 10.0 (SPSS Science, Chicago).

The climate zones used for this analysis are:

- **Northern** – this group includes participants from Queensland and Northern Territory;
- **Southern** – this group includes participants from the all of the southern states as well as those from the southern parts of Western Australia;
- **National** – this group includes those with a national focus and those with operations in both northern and southern climate zones.

The forest types used for this analysis are:

- **Native forest** – this category includes remnant forests on all types of tenure;
- **Plantation** – this category includes any form of forest planted from seed, seedlings or cuttings;
- **Both plantation and native forests** – many participants manage both categories;
- **Researchers and policy analysts**[1].

The forest uses were coded to capture any differences that might appear between forests managed for production or extraction values and those managed for conservation values:

- **Production** – forests managed primarily for production or extraction of products;
- **Conservation** – managed for conservation only;
- **Both** – those that could not be allocated to a single category.

[1] Among those interviewed were several who have multiple linkages to different aspects of forest policy and management: actively managing forests themselves and at the same time serving on advisory boards and industry representative bodies. This complexity means that on occasion they operate as lobbyists.

3 Results from stakeholder consultation

3.1 Stakeholder group categories

3.1.1 Policy and/or management

The majority of participants had extensive experience in forest work, gained over many years in the sector and most held senior positions in their respective organisations. Included within the mix of participants were farmers with integrated plantings, Managed Investment Scheme organisations financed by large institutional and foreign investors, various forestry and farmer representative organisations and forest industry researchers. Both policy and management people were targeted in the selection of participants and in the final mix there was a good representation in both categories. We interviewed many who identified as being engaged in both a policy and a management role (10 policy, 18 managers and 6 involved in both capacities). Stakeholder selection ensured that we interviewed participants engaged in both policy and management for production and conservation forests. In the larger, state-based organisations there is a structural and institutional differentiation made between a policy body and management enterprises set up as state-owned forest production for profit statutory bodies. Participants were also drawn from both of these categories.

3.1.2 Forest use, forest type and land tenure

Participants were asked to nominate which of the stakeholder categories fitted their profile. Many nominated more than one category. This is also reflected in the identification of multiple forest types and forest uses by forest managers. Some amplified their responses with explanations:

- A participant from south east Australia noted perceived differences in understandings about farm forestry: *"it's a little bit more than farm forestry approaches. It's a little bit more than the odd wood lot here ….it's quite an active land lease market down here. A lot of the forestry companies lease land off farm owners, farmers, to farm up the trees. So it's not just simply farm forestry as people romantically think of it… But, you know, it's a more complex business down here than anywhere else."* (F1)[2]
- Another participant pointed out : "*we're a fully integrated company, not just a plantation company*" (E6)
- A South Australian noted that: "*our industry is solely based on plantations. There's no harvesting for commercial reasons of any native forests…."* (A3)
- One plantation manager, with extensive range land grazing interests explained: "about *half of the forest that we run in northern Australia are native forests, the other half is plantation forests, and native forests are unavailable for clearing and they provide a wealth of natural biodiversity*" (E5)

[2] See Annex 3 for a list of audio and transcript files from participant interviews

- A conservation forest manager indicated that in addition to state owned native forests they were responsible for operating : "*a plantation scheme which provides the offsets for the whole of the state government vehicle fleet*" (A1)
- A state government forestry manager stated : "*We're a multiple use manager, so we manage plantations, production native forest and reserves equally*" (C2)
- A manager from an organisation involved in restoration forest described their perspective saying *: " We're about indigenous species and recreating bio-diverse landscapes"* (G2)

Table 4 indicates the range of forest uses nominated by the participants interviewed. It also shows the forest types managed by these same people. Participants who self- identified as solely or mainly engaged in forest policy were not asked specific questions about forest use, forest type or land tenure. This did not prevent policy-focused participants from raising and discussing relevant issues related to forest use, forest type or land tenure.

Table 4 Forest use, forest type and land tenure managed by participants

Forest Use	~n	Forest type	~n	Land tenure	~n
Grazing	11	Plantation forest	12	Freehold	18
Cropping	1	Private native forest	7	Native title	7
Timber production	16	Farm Forest	1	Leasehold	12
Conservation	14	Restoration Forest	6	Crown land	9
Carbon Credits	4	National Park	6	Reserve	7
Recreation	9	State Forest	8	National park	5
Heritage values	11	Grazing Lease	6	Unallocated state land	1
Woodchip production	1	Nature refuge	1		

The area of land managed by stakeholders interviewed ranged from 500 hectares through to 38,000,000 ha. Individual stakeholders were found to manage forest land with several different types of land tenure. One participant involved in both policy and management for conservation forest explained that their organisation provided stewardship oversight for: "*a mosaic of different tenures …I don't manage tenure, I manage the landscape*" (B2). Table 4 also sets out the types of land tenure identified by stakeholders interviewed including forest areas subject to native title. The area of land subject to covenant is expected to rise along with sequestration efforts and this was perceived to have implications for the valuation and disposal of assets (n=2).

3.2 Key Issues raised during interviews

When asked during the initial stages of the interview about the most pressing forestry-related issue/s facing them or their constituency, the responses of participants were quite varied in both nature and depth. Most of the issues raised could be classified broadly as focussing on either biophysical, socio-economic or governance issues and the nature of their key concerns generally reflected whether they were dealing with native or plantation forests or both. Forest researchers and higher level policy analysts stood out as two distinctive sub-groups, raising issues that cut across both types of forests. A summary of these key issues of concern raised by participants is presented below under the broad headings of biophysical, socio-economic or governance with key differences between some of these groups highlighted. Where geographical location also seemed to influence the types of priorities raised this is highlighted.

3.2.1 Biophysical issues

The key biophysical issues put forward by participants ranged from general concerns about how forest systems might be impacted by climate change with regards to biodiversity, water, ecosystem health and sustained yield, to very particular concerns that were location and context-specific. Alongside concern about general species loss, changes to species diversity within ecosystems and impacts on ecosystem services, the potential for future extinctions was raised. One researcher pointed out that there had been a localised extinction of a eucalypt species (not identified during the interview) in the northern Flinders Ranges after an extreme heat event (C4). One participant responsible for conserving native forests including national parks highlighted the importance of two related issues: understanding the implications of climate change on our reserves and maximising the resilience of our reserves to be able to adapt to climate change (B3). Matters raised by participants in regard to biodiversity protection include connectivity, recruitment, forest succession and regeneration, fragmentation and the integrity of buffer zones. The feasibility of creating climate migration buffers to enhance opportunities for the movement of biodiversity across the landscape were also noted.

Disturbance pathways caused by drought, fire, weeds and pests, feral animals, grazing and extreme weather events were among the main points of concern raised for conservation forests. One participant highlighted the pressing need to manage and protect reserves against a broader range of threats in the future such as : *"changes in fire regimes, changes in wind, changes in pollinator yields and potentially changes in pest animals and plant diseases instead of… just the current primary threat of grazing"* (G4). These issues were also reflected in the discussions at the stakeholder workshop.

Concerns that centred on fire, fire frequency, and fire intensity cut across all stakeholder groups interviewed. A South Australian participant reported concerns about possible changes in the seasonal activity of storms, resulting in an increase in the number of fires ignited by lightning (E10). Other concerns were raised about shrinking weather windows for prescribed burns and the problems of preventing fire escapes even in benign fire conditions (C2). Social licence issues were raised in relation to smoke hazards created during these activities (C2). Native forest managers reviewed in detail the problems for fire management and the protection of life and property in the urban interface zone, where residential and key essential services are located in close proximity to forest areas (n=2). Questions about the capacity of emergency services to respond to larger, more intense fires were also raised (G5).

Issues connected to changing fire regimes as a result of climate change and the impact of fire management on carbon storage were also raised by native forest managers. This particular issue was also raised by those responsible for both native and plantation forests in the context of: *"production forests being converted into national parks and the relative fire fighting capacity of, and access for fire fighting capacity in production forests versus national parks"* (E3). Possible impacts of fire on the security of carbon in sequestration forests was discussed as a concern (C4) as well as the overall impact of climate change on carbon storage within reserves (A1).

Those involved in plantations also raised a suite of general issues related to the capacity of their existing plantations to cope and remain productive under changing climate regimes. In terms of productivity for commercial forests, participants noted issues in relation to:

- Species and provenance selection, tolerance and survival;
- Future growth rates, the potential quality and quantity of timber produced and reliance on narrow range of species;
- Water use and availability, potential drought mortality and slower establishment.
- Limited sources for seed; and
- Rates of change in relation to cropping rotations were also mentioned in this regard.

Quite often the coping range of specific species in relation to predicted future rainfall patterns was mentioned. One participant used the example of *radiata* pine growing best in areas with >700mm rainfall, making some plantations in that state marginal (C3). In the southern areas, annual rainfall totals falling below the tolerable thresholds appeared to be a consistent issue. Connected with this was the pressing issue of land availability and the need to move into new microclimates to maintain the productive capacity of plantation forests (E5). It was observed by one participant that this had resulted in forest activities being: "*forced out to areas that are drier and drier to get access to land*" (F1).

Soil moisture was one of the key issues for plantation forest managers interviewed. The importance of this was further highlighted during the workshop. This was made clear by one participant engaged in regeneration planting who pointed out : "*Currently the soil moisture in western Victoria at the bottom end of that...are as low as they were 10,500 years ago at the end of the last glacial…. So soil moisture and the availability of water and our capacity to reforest and grow things is severely limited*" (G5). Uncertainties about future soil moisture were raised by participants along with their desire to have the means to accurately incorporate this into production projections. Salinity and soil erosion issues also figured in the interviews. Problems with soil erosion for plantations in northern Australia were highlighted (n=2). For a participant from the West the current problem of too much soil moisture was an issue: "*one of the issues that our loggers face is that there are quite strict rules now for soil protection reasons for not logging in wet areas. So they really notice the rain when it comes down because it stops them working. The loss of working days through rain has been one of the biggest issues*" (F3).

Weeds were noted as an ongoing problem that requires consistent management. The presence of declared weeds in forests necessitates a range of measures irrespective of the forest use or forest type. Some spoke of requirements for wash down facilities, others of the costs involved in management. Plantation forest managers have more options available for management in that they can use grazing, regular spray regimes and mechanical means for control (F4). Nonetheless, plantation managers noted the problems that weeds cause during the establishment phase with weeds creating competition for water and nutrients (F4). For conservation forest managers the problems are exacerbated by recreational forest users spreading weeds. When discussed in relation to climate change, uncertainty about new weeds and the movement of weeds across the landscape was noted.

Wind impacts were also discussed by several plantation managers. One indicated that: : "*Wind is the most damaging, more damaging than pests, more damaging than fire, more damaging than drought*" (E5). Management of windthrow risk (C2), storm and cyclone damage were also mentioned. Two plantation managers explained how possible wind impact from cyclones was taken into account during the land selection process. A southern forest policy manager pointed out the importance of silvicultural practices to reduce wind impact on plantation forests.

The most important issues raised by participants in relation to plantations in the northern climatic zones were quite different and more varied than the south. Dealing with changing patterns of rainfall was raised again, but rather than annual totals, one participant from Queensland highlighted the need to consider the changing distribution of rainfall through the entire year. The issue was presented in these terms: *"high levels of rainfall over a three to four month period .....followed by long dry spells before the next heavy rainfall events at the end of the year, cause the trees to go from a stressed level for three to four months of water inundation, then dry out very quickly to drought stress, very little rainfall in between*" (E2).

Another category of concerns raised by several participants responsible for plantations in the northern climatic regions was pests and diseases. This was described in the following way: *"the rapidity with which disease can spread through the plantations and the need to be pretty vigilant given that it's a globalised travel market and there are things that are being introduced all the time in people's luggage and horticultural plants. New pests and new diseases are appearing much more rapidly in Australia than they ever have in the past, so that's one very, very pressing issue"* (E8). Other participants described problems with specific plant pathogens and raised the need to direct research into finding more tolerant species as an adaptation response. Possible connections were also made between disease outbreaks in plantations and the issue of prolonged inundation mentioned above (E2).

Disease concerns were also raised by southern forest managers. One participant discussed his concerns: "*The spread of dieback is noticeable and according to the conservation commission it's increasing…. It's spreading like fury in the national parks where everyone goes*" (F3).

Other biophysical issues raised by participants representing production forests dealt with the following:

- a need for more localised climate modelling to help plan appropriate adaptations built around species selection and water management (n=2);
- "*getting the genetics right*" (n=2);
- management strategies for dealing with soil erosion and catchment management issues that are appropriate to the northern climatic regions (n=2);
- the difficulties associated with changing landscapes from agricultural landscapes to those which have an integration of forestry; (n=2) : "*It has to be a landscape approach, trees and agriculture integrated systems .... It's not just carbon credits for trees, but where are the trees going and how does that affect the landscape with regards to agricultural production*" (E9); and
- the most appropriate ways to deal with forestry residue and the co-benefits that can be achieved.(n=4) : "…*opportunities to manage vegetation to minimise fire risk or hazard by using those fuels for other uses. So if they're not burnt or grazed, using them as a biomass for some use*" (F5).

The biophysical issues raised by stakeholders are summarised in Box 2.

Box 2 Summary of Biophysical issues raised

Production	**Conservation**
Reduced plantation productivity	Threats to biodiversity
Changes in rainfall	Impacts on capacity for regeneration
Escalation or change to disturbance pathways (weeds, pests, diseases, extreme weather events, drought, fire, wind)	Escalation or change to disturbance pathways (weeds, pests, diseases, extreme weather events, drought, fire, wind, human interference)
Increased risks related to fire	Increased risks related to fire
Water availability and management	Water availability and management
Soil conditions	Soil conditions
Temperature	

3.2.2 Socio-economic issues

Economic issues of concern were prominent in the majority of interviews across both the native and plantation forestry sectors. Many of the issues raised revolved around how the forestry industry could gain the most advantage out of the proposed Carbon Pollution Reduction Scheme and carbon trading in general. In the words of one policy analyst: "*upper management are looking into every source of possible revenue streams which include carbon sequestration*" (E2) and another : "*again a lot of attention on the policy, writing submissions, writing information sheets, putting information up on the websites specifically related to forestry and carbon sequestration and the potential for carbon credits and carbon trading"* (E3).

Specific issues ranged from the recognition of stored carbon in harvested timber to the promotion of farm-based forestry for carbon credits: "*My dream was that farmers would put 10, 20, 30 per cent of their farm under managed plantations and get carbon credits for it, which would be beneficial. They would get cash flow from the carbon credits, because farmers are cash poor and asset rich. So it's improving the cash flow. My dream was that carbon credits would address this issue and so far it's not happening"* (F4).

While these issues relate to climate change mitigation rather than climate change adaptation, its expressed importance to the industry has come through strongly. Also, as one participant noted: "*there would be constraints on how we manage forests for wood outcomes or for timber outcomes versus potentially carbon trading*" (C3).

Even the conservation forestry sector has actively engaged with the carbon issue within a mix of other priorities. For example*: "couple of hundred hectares which was almost all cleared when we obtained the property and we're re-vegetating it back to a full woodland cover over a period of time and, as part of that, we're accounting for the carbon that goes in that by the same rules as the Commonwealth uses, but we're doing it not to go to the market place but to be able to talk to our supporters and members and say we're offsetting emission [inaudible] organisation*" (G7).

Many issues were raised about land-related matters. The first of these involves concerns about land clearing and the impacts of land clearing moratoriums on operations (n=2). Some participants raised concerns about land availability, particularly land that was going to be suitable for growing productive forests in a climate-changed future (n=4). Others raised the issues of conflicting land-use and problems of plantations competing with agriculture for prime productive land (n=2). One east coast participant explained how councils consider forestry a change of practice and this was leading to problems for the expansion of plantations (C1). Other participants saw the push towards broad scale biosequestration as a threat to the viability of future food production (n=2). The availability of suitable land for any expansion of the conservation estate was also discussed (n=2).

Water issues were raised by both conservation and plantation managers, as well as by policy analysts at a national and state level. Concerns were raised at various scales, relating to catchments and regional aquifers. One conservation manager explained the complexities faced in the management of water points during drought conditions. For plantation managers the ongoing availability of water, water quality and possible restrictions on sources were noted as an issue. Several spoke about the implications of moves to licence non-point source water, others about concerns linked to bio-sequestration and water use.

Staffing and personnel concerns were raised both in terms of a loss of people from the sector with specific skills and a lack of people willing to engage in manual labour (n=6).

Economic viability was raised by participants involved with both plantation and extraction of timber from native forests. In this regard, one participant noted that the quality of logs had deteriorated and the cost of production had risen resulting in: "*making the industry only marginally viable and so we've had these long discussions in the industry about economic viability*" (F3). Participants from Western Australia, South Australia and Queensland pointed to concerns about shortages of timber and potential problems meeting supply agreements. Other participants discussed issues related to return on investment and the predictability of return. One participant reported problems associated with raising finance for farm forest projects associated with biosequestration because banks were assessing proposals in a context of legislative uncertainty and possible restrictions on tenure such as covenants (F6).

Concern was raised by participants during the interviews and during the workshop about reduced funding and availability of Research and Development in the sector. One policy analyst observed that: "*increasing pressure on R&D resources generally as a result of climate change issues emerging which are taking a lot of the process away from the traditional pro-activity based research areas which is still vital*" (F2).

Several concerns were raised in relation to forestry communities and the need for social infrastructure when forestry operations decline in traditional areas and move to new locations. A northern plantation manager pointed out some problems their operations have faced: "*A lot of our roads get closed over the wet season so we can't actually access our properties with, in some cases, even light traffic. So the setting up of infrastructure. We've got no electricity down there. There's no community settlements down there. So all those sort of social issues that go with forestry organisations and getting them set up in a new area*" (E7).

Conservation park managers raised issues linked to population growth including urban encroachment, and increased visitation. They raised concerns about impacts on amenity and cultural heritage. Changes in community expectations were also raised as an issue, particularly in terms of management of national parks. Disturbance pathways were also seen as impacting on resources within tight budgets. Participants observed that against other community demands conservation issues didn't always rate highly enough to be adequately funded. Comments in this vein included: *"the most pressing issue is really some kind of adequate conservation status and, I guess, the environment portfolio is always a second and poorer cousin to the production and human societal management component"* (C4).

Box 3 Summary of socio-economic issues raised.

Production	Conservation
Policy and regulatory environment	Biodiversity and ecosystem services
Productive capacity	Disturbance pathways – impacts of fire, weeds, extreme weather events, disease
Land use conflict and availability	Socio-cultural impacts – amenity, heritage
Human capacity – skills, R&D, extension services	Community expectations
Social infrastructure	Population growth – increased visitation, urban encroachment
Interaction with bio-physical pressures	Governance and policy
Interaction and engagement with government initiatives	Human capacity – skills, monitoring
Water management – non-point source licensing	Land use and connectivity – availability of suitable land
	Water management

3.2.3 Governance issues

The types of governance and policy issues raised by participants during the initial parts of the interviews were centred primarily around the problems associated with uncertainty in a range of forms. Decisions about managing most types of forests have planning horizons of several decades and numerous examples were provided of the types of problems faced by forest managers when policy decisions affecting their core business were not made or delayed. The need for timely adaptive management to deal with climate change adds another dimension to this complex arena.

These expressions of frustration were quite consistent among the participants and are captured in the following statement: "*The most pressing issue is – can I say lack of policy?"* (F5). One participant with connections to Managed Investment Scheme plantations pointed out the costs to business: "*we have spent a truckload of time, and most of that has been completely and utterly wasted. Our resources have been completely and utterly wasted internally and externally due to the Federal Government's constant meandering and movement on the topic*" (E5).

"*Strangely it is not climate change itself but the policy reaction to climate change and the prevarication of the government in coming to grips with a climate change policy...It has had a major impact in terms of anybody wanting to do anything. I am sure you have heard that one before"* (E4).

Other issues were noted by NGOs and a policy analyst who nominated concerns about funding cycles and changes to federal funding conduits and programs. Compatibility between policy and legislation at the three levels of government was discussed and concerns were raised about perverse policy. This was one of the issues which emerged from the workshop reinforcing sentiments coming from the interviews. One interview participant raised concerns about policy silos and resultant gaps in departmental understanding (G5). Another talked about responses which were seen as questionable because they were: "*a political response, and not an institutional response*" (F1). Regional Forest Agreements and Forest Management Plans were also discussed by participants.

3.3 Analysis of responses data on biophysical drivers

Given the small number of interviews (34) and the spread across the stakeholder groups it was not appropriate to conduct a full statistical analysis.

3.3.1 Climate zone – fire frequency

Most (77%) of participants from the southern climate zone gave fire frequency an importance rating of ≥4 and 53% gave it the highest rating of 5. Participants from the northern climate zone were less likely to rate fire frequency as very important (Table 5). Over half (63%) of northern climate zone participants gave fire frequency a rating of ≥ 4 and only 25% considered it very important. All participants with a national focus rated fire frequency ≥ 4 and 57% considered it very important.

Table 5 Number of participants (percent) who ranked fire frequency in each importance category (not important – very important) by climate zone. Northern Australia = participants from Queensland and the Northern Territory, Southern Australia = participants from all other states and territories, national = participants with a whole of Australia focus.

Climate Zone	Perceived Importance of Fire Frequency					
	Not important <--->Very Important					
	1	2	3	4	5	~n
Northern	1 (13%)	2 (25%)	0	3 (38%)	2 (25%)	8
Southern	1 (6%)	2 (12%0	1 (6%)	4 (24%)	9 (53%)	17
National	0	0	0	3 (43%)	4 (57%)	7

One plantation manager from south eastern Australia explained why fire frequency is important to him: "Three *instances have made it quite clear that blue gum plantations do react differently in fire situations compared with the natural surrounding bush. When you put the two together it's very unpredictable. So the longer hotter, drier summer periods that we seem to be experiencing makes the blue gum fire situation different to start with but when you combine the two and it makes it extremely difficult to fight fire.*"(E10). At the same time, another southern Australian plantation manager reported that: "*fire frequency is not too much of a concern. We use fire resistant tree* *species in our plantations, so our business model is not really open for too much risk from fire frequency*"(E9). A northern plantation manager commented that: "*we can live with fire*" (E5).

3.3.2 Climate zone – drought

More participants in the southern climate zone or with a national focus (69% and 67% respectively) than those in the northern zone (38%) rated drought as important ≥ 4 (Table 6).

Table 6 Number of participants (percent) who ranked drought in each importance category (not important – very important) by climate zone. Northern Australia = participants from Queensland and the Northern Territory, Southern Australia = participants from all other states and territories, national = participants with a whole of Australia focus.

Climate Zone	Perceived Importance of Drought						
	Not important <--->Very Important						
	1	2	3	4	5	N/A[3]	~n
Northern	0	3 (38%)	2 (25%)	0	3 (38%)	0	8
Southern	0	1 (6%)	3 (19%	5 (31%)	6 (38%)	1 (6%)	16
National	0	0	1 (17%)	3 (50%)	1 (17%)	1 (17%)	6

A southern forest manager explained: "*we anticipate that as a function of drought – increased drought – we'll have to remove ourselves from certain areas of our plantation estate as it currently stands*." Another plantation manager described how drought had impacted on their operation: "*I know our organisation has been caught out in northern New South Wales with areas they established. They had three good years and then seven years of drought. That's had a huge toll on some of the plantations*" (E7). In contrast a manager of a large northern native forest estate stated: "*I don't consciously sit down and think about drought and its effect on forest when I'm planning*" (B1).

3.3.3 Forest type – fire frequency

All (100%) of those participants who manage native forest rated fire frequency as important (≥ 4). Most plantation managers interviewed and participants from the researchers and policy analysts group (75% in each case) also viewed fire frequency as important. Less participants (60%) from the grouping that manage both plantation and native forest rated fire frequency ≥ 4. Overall 78% of participants rated fire frequency ≥ 4 (Table 7).

[3] No scale given – comment suggests not applicable.

Table 7 Number of participants (percent) who ranked fire frequency in each importance category (not important – very important) by Forest Type.

Forest Type	Perceived Importance of Fire Frequency					
	Not important <-------------------------------->Very Important					
	1	2	3	4	5	~n
Native Forest Managers	0	0	0	3 (43%)	4 (57%)	7
Plantation Managers	0	3 (25%)	0	3 (25%)	6 (50%)	12
Both Plantation and Native Forest Managers	0	1 (20%)	1 (20%)	2 (40%)	1 (20%)	5
Researchers and Policy Analysts	2 (25%)	0	0	2 (25%)	4 (50%)	8

Participants related their concerns to management strategies. One manager of a mixed use forest discussed how prescribed or hazard reduction burns have become more difficult : "*we are really getting squeezed in terms of that boundary between risk of escape and achieving satisfactory burnout that comes with those fires*" (C2). For one restoration planting manager the issue of fire has prompted consideration of species selection: "*we're also planting indigenous – 80 to 120 species to build into the planting the resilience to fire that an indigenous species gives you*" (G5).

3.3.4 Forest type – rainfall variability

Rainfall variability was rated as very important for 50% of plantation managers yet only 11% of native forest managers considered this issue very important. Of those participants who manage both native vegetation and plantation forests, 20% rated rainfall variability as very important. More participants from the researchers and policy analysts group considered (43%) rainfall variability very important (Table 8).

A plantation manager laid out the key issues related to rainfall variability for his business*: "the unpredictability of the rainfall makes it a lot more difficult to plan for the fire season and planting times and silvicultural operations for minimum risk*" (E8). Another from Queensland explained: "*there's no real strategy with the variability because we tend to try and tie in the planting with wettest period of the year*" (E2). One farm forester with both native forest and plantation on his property pointed out : "*we're seeing 20 year variations in rainfalls in lots of areas anyway, so the natural pattern that we historically have has a more dramatic effect than anything I think of at the moment from climate change*" (F1). Another participant with northern forest interests pointed out: "*In times of drought we do have to undertake salvage sales of drought-affected timber. Stands just*

Table 8 Number of participants (percent) who ranked rainfall variability in each importance category (not important – very important) by Forest Type.

Forest Type	Perceived Importance of Rainfall Variability						
	Not important <------------------->Very Important						
	1	2	3	4	5	N/A	~n
Native Forest Managers	0	1 (11%)	3 (33%)	4 (44%)	1 (11%)	0	9
Plantation Managers	1 (8%)	2 (17%)	1 (8%)	2 (17%)	6 (50%)	0	12
Both plantation and Native Forest Managers	0	0	3 (60%)	1 (20%)	1 (20%)	0	5
Researchers and Policy analysts	0	2 (29%)	1 (14%)	1 (14%)	3 (43%)	1 (14%)	7

start to die off of drought" reflecting further that this was linked to soil types (A2). A researcher discussing rainfall and its implications for carbon offsets commented that : "*when you look at the results of any assessments of timber plantings in sub 700 mm rainfall and after five or ten years you've got a couple of bloody curly sticks sticking out of the ground and they sure haven't got too much carbon in them*" (G6). In a similar vein, a participant with a focus on both native and plantation forests offered this observation: "Most *of our plant communities are adapted to periods of drought, but it's the frequency of those droughts that I think is important*" (G4).

3.3.5 Forest use – fire frequency

Most (68%) participants responsible for managing forests for production or extraction ranked fire frequency as an important issue with a ranking ≥4. However, all (100%) the participants managing forests purely for conservation values ranked it as an important issue with a ranking ≥4 (Table 9).

From one plantation operator's point of view, fire is: "*a completely assessable risk*." Another commercial forester explained that: "*fire is the only weather extreme that we actually manage specifically for and we have a standard operating process in that regard*" (G1). It was pointed out by one production manager that: "*generally in plantations you salvage somewhere about 90 per cent of the actual material which is burnt*" (E5).

Table 9 Number of participants (percent) who ranked fire frequency in each importance category (not important – very important) by Forest Use. Production = participants managing forests primarily for production (extraction), Conservation = participants that manage forests for conservation and, Both = participants that could not be allocated to either category.

Forest Use	Perceived Importance of Fire Frequency					
	Not important <--->Very Important					
	1	2	3	4	5	~n
Production	2 (9%)	4 (18%)	1 (5%)	7 (32%)	8 (36%)	22
Conservation	0	0	0	3 (33%)	6 (67%)	9
Both	0	0	0	0	1 (100%)	1

3.3.6 Forest use – weeds and pests

Only 22% of production forest participants rated weeds and pests as important with a rating of ≥ 4, while only 8.6% consider these very important. In contrast, 77% of conservation forest participants saw weeds and pests as important with a rating of ≥ 4 and 33% viewed the issue as very important (Table 10).

Table 10 Number of participants (percent) who ranked weeds and pests in each importance category (not important – very important) by Forest Use. Production = participants that manage forests primarily for production (extraction), Conservation = participants that manage forests only for conservation and, Both =participants that could not be allocated to either category.

Forest Use	Perceived Importance of Weeds and Pests					
	Not important <--->Very Important					
	1	2	3	4	5	~n
Production	1 (4%)	7 (30%)	10 (43%)	4 (13%)	2 (9%)	23
Conservation	0	0	2 (22%)	4 (44%)	3 (33%)	9
Both	0	0	1 (100%)	0	0	1

By way of explanation, a plantation operator stated that: "*weeds are a known problem*" (E6) that can be managed. But for a manager of a large conservation estate, weeds and pests rated highly: "*just monumental*" (B1). The impact on resources was noted by this manager: "*if we had the resources it would be an endless bucket trying to deal with weeds on the estate. But we focus on weeds of national significance and those that are declared. But there's a real concern that the southerly spread of those weeds is increasing*" (B1).

It is worth noting that fire frequency was rated as important (≥ 4) persistently whichever way the participants were grouped for SPSS.

3.4 Extent climate change adaptation is being considered in current planning and management

Characterising the extent to which the stakeholders interviewed have considered climate change adaptation (CCA) at a strategic planning and /or operational level was a challenging task for several reasons. First, the individuals interviewed represented a rich variety of stakeholder groups with contrasting organisational priorities within the forestry sector, yet they were not there to give an official public account of their organisations' position. Second, the construct of 'adaptation' is a complex one that can have a plurality of meanings to different stakeholders, even when framed within a defined context. Finally, it is likely to be difficult for anyone to communicate "on the spot" where their organisation is situated on the continuum of climate change adaptation during a telephone interview. Nevertheless, those interviewed were selected for their 'information value' and the interview process was able to capture a preliminary overview of where various groups of stakeholders were in respect to considering climate change adaption in their current planning and management. The same interview data are explored more thoroughly alongside relevant literature through the lens of adaptive capacity and vulnerability within WP4.

In exploring the transcripts, those participants with more of a policy role seemed to respond to this issue differently when compared to those more directly involved in forestry management as shown by the following results. Those interviewed who nominated themselves as having a policy role held quite senior positions within their respective organisations. Many also sat on various consultative or advisory committees and had some level of input into strategic planning documents related to climate change. If not directly involved, the majority were at least aware of some strategic climate change initiatives that impacted on their core business. Participants responded differently to the initial prompts about whether they were aware of any action plans or other initiatives on climate change adaptation. Some launched straight into describing various initiatives underway while others were more reticent to begin with and their story emerged through further probing. The range of responses could be classified broadly into the following categories. Excerpts are provided under each from selected cases to highlight this range across different stakeholder groups.

Category 1: Mention of specific action plan or similar initiative for climate change that deals with CCA – either in use or currently being prepared.

Government agencies dealing directly with plantation forestry appeared in this first category. From Queensland: "*We've got some initiatives we're working on. I am very much aware though and have had extensive input to the climate change action plan for forestry that's been developed at the whole of government level"* (A2). Those from government mentioned the need for formal ratification of such action plans through several standing committees.

Those developing plans for native forests also reported having specific climate change strategies. For example: *"Basically how we're managing climate change at the moment is we are just finalising an overarching climate change strategy….. Out of that we've got five objectives and those objectives cascade down into park-specific climate change strategies"* (B3).

The response by participants from two different non-government conservation organisations reflected distinctive strategies towards climate change adaptation. They both reported having action plans that addressed not only biophysical measures that could be taken to enhance the resilience of their own plantings, but also aimed to raise the awareness of the community about what they could do to adapt to climate change. They saw the need to: "*take the issue out into the community, not in the same policy-making sense as other organisations but in the sense that we need to get people focused on how they can adapt to climate change*" (G7).

Category 2: Reference made to a broader strategy document within their sector that incorporated climate change within it.

The imminent release of the National Climate Change and Commercial Forestry Action Plan was mentioned by two participants whilst discussing action plans.

Participants from various forestry industry groups exemplified this category as reflected in the following: "*Not specifically, I think that's true, we certainly are developing an industry development plan. I mean we've always been supporting and involved in industry development" (A3).* In describing such plans further, the argument was presented that good strategies for managing other relevant forestry issues such as biodiversity covered climate change because they needed to protect forests from any threat, including climate change and *: "if you were doing it properly, you're already covering it*" (A3).

The Climate Change Research Strategy for Primary Industries was referred to by one group from the agriculture sector as a document that was useful for them as it contained: "*a whole range of adaptation strategies*" (F2) that covered agriculture as well as some plantation issues.

Category 3: No mention of a specific policy, but dialogue revealed specific policies and actions being taken or developed on climate change adaptation

One participant who illustrated this position came from farm forestry: "*we don't have a specific strategy although some of the research we're doing I guess is specifically targeted at landholder adaption to climate change. So I guess you could say yes we do in that respect, we're trialling different farm forestry options that allow farmers to integrate commercial trees on their farms for their agricultural activities. In some cases those things actually provide a form of adaptation in terms of stock shelter and so forth*" (E3).

One conservation group did not mention any specific action plan for climate change adaptation, but described themselves as being in: "*a continuous adaptation mode*" (G7).

Category 4: Minimal or no plans to develop adaptation measures

While most stakeholders interviewed revealed their plans for developing climate change adaptation strategies, there were cases where it simply was not seen as a priority or no indication was given that climate change plans would be developed in the future. One participant in this category described the most pressing issues to be economic ones with their whole business of harvesting native forests becoming only marginally viable.

Category 5: Specific adaptation measures

The narratives from those who identified themselves as having predominantly a management role, both policy and management role or a research role tended to reflect a more 'hands-on' level of engagement with climate change adaptation than those dealing solely with policy. Quite a few described trials and experiments they were undertaking while others described changes to their specific operational procedures. Some of these changes to management practices are illustrated as follows:

"*We are working to ensure that the species that we plant cross as many eco [tones] as possible so that we manage that risk. - so we're actually planting with an understanding of climate variability today and climate variability in the future*." (G5)

Similarly, a participant from a managed investment scheme described being: "*somewhat proactive about these things in terms of putting tests of genetic material into what we perceive as climate extremes in order to look at their overall resilience of the population. Many of the new tests that we plan this year are at the extremes of the range where they would normally be planted so that we can gauge the response of the prime material to more extremes in terms of the weather and pests*" (E8).

A forest researcher described how their team had produced a technical report on a forest region which: *"focused on the impacts of climate change on the wet tropics and in that we outlined some general directions that we believe need to be pursued to make the rainforest more resilient to the risk of climate change, so that's as close as we've gone to a strategy"* (B2).

Other stakeholder groups described changes that involved wholesale restructuring as a climate change mitigation measure. In one instance a conservation plantation group has decided to build resilience in their operations by spreading out across a whole range of landscapes across Australia. Similarly, another group simply moved operations from a sensitive region: "*the business I currently work for has actually moved from the temperate area to the tropical area to get away from those issues….So that's a corporate plan … to get out of the temperate areas*" (E5).

Other evidence emerged in terms of budgetary considerations: " *we were going to transition about a third of our budget over the next five years. We'll be specifically addressing climate change type issues. We've got a range of projects…*" (C1). A conservation manager pointed out "*we don't have a separate bucket of money for climate change, so all of the strategies identified in the climate change strategies need to be funded out of the existing resources*" (B3).

Some spoke of making changes in collaboration and information sharing activities: "*we have changed is that in the information sharing and the education component of involving volunteer workers in our activities. We're more openly and intentionally informing and educating our volunteers about climate change and the impacts of climate change*" (G3). An adviser working with farm forestry pointed out : "*we're being a bit more conservative, doing more if you like sensitivity* *analysis of what's possible in these areas that we're now providing advice for and being involved in*" (F1).

A conservation NGO elaborated on their focus: "*trying to address what we can do for a number of species, bird and animal species, which we believe, from the technical advice we receive, could benefit in a climate change world by activities now. In other words through enhanced plantings of tree species or habitat species in key areas so we've tried to focus our programs so it's a clear response to climate change*" (G7).

Other management strategies mentioned include investment in seed banks in different regions across Australia and different tillage practices (n=2).

In summary, most stakeholders interviewed have considered climate change adaptation at a strategic planning and /or an operational level. The examples highlighted here hint at the wide variety of circumstances affecting the capacity of various forestry stakeholder groups to adapt to climate change. These issues are addressed further in the research conducted within WP4.

3.5 Information needs expressed by forest managers and policy makers

Capturing the information needs of forestry stakeholders was the third objective of Work Package 1. In-depth telephone interviews of key informants formed the primary source of data for this task and the questions probing what types of information would assist them in advancing their climate change adaptation initiatives were reserved until the final stages of the interviews. This allowed both interviewees and facilitators to reflect on the preceding dialogue prior to responding. The needs expressed by those interviewed were embedded within the context of their personal and/ or organisational experiences up until the time of their interview and they are presented here as such. However, many of the stakeholders interviewed attended the stakeholder workshop in November 2009, where they had the opportunity to interact with each other and the researchers from all Work Packages in a facilitated workshop. A significant amount of valuable, collective learning took place during this workshop and some of the stakeholders' information needs would have been met, modified or expanded as a result. Without going back and repeating all of the interviews, this learning could not be captured at the individual level, but the collective insights on key information needs from the workshop are incorporated into this section of the report.

The information and other needs expressed by the participants were explored and categorised into the following: specific types of information that might be generated through modelling; basic scientific information from empirical studies; needs centred on communication and sharing of knowledge and finally, general insights related to information needs.

3.5.1 Information needs from modelling

One of the most consistent views expressed across all of the interviews and at the workshop, was that modelled predictions of climate change impacts be scaled down to a regional level. Landholders and those responsible for managing all types of forests found that the modelling results that they had accessed were simply not at a sufficient resolution to help manage their forests into the future. As one participant expressed: "*that's one of the things that I think could help because if we haven't got that there's no point trying to come up with a set of strategic responses if you don't really know what you're trying to respond to*" (C3). The request was delivered by another participant in terms of: "*intensive rather than extensive climate modelling*" that is useful and applicable at a farm scale (G1).The other general view expressed by several participants about models was that the wide range of them available made it confusing: "*Lots of different models around – CSIRO, BoM – there are many of them, you'll have trouble trying to work out which ones you really believe and they can all change over time*" (C3).

Some of the specific types of information sought from models to assist with developing adaptation options varied depending on the types of forests being managed and to a lesser extent, the regions. Those working with plantations highlighted the following:

- Detailed rainfall predictions at an appropriate resolution as a priority, along with temperature predictions as these two variables are critical for forest establishment. Frost was mentioned as being important in some regions; (G6)
- Soil and catchment models for the northern tropics, especially the Northern Territory, were considered vital for plantations; (E5)
- Modelling for mixed plantations rather than monocultures was viewed as being important for adaptation. This was amplified by one participant: *"Very little has been done to look carefully at near neighbour and effects and competition effects of planting species that have different phenologies adjacent to each other. And most plantations are monocultures and those are not necessarily the most effective plantations for carbon sequestration. They're very effective if the one thing that you're planning to do is harvest an above ground crop and therefore the more uniformity that you can get, the better. But if you're trying to encourage as much as possible sequestration throughout the year above and below ground, it may be much more effective to plant mixtures. But we don't know very much about managing those"* (E8).

Those managing native forests also expressed the need for models downscaled to the regional and local level, but also raised the issue of models that would assist with vulnerability assessment (n=3). A conservation manager explained: "*need to get accurate elevation models and then we need to get useful spatial information systems to be able to look in different scenarios and see what* *the impacts would be on certain species or communities*" (B3). Accurate ecological models were mentioned as desirable, particularly those with application for understanding the impacts of climate change on regeneration niches and the movement of biodiversity across the landscape (C4).

One researcher emphasised a need to move beyond modelling to detecting the actual impacts of climate change (C2).

3.5.2 Basic scientific knowledge needs

Those researching and managing both native and plantation forests identified a range of specific information requirements that would assist them in planning adaptations. One fundamental issue identified related to improved and consistent monitoring: "*because the basic data that goes into the predictive models are - it is quite basic. So if we can do some kind of systematic monitoring so we can improve those models then that would help as well. It would also help us understand exactly how our systems are changing and then be able to manage those in the future*" (C4). More specific needs are as follows:

- "*there is a pressing need to understand to what extent we can use genetic adaptation to withstand some of those climate effects at the extremes of a distribution of a species. That's a gap of our understanding that we have to fill in the short term …" (*C2).
- "*We need a new generation of satellites, I think, before we can really develop good operational tools to use remote sensing for measuring change in the status of health with the native forests. I think that's the critical area that's still a gap*" (C2).
- Trialling different restoration or translocation programs to see if we can help some of these species adapt to climate change (C4).
- Basic knowledge regarding carbon fixation in plantation forests and what is going on underground - how ground preparation can disturb carbon balance associated with roots (E8).
- Water use efficiency within plantations and how it can be modulated (E8).
- How climate change might impact on weeds with respect to the spread of weeds and control strategies – some may benefit, others may not (B3). This is likely to be important at a regional level. As noted by one participant: "*We have major disease issues in the south west forest with phytophthora and the interaction with climate change will be an important one*" (A1).
- Understanding interplay of factors that could be contributing to shifts in dominant vegetation type – e.g. Grasslands in native reserves being taken over by woody scrubs and vines: "*this is where our science, we're working with the best available information,*

but sometimes our science lets us down. We don't know whether it's change in rainfall, change in temperature, human impact, feral animal impact, horses and cattle spreading weeds, we don't know what's actually causing it and we don't know if we're doing the right thing by changing our burning regime or not" (B1).

- "*how many plants do we need to collect our seeds from for different species in order to get the full, you know, natural lines with genetic diversity*" (G4).
- Information about where to collect seeds from. This comes back to the need for regional models as expressed by a manager: "*one school of thought that says we should be collecting our seeds from, you know, 100 kilometres further north than where we are now so that the seed will be adapted to future climates, but what that is, it means it's really guesswork at this stage. So what we need to, what the information we really need is better regional climate change models*" (G4).
- At a more general level for farm forestry: "*How do you establish and grow plantations to maximise their growth, to maximise their survival to maximise carbon uptake. That's starting to feature very strongly. How do you do that in a way that also allows landholders to run their livestock or cropping activities and not be too detrimental for those activities*"(E3).

3.5.3 Communication, training and workforce needs

The issues raised by participants in connection with communication, training and workforce needs have been collected together in this section due to their cross-cutting nature. Better communication was a need that was expressed strongly and consistently across the different stakeholder groups throughout the interviews and the stakeholder workshop. Different contexts and examples were used to illustrate this need, but there was an underlying consensus that adapting to climate change within the forestry sector was a continuous process that needed to be underpinned by the sharing of scientific knowledge and best practice. When many of the stakeholders were able to come together for the workshop, the liberal sharing of knowledge, shared concerns and needs confirmed the observation made previously, that opportunities for collective learning were needed and valued by stakeholders.

Through the interviews, several participants expressed the view that the knowledge needed to support climate change adaptation was accumulating in 'pockets', in a fragmented, disconnected way and that there needed to be better knowledge transfer to those who needed it within the industry and community and that this needed to be resourced (n=3).The different phrases used to describe this need included: information sharing, knowledge brokering, extension and collaboration.

Certain participants expressed a sense of frustration that they were not being resourced adequately to disseminate information available: "*I think the knowledge one is a constraint ... there's a great deal of information out there, but to actually put it in a form which enables people to* *access it and use it and understand it, it's quite a considerable task. And certainly, given state government responses to funding crises, staffing levels and expertise levels within our organisation is a real issue*" (F1). In a similar fashion, some felt they had expertise that could be utilised to help with the prediction of distribution and redistribution of species, if only they had better access to reliable climate predictions. So it was evident that participants valued various communication pathways differently depending on their personal experiences and/or their organisational priorities. Some more examples of these follow:

- Communication between organisations: "*More comprehensive collaboration between educational institutions and research organisations regarding data sharing is needed*" (E9).
- Basic extension: "*I mean we also need to look at the extension needs, particularly for adaptation and the take up of new technologies and new production methods to help farmers adapt to a changing climate*" (F2).
- Changing skill sets: "*We're an ageing lot, there's a different skill set required, we already have a few empty spots which we can't get money to fill. So we have a challenge in front of us, and that challenge is a different challenge than we had in the past, and we do need a slightly different skill set. And it's been difficult to get that altogether*" (F1).

Plantation managers raised some specific training needs in relation to the transfer of production forestry to the tropical north: "*when people start moving from one part of the landscape, say it's a southern temperate forest of, you know, 100 years of history, to new tropical plantations with five or 10 years of growing history it's quite difficult, quite different stuff. So, that would necessitate a whole group of research and development activities. Little of those are actually practically happening at the moment*." (E5).

With regard to training and workforce development, there is consensus about a general lack of appropriately qualified professionals now and that this would become more serious in the future. More extension officers with generalist knowledge and good communication skills are needed, along with professionals with specialist expertise in areas such rare species identification and knowledge on how to set up refugia.

3.5.4 Organisational needs – capacity

The capacity of organisations to adapt to climate change is an issue explored within Work Package 4 (Wilson and Turton, 2011). This research will also highlight the constraints to effective adaptation and tools and advice that will assist.

4 Climate scenarios

The scenario work conducted by CLIMsystems (refer to Annex 4 & Annex 5) points to seven important patterns of change in the medium- to long-term (2030 and 2070):

i. Annual rainfall increases in the tropical north and decreases elsewhere
ii. In northern Australia, the wet season gets wetter, the dry season gets drier
iii. In southern Australia, widespread decreases in rainfall occur during winter and spring. The west and southern coasts show decreases in rainfall in all seasons.
iv. Mean maximum temperature in February increases by 3.5 – 4.5 degrees over much of Australia
v. The increase in number of days exceeding both 35°C and >40°C is greatest in the interiors of Northern Territory and northern Western Australia
vi. From many coastal areas to the interior, there may be large spatial shifts in the number of days exceeding the designated maximum temperature thresholds
vii. The decrease in the number of frost days may be most evident as large elevational shifts over short distance as minimum temperatures increase

These patterns, using model outputs from IPCC AR4, provide an indication of national levels of exposure to potential change which have significant implications for key factors influencing forest vulnerability and, therefore, adaptability.

Water availability or soil moisture is one of the key limiting variables. Changes to seasonal distribution of rainfall or significant changes in annual mean rainfall or an exacerbation of drought patterns will have direct impacts on the vulnerability of existing forests and add to the constraints which limit adaptive capacity of forests. In addition, forest vulnerability is expected to be intensified through exposure to and sensitivity to the indirect impacts of changes to rainfall patterns which occur through altered fire regimes and changes to pests and diseases. Changed temperature patterns (T_{max}, T_{min} and average daily temperatures) will also create both direct and indirect impacts on forests. When combined these limiting variables of water availability and temperature have interacting implications for adaptive responses, particularly for those linked to genetic stock and the suitability of available land.

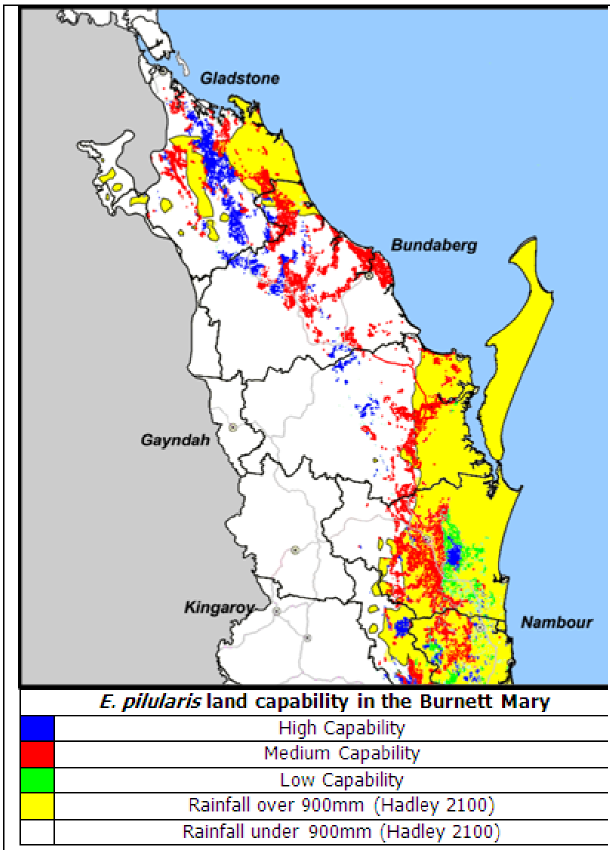
The scenario outputs can facilitate a consideration of the scale of potential impact linked to time for changes in rainfall and temperature. Both stakeholders and interview participants expressed a desire for customised downscaled climate change scenarios. Customisation of climate change scenarios for forest impact analysis and adaptive capacity has been conducted for regional South East Queensland by the University of the Sunshine Coast. The following example in Laves and

Waterman (2008) uses data from the 1999 SEQ Comprehensive Regional Assessment (CRA) (Queensland Government and Commonwealth of Australia) report which examined the land capability in south east Queensland for commercial plantations . The *E. pilularis* mapping from this report is overlayed by SimCLIM rainfall outputs. One of the key limiting variables impacting on the potential for *E. pilularis* is a requirement for annual rainfall in the range between 900mm and 1750mm. Figure 4 adapted from Laves and Waterman (2008) overlays projected mean annual rainfall for 2100 on to areas of land considered by the CRA to have high, medium and low capability. The yellow zones mark the areas which will continue to have sufficient rainfall to support *E. pilularis.* This highlights potential problems for forests dominated by *E. pilularis* and is indicative of some of the challenges that need to be considered in terms of adaptation particularly in relation to the specific requirements of a single species linked to limitations of availability of suitable land.

Figure 5 also adapted from Laves and Waterman (2008) provides an example where land suitability and potential profitability have been linked to rainfall in 2100, making it evident that continued profitability will be constrained for any future *E. pilularis* plantations based on evaluations conducted by the CRA. Similar assessments could be made for other species in other regions which have baseline suitability data generated through Regional Forest Agreement CRA processes or more recent data being generated through provenance trials.

Box 4 Summary of information needs identified by participants.

Production	**Conservation**
Regional – downscaled climate change modelling for rainfall, temperature and frost	Regional – downscaled climate change modelling
Mixed plantation modelling – for sequestration	Accurate elevation models
Systematic monitoring and data collection	Ecological models
New generation of remote sensing capability to monitor forest health	Systematic monitoring and data collection
Below ground carbon fixation in plantations	New generation of remote sensing capability to monitor forest health
Impact of soil disturbance on carbon	Restoration and relocation trials
Water use efficiency	Management regimes for changing ecosystems
Climate change impacts on disease and pests	Better information to support seed/ collection of genetic material
Optimisation of forestry enterprise with grazing and cropping	Improvements to knowledge transfer and information sharing
Expansion of extension services and collaboration between research and end users	Collaboration between researchers and end users
Improvements to knowledge transfer and	



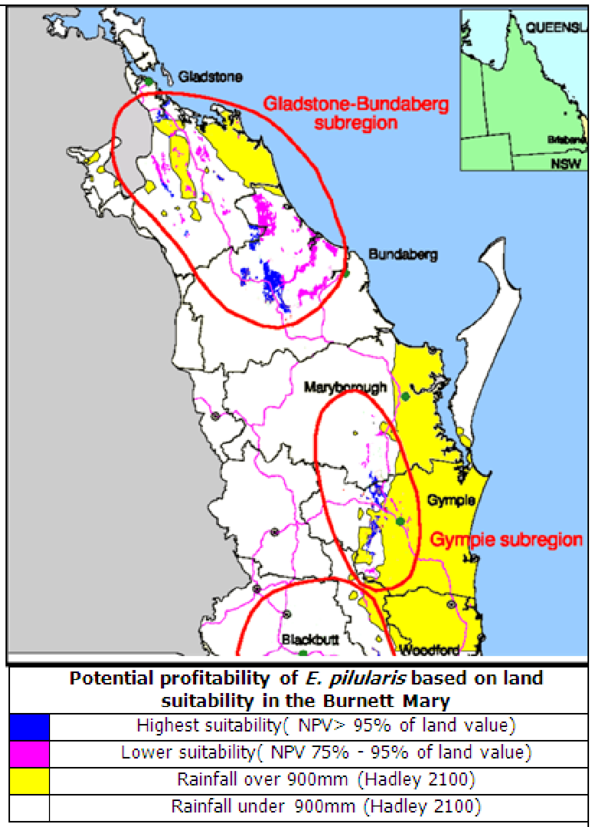


Figure 4 Distribution of land capable of supporting *E. Pilularis* by mean rainfall for 2100 (Hadley GCM, A1FI Emission Scenario with High Sensitivity) using 1998 CRA land classification

Figure 5 Distribution of land by potential profitability (NPV as percentage of land value) based on suitability for *E. Pilularis* by mean rainfall for 2100 (Hadley GCM, A1FI Emission Scenario with High Sensitivity) using 1998 CRA land classification

Whilst it is possible to derive valuable information for considerations of vulnerability from these types of scenarios it is important to recognise that they cannot provide any indication of periods of rapid change or non-linear events which may have an effect on mean values of key climate factors or on the statistical moments which impact as climate variability, nor can they account for potential climate surprises (Schneider 2004).

5 Discussion

Australian forests provide a diversity of values and ecosystem services to communities. In addition to the provision of wood based products, forests are valued for a wide range of other services such as recreation opportunities; water protection; biodiversity conservation; aesthetic, cultural and heritage values; shelter for live stock; soil protection; as well as carbon sequestration (Howell et al. 2008). Many of these services come from forests managed for mixed uses or from family farm-based forests. Forests represent long-lived natural assets and are susceptible to the pervasive impacts of climate change. Climate change impacts will not be evenly distributed across spatial or temporal scales, nor will they impact on individual biomes or forest types equally. These impacts have the potential to threaten ecological sustainability and resilience at a local or regional scale, could compromise the economic viability and competitiveness of productive forestry, and may lead to changes in the social acceptability of some forest uses. Climate change impacts may also represent risks to the security of forest carbon stocks and therefore the reliability of mitigation efforts based on reforestation.

The vulnerability of Australian forests is in part a function of critical thresholds which impact at both individual and population levels (Steffen et al. 2009) .Critical thresholds linked to exposure levels and sensitivity to distinct climate signals such as rainfall or temperature are determinants of productivity, long-term survival and regeneration. Steffen, et al. (2009) nominated threshold values for habitat structural species as a key knowledge gap in their national vulnerability assessment for biodiversity. Any assessment of vulnerability must consider critical thresholds and the possibility of "*rapid transients and non-linear events*" that could "*affect not only the mean values of key climate indicators but also higher statistical moments, such as variability, of the climate*" (Schneider 2004). In this context high consequence extreme events are important. For Australian forests the key threshold factors identified by forest managers that influence forest vulnerability are rainfall and water availability, temperature, fire, pest and disease, genetic stock and availability of suitable land. Biophysical or socio-economic thresholds may be overtaken through either incremental change or sudden step change which could occur at a global or a regional scale. Walker et al. (2009) show how biophysical and socio-economic threshold interactions, cascading impacts and governance are important to regional resilience. Knowledge of thresholds is a key element of risk management for forest management.

Potential adaptive capacity is in part shaped by the identification of risks that incorporate critical thresholds and the subsequent processes of problem definition. Some of these thresholds may be linked to existing or historical stress points which could be at or even beyond current capacity to respond. Therefore it is important to recognise both where these stress points lie and the limits of current capacity. Many thresholds have implications for governance. Key factors influencing forest adaptability such as water availability, fire, pests and disease, genetic resources and land availability are subject to regulation. Appropriate threat mitigation and adaptation measures need to be implemented in time. Therefore prudent and sustained observation over time is needed to allow for the detection of new threats or any escalation of existing threats. This would facilitate an integrative assessment of multiple threats, including those posed by climate change.

In addition to the biophysical conditions which are directly impacted by climate change, the resilience of Australian forests could be compromised indirectly by a systemic failure or limitations in the response to climate change within:

- forest based science;
- the communication and diffusion of knowledge between researchers, government and forest managers;
- the operational practices of forest managers;

- market forces;
- social awareness and understanding; and
- governance.

These areas are all influenced by competing stakeholder perceptions about levels of exposure to the impacts of climate change and understanding about the severity, timing and trajectories of change. These perceptions, in turn have consequences for the nature of intervention considered appropriate for both adaptation and mitigation. Lag effects and uncertainty reduce the immediacy of noticeable and measurable impacts. This results in a reluctance to engage in effective decision making and prioritisation which make it difficult to avoid some of the key adaptation pitfalls such as:

- Insufficient adaptation, which occurs when the threat of climate change is ignored or other issues are inappropriately given a higher priority;
- Misguided adaptation, which occurs when available information and guidance is ignored;
- Unnecessary adaptation, which occurs when the threat of climate change is given a higher priority than other critical issues; and
- Mal- adaptation, which occurs when decisions compromise or foreclose on the ability to effectively manage future impacts of climate change.

Many of the issues that were raised by participants represent persistent vulnerabilities and involve complex interactions. It is clear from the interviews conducted that climate change is just one of many pressing concerns. Therefore climate change vulnerability for Australian forests needs to be considered within the context of current threats and drivers. The Australian forest estate has a range of issues that intersect with climate change including problems associated with deforestation, population growth, biosecurity threats and extraction of water from catchments. Other factors such as regional difference, scale and proximity to urban areas add to the complexity of concerns. Some of the concerns impacting commercial forest stakeholders are quite different to those with a conservation focus. This suggests that a range of carefully targeted strategies and actions will be needed to increase resilience and adaptive capacity.

The following sections reflect further on the key biophysical, socio-economic, governance issues and information needs raised by participants. The way forward is highlighted for each of these. The extent to which climate change adaptation is being considered is assessed against a set of indicators developed for the project. A set of notes for policy makers and forest managers is provided.

5.1 Key Issues of Concern

5.1.1 Biophysical Issues

Most forest estate groups are concerned about an increased threat profile for disturbance-pathways caused by pests, diseases, weeds, wind, fire and extreme weather. In general, forest managers prefer a risk-based approach to the management of perceived threats. However, some participants may not have a good understanding of the severity of impact or threshold consequences that might be expected in a changed climate which could result in insufficient or mal-adaptation. Hennessy et al. (2007) observed that a change in temperature greater than 1.5°C would be a threshold for increased vulnerability for many Australian species and ecosystems. Nitschke and Hickey (2007) found: "a *significant change in species vulnerability with a 1.4°C increase in annual temperature coupled with a 5% decline in annual precipitation in 2055. This threshold was the same for eucalypt, rainforest and acacia species*." With higher temperatures, even in areas with higher rainfalls, forest systems are nonetheless drier through higher rates of evapotranspiration. There is a general awareness of variability in exposure levels across spatial scales with some understanding that exposure levels will vary. There is also an understanding that individual forest types, genetic stocks and biomes will be differentially impacted through variations in sensitivity imposed by individual and population based physiological thresholds (Steffen et al. 2009)

Concerns about fire frequency and fire intensity were apparent across all forest groupings. This is one area where discussion about intensity, frequency and trajectory of change was very apparent. Awareness levels were, no doubt increased by events in which large scale, high intensity fires impacted on forest communities in southern Australia between 2003 and 2010. A large body of literature is being amassed on the implications of fire, fire regimes and appropriate management for the national forest estate (e.g. Victorian Bushfires 2009 Research Taskforce 2009; Pitman et al. 2007; Gibbons et al 2000; Griffiths 2002; Lindenmayer 2009). Much of the research has been generated through activities of the Bushfire CRC in response to devastating fires which have claimed lives and imposed serious economic hardship on communities. Changes to fire events in forests are an indirect effect of changing rainfall patterns, escalating droughts and increases in the number of consecutive days of high temperatures resulting in dry fuel loads. High intensity fires have an impact on population dynamics and the mix of age cohorts within forests. Changes in fire interval and changes in fire timing also impact on population dynamics. These impacts extend to vertebrate and invertebrate populations which rely on forests. Issues related to fire highlight the importance of historical legacies such as landuse decisions, forest management practices, infrastructure integrity and community resilience networks. Recent fires have shown that there are significant costs resulting from a do nothing approach to climate change adaptation.

Biophysical issues relating to rainfall variability were raised by participants from all groupings of the national forest estate. Many linked these to drought, and referred to cyclical variation and shifts in the annual and seasonal rainfall patterns. Rainfall variability is a key risk factor impacting on current management and driving uncertainty for future-based decision making. Prolonged drought in southern Australia has resulted in the marginalisation of previously productive forest areas, and has forced forest managers to consider the risks of some production areas becoming permanently drought-affected. This has prompted some forest managers to move operations, change species or contemplate new crops. In mallee-growing areas, the focus is moving towards biomass-harvesting of coppice for biofuel and hopes that the carbon stored in retained root mass will provide an income from sequestration or offsets.

Drought impacts in the form of reduced plant growth and productivity are accepted as limitations. Plantation productivity was discussed by many participants. In this context, species selection and survival was a key theme and many spoke of the need for tree breeding programs, provenance trials and seed sourcing strategies. Nitschke and Hickey's, (2007) study provides an important contribution to the impact of climate change on these issues. Some studies exist on the selection of species and provenances for low rainfall areas, (e.g. Ngugi et al. 2004), but there are large knowledge gaps. The 2008 State of the Forests Report indicated that tree breeding and genetic improvement programs could improve the capacity for conserving native forest genetic resources, including those of non- commercial endangered species (Montreal Process Implementation Group for Australia 2008) This is in part being achieved by creating genetic resource conservation plans for native timber and oil producing species Montreal Process Implementation Group for Australia 2008).

For the plantation, Managed Investment Schemes and sequestration forestry sectors, the issues of water rights, access to water and the trade off between water and bio-sequestration were raised. Some recent research has explored the interaction between forests, water catchments, water quality and water use (Feikema et al. 2008; Malmer et al. 2009; Benyon et al. 2007; Batini 2007; Benyon et al. 2009). The National Water Initiative has changed the relationship between forest producers and water by recognising large-scale afforestation as a water-interception activity. This has led to recommendations for the inclusion of forestry in water catchment management policies (Burns et al. 2009) .

Soil moisture is one of the key issues for plantation forest managers. Uncertainties about future soil moisture were raised by participants along with their desire to have the means to accurately incorporate this into production projections. Salinity and soil erosion issues also figured in the interviews. Problems with soil erosion for plantations in northern Australia were highlighted. The 2008 State of the Forests Report noted that measures to mitigate soil erosion are not applied evenly across the national forest estate.

Fire and disease are recognised as significant threats to old-growth forests in Australia Montreal Process Implementation Group for Australia 2008). Once a forest has been burnt, it is automatically reclassified as regeneration. A spread of fungal pathogens would have significant implications for all types of forest use. Phytophthora is a significant cause of disturbance in the national forest estate. It is expected that sporulation and colonisation of fungal pathogens will be changed by climate impacts with spatial contraction in some regions and expansion in others. However, most damage to forest ecosystems caused by native insect pests and pathogens, whilst widespread, is not severe but can have an adverse impact on commercial values for timber Montreal Process Implementation Group for Australia 2008) Predator host relationships are mediated by climate both through direct effects on their relative growth rates but also through effects on the resistance of the host (Sutherst et al. 2007)

A need for monitoring for new pests and diseases was voiced frequently, with new disease threats representing a major unknown. Some larger organisations are already using remote sensing alongside ground truthing to monitor forest health (Table 11).

Invasive weeds are an issue for all types of forest. Within the plantation sector, weeds represent a threat during the establishment phase, with one participant likening the impact to a drought effect due to the competition for moisture. Weeds also impact on successful regeneration and recruitment in native forest areas. For plantation managers, weed management is a routine, frequently triggered by specific thresholds or regulatory mandates. For managers of native forest, weeds are an ongoing problem, for which they often don't have sufficient resources to combat effectively. Improved access to national parks has exacerbated the spread of some weeds. Climate change is likely to have impacts on weed dynamics in both native forests and plantations. (Scott et al. 2008; Crossman et al. 2008; Kriticos et al. 2003).

The problem of impact through extreme weather events, in particular wind disturbance, is generally viewed pragmatically. Where events create large impacts and subsequent wind-throw, foresters take the opportunity to salvage. This was the case after Cyclone Larry[4]. However, a significant loss to the scientific community occurred through the destruction of a large number of provenance trials that were in the path of the cyclone which has had an impact on research.[5] Aerial surveillance is used to identify tracts of forest that have been impacted in order to facilitate timely salvage. One Queensland participant lamented the impact that a series of extreme weather events had on the state's park system. A tool has been developed in Tasmania to predict the impact of wind events on plantation stands.

Table 11 Definitions of the four main health surveillance and monitoring activities carried out by forest managers in Australia.

Activity	Definition	Jurisdictional use
Forest health surveillance	Damage-focused and optimised to detect then quantify damage (rate, incidence and severity in delineated area). Introduced to Australia in 1996-97.	Qld – softwood NSW – softwood, hardwood & multiple –use public native Tas – softwood & hardwood
Health/condition	Tree/forest-focused and optimised to describe	NSW - public nature

[4] K Wood: member of Emergency Management Queensland task force response to cyclone; and subsequent further personal communication with L Walkden about salvage processes.
[5] Personal communication with David Lee

monitoring	the condition of trees and detect change	conservation reserves Vic – softwood, hardwood& multiple –use public native WA - multiple –use public native
Pest population monitoring	Pest-focused and optimised to measure populations of the target pest.	Qld – softwood NSW – softwood &public nature conservation reserves Vic – softwood & hardwood Tas – softwood & hardwood SA – softwood & hardwood WA – softwood, hardwood & multiple-use public native forests
Ad hoc detection	Damage-focused and designed to incur the least cost (for detection). The term 'guided ad hoc detection' is used if forest workers receive training to focus attention on specific pest and disease issues	Qld – hardwood & multiple –use public native NSW – hardwood, multiple–use public native & public nature conservation reserves Vic – hardwood Tas – hardwood & multiple–use public native SA – hardwood WA - hardwood

Other extreme events are related to temperature, which is an important variable for tree growth, survival and reproduction. One participant pointed out that there had been a localised extinction of a eucalypt species (not identified during the interview) in the northern Flinders Ranges after an extreme heat event. The potential for extinctions from other climate change impacts have been well covered in recent reports (Australian National University 2009; National Resource Management Ministerial Council 2004; Wet Tropics Management Authority 2008). Heat waves are associated with increased transpirational demand, they are usually associated with low humidity and increased rates of radiant heat in southern and inland Australia.

Loss of biodiversity was raised as an issue. Species and ecosystems in Australia are potentially vulnerable to changed climatic conditions because they have narrow ecological ranges (Nitschke and Hickey 2007; Hennessy et al. 2007). These altered biophysical parameters interact with physiological mechanisms and tolerances impacting on productivity, regeneration, and the long term integrity of systems (Nitschke and Hickey 2007). The ability of ecosystems to adapt to changing climate conditions is influenced by a suite of local characteristics including: topography and micro-refugia, existing biodiversity, presence of invasive species, the successional ecosystem state, and fragmentation of the landscape (Joyce et al. 2009). These issues impact on native forest managers as they attempt to address and prevent species loss within threatened ecosystems. Matters raised by participants in regard to biodiversity protection include recruitment, forest succession and regeneration, fragmentation and the integrity of buffer zones. The possibility of creating climate migration corridors to enhance opportunities for the movement of biodiversity across the landscape was also noted. One instrument that might offer an immediate benefit is the use of stewardship payments to landowners for the protection of refugia, remnant vegetation and buffer zones in recognition for the ecosystem services these provide to the community. An example of this scheme is the box gum woodlands bioregion New South Wales stewardship program (Hajkowicz 2009). Bodin and Wiman (2007) have pointed out that "*no management option is likely to maximise all forest ecosystem functions*", thus forest managers will be forced to consider options which pit ecosystem function against ecosystem composition. Variation in species sensitivity will inevitably produce novel systems.

An integrated vulnerability assessment framework for both individual species and ecosystems is required that draws together the components of biotic vulnerability, regional and local exposure factors, potential feedbacks along with adaptive (evolutionary and plastic ecological) and management responses which build resilience (Williams et al. 2008).

Four national action plans (National Agriculture and Climate Change Action Plan, National Climate Change and Commercial Forestry Action Plan, Forest Research Strategy Directions, and the National Biodiversity and Climate Change Action Plan) provide a suite of current national targets that are relevant to the biophysical issues raised by participants (Refer to Annex 6 for a table setting out these strategies). These emphasize a risk management approach. Capacity building is emphasised through targets which aim to incorporate climate change adaptation into policies and programs that impact on forest management. The capacity of managers to predict impacts is also targeted. Strategies which can be categorised as, risk assessment, prioritisation for actions, monitoring, the identification of adaptive responses and planning are included and form the basis for implementation plans. These categories include actions targeting some of the key influences of forest adaptive capacity: water availability, fire, pests and diseases, and land availability. Specific conservation strategies target reserve acquisition, threatened species protection and recovery. Evaluation criteria are implied in targets associated with water and fire management but not outlined. Implementation, monitoring and communication of the results is required to assess whether issues raised by participants can be addressed fully through these aspirational statements. Both the agricultural and biodiversity plans have reached the first review period.

Biophysical issues: The way forward

To address the biophysical issues raised by participants the following initiatives need to be prioritised for implementation:

i. Increased investment in response to existing issues such as weeds, pests and disease, fire, and drought to increase the resilience of both conservation and production forests;

ii. Research into the cumulative and interacting effects that can occur between pre-existing issues and climate change (e.g. changes in predator host relationships);

iii. Investment in forest and climate sciences coupled with better knowledge transfer between sectors;

iv. Species tolerance research that can be applied in both plantation and conservation forests;

v. Forest health monitoring extended to include climate change impacts;

vi. Identification of climate change refugia; and

vii. Increased investment in ex-situ conservation efforts.

5.1.2 Socioeconomic issues

Many complex interactions between biophysical conditions, market and policy realities shape socio-economic issues for stakeholders at a national, regional and local level (Burns et al. 2009). This is true for the complex interactions around forest production. Participants raised several issues in this regard. The industry is based on a narrow range of species in Australia and this could expose the industry to threats from pests and diseases as well as the impacts of climate change. Participants flagged the problem of impending shortages of timber. This has been a concern for processors for sometime, particularly in relation to timber that might once have been sourced from native forest (URS Forestry 2007). This decline in native timber supply has been evident since completion of the RFA process (Burns et al. 2009). Some participants raised concerns about meeting supply agreements, given the long planning horizons required there is a degree of uncertainty and exposure posed by possibilities of declining plantation productivity. These concerns are driving efforts to address species selection. The need for information about provenances, climate-proof genetic stock and climate-based decision making tools were raised across all forest estate groupings. Climate change adaptation efforts need to ensure that timber supplies are not restricted in the future to maintain viable investment in capital-intensive processing.

Water management, water availability and the potential licensing of non point water were issues raised by southern forest managers and participants. Changed rainfall patterns, exacerbated droughts and increased competition and regulation of water supply will impact on production forestry, particularly plantation forests. Participants noted concerns about the impacts of increased plantings, such as those for carbon sequestration, on water catchments and groundwater supplies. This has been the subject for recent research (for example: Batini 2007; Benyon et al. 2007; Benyon et al. 2009; Feikema et al. 2008; Morris and Collopy 2001). Participants reported that they were considering changing water application during planting and establishment phases. A need for more research into water efficiency measures was voiced for plantations outside of the southern production zones.

Many issues were raised about land-related matters. The first of these involves concerns about land clearing and the impacts of land clearing moratoriums on operations. There has been a national commitment supported through all jurisdictions to strengthen controls on the broad scale clearing of native vegetation, as well as a commitment to increasing the size of the native forest protected (Montreal Process Implementation Group 2008). Some participants raised concerns about land availability, particularly land that was going to be suitable for growing productive forests in a climate-changed future. Others raised the issues of conflicting land-use and problems of plantations competing with agriculture for prime productive land. These issues are similar to those noted in the research conducted by (Schirmer et al. 2008). Some participants saw the push towards broad scale bio-sequestration as a threat to the viability of future food production.

Several of the participants spoke about their experience within the new bio-sequestration markets. They spoke of a need for tax incentives for bio-diverse planting and a need for some regulation or accreditation to ensure the long term credibility of operators in the market. One spoke of a need for restrictions on the entry of suppliers into the market to prevent rogue operators from establishing themselves in an unregulated market and cashing in on consumer naivety.

A set of issues that is impacting on stakeholders concerns human capacity. These issues are comparable to those covered in the work undertaken by URS Forestry (2007). Participants raised the problem of being able to get enough staff, as well as suitably qualified staff. Some wanted staff with skills in monitoring; others want staff trained in climate change science and able to apply their knowledge in the field. Many participants pointed to a reduction in the availability of extension services. Discussions with Commonwealth stakeholders suggest that this is one issue which is caught in a shift of jurisdictional burdens. Several participants discussed the possibility of using their collaborative networks to fill gaps in their skill base. A new market has arisen to provide skilled advice to farm forestry and bio-sequestration plantation managers.

Climate change impacts, along with community responses and mitigation efforts are expected to increase capital and operating costs for the forest sector. Concern is evident about who will bear these costs across the community and there is recognition that some regional communities will be exposed more than others if forest production is substantially curtailed or becomes unviable. Uncertainty about the timing and intensity of impacts is compounded by lack of access to information. Movement of production across the landscape carries with it social infrastructure costs.

The lack of social infrastructure in new production areas was raised by participants. Climate change induced population shift was raised by workshop participants as the interior of the continent becomes less conducive to human habitation creating competition for shrinking parcels of land. Conservation managers raised the issue of population growth in terms of its impact through increased visitation and urban encroachment on forest fringes. This has a significant impact through community demands for fire management and fuel reduction. Changing community expectations was raised as an issue by participants, both in terms of greater value being placed on some ecosystem services and also in terms of expectations about levels of access and management practices.

Policy makers and managers need to be able to recognise the economic and social costs of doing nothing or of acting too slowly in terms of climate change adaptation. The socio-economic costs of sudden climate change that occurs outside of a linear progression also need to be considered in an integrated assessment. An integrated approach can bring together efforts to optimise the management effort in the face of risks and vulnerabilities to observed rates of change; social, political and scientific resolve; the consequences of inaction; market issues and the availability of resources and management tools (Williams et al. 2008). Participants spoke of the increasing costs involved in engagement with policy making, the regulatory and funding environments. An integrated approach requires an understanding on the part of governance structures that adaptive policy making needs a facilitated process of engagement with stakeholders which isn’t hindered unnecessarily by cost or wasted effort. This is particularly important in a situation where rapid environmental change creates pressures on the policy making cycle.

Current national targets (refer to Annex 6) that are relevant to participant concerns about socio-economic issues are contained in the National Agriculture and Climate Change Action Plan, National Climate Change and Commercial Forestry Action Plan, Forest Research Strategy Directions and National Biodiversity and Climate Change Action Plan documents. These strategies cover plans for the enhancement of bio-sequestration and mitigation, risk assessment and risk reduction, land-use planning and the dissemination of information. Future timber supplies are targeted along with the goal of integration of forest management into agricultural production systems.

Socio-economic issues: The way forward

Immediate investment is required for the development of:

i. Climate-proof genetic stock to ensure ongoing supplies of quality timber and other wood products;

ii. Climate change-based decision making tools;

iii. Human capacity through skill building and effective information dissemination;

iv. Stewardship payment systems to reward landowners with significant forest holdings for the ongoing provision of ecosystem services;

v. Land-use management systems that recognise the ecosystem services values of forest;

vi. Efficient water management systems for plantation forest; and

vii. Nationally recognised markets for bio-sequestration that includes bio-diverse plantings.

5.1.3 Governance

Interviews were conducted at a time when there was considerable uncertainty surrounding three important market sectors. Upper-most was the continued uncertainty and confusion over the fate of the Commonwealth Government's proposed CPRS legislation. This issue was the subject of much debate in the media, lobby action from all parts of the community, business and various peak organisations representing interests across the national forest estate. It is highly probable that this impacted on the way interview participants addressed some of the questions put to them during the interview. Clearly this confused regulatory environment was impacting significantly on investment decision making. Linked to this was confusion over possible status of various forest products, types of forest and stages of forest growth in the bio-sequestration and carbon credits setting. Once there is some legislative certainty, clarity around market roles and opportunities will ease many of the concerns raised.

The second area of anxiety was related to the MIS review being undertaken by the Commonwealth which coincided with several MIS companies collapsing into receivership, creating uncertainty in the market. Issues raised by participants pointed to concerns over the rights and protection of investors in this market. Participants noted that if bio-sequestration was afforded a similar tax treatment to MIS plantations this would have multiple benefits across a number of the forest estate sectors, particularly if bio-diverse plantings were recognised.

The third area of uncertainty centred on the debate over bio-energy and the possible roles for forest harvested biomass. This has been the subject of debate across and within jurisdictions and this was noted by some participants. The biodiversity implications of salvaging wind throw from the forest floor and the fire mitigation potential were noted by participants and these issues have been the focus of recent scientific studies (Gibbons et al. 2000; Becker et al. 2009).

Hajkowicz (2009) observed that "Australian *natural resource management is now influenced by four governance levels: Federal; State/Territory; Local and regional. Each level is creating its own policies, plans and legislation. This complex governance environment is costly to run and can potentially create confusion through overlapping, redundant or conflicting policies*". Embedded within this complexity are "*56 regional natural resource management bodies with boundaries* *defined by water catchments and other bio-geographic, socio-economic and administrative regions*” (Hajkowicz 2009). A coordinated and integrated policy approach is therefore a significant challenge and real tensions exist in establishing a coordinated yet decentralised approach to climate change adaptation within a context in which the landscape is managed for a multitude of productive outcomes. This calls for adaptive governance and adaptive management across multiple scales. Adding complexity to this is the emergence of non-regulatory networks which seek to impose market-based pressures to enforce adherence with voluntary certification guidelines. Some of these processes at the practitioner/manager and consumer level have succeeded in mandating sustainable forest practices where organised governance systems had failed.

Participants reported impacts of perverse policy and opposing market signals in spite of: industry and community consultation, policy impact analysis and national attempts at reducing inconsistency and incompatibility between jurisdictions. Many points of tension reflect legacies of historic decisions which have embedded or favoured sectoral interests. Policy needs to be aligned so that policy impacts do not impede adaptation efforts. Existing management and governance structures can be more effectively utilised to deliver the necessary policies and programs. However, these need to be commensurate with both the time scale and the severity implications of the climate change risks to the national forest estate and to individual forest systems within that estate. A key element will be balancing resource efficiency against vulnerability reduction when there is an extended time lag between cost and benefit.

Three current national targets set out in the National Agriculture and Climate Change Action Plan and the Forest Research Strategy Directions document are relevant to governance issues raised by participants (Refer to Annex 6). The first points to the need for integration of climate change issues into policy as well as program communications. The second one addresses a perceived need to prepare the forest industry for a carbon trading environment. The final target seeks to improve policy decision making to meet the multiple demands on Australian forests. There are two elements missing: commitment to ensure that policy making does not result in perverse impacts, and review or realignment of the roles for the four governance levels.

Governance issues: The way forward

Immediate efforts need to be invested in:

i. Creating legislative clarity at all governance levels to provide stability for investment, and reduce wasted effort within sectoral organisations

ii. Minimizing perverse policy outcomes at all scales

iii. Establishing effective adaptive governance cycles which reflect the needs of forest managers and the providers of services, such as research, to forest managers

iv. Recognizing biosequestration achieved through biodiversity plantings within incentive schemes

v. Managing national accreditation for operators in the bio-sequestration market.

5.1.4 Regional forest agreements

Regional forest agreements were established in Western Australia, Victoria, Tasmania, and New South Wales in the 1990s to provide a rational intergovernmental and consultative mechanism to manage competing demands over a range of forest values. Queensland set up a separately negotiated agreement between the timber board and conservation groups to manage a staged retreat of native forest logging from the state owned forest estate by 2024 (Burns et al. 2009). These agreements affected a transfer of tenure from multiple-use to conservation reserve. This reserve is increasingly being seen as providing a buffer for biodiversity and climate- driven genetic migration.

The new round of regional forest agreements that will begin to come into force in 2012 will focus attention on climate change issues in a more targeted way than in the past. There is potential to incorporate new findings from climate change science so that consideration is given to rates of change, thresholds, and the possibility of abrupt changes in climate. These new agreements will also reflect changed social licence conditions, increased values for bio-diverse carbon and new markets and values for other ecosystems services. Consultation with Commonwealth stakeholders indicates that material from the Forest Vulnerability Assessment will feed into this process of renewal and renegotiation.

Only Tasmania has completed a review of the RFA operating in the state. The rest of the states are yet to complete this process. Climate change impacts could be missed without sufficient monitoring and reporting. The RFA process will need to be refined to ensure opportunities for planned adaptation are not lost.

Past criticisms (McDonald 1999) of a lack of transparency and failure within some of the original RFA processes to conform to 'credible scientific practice' (Horwitz and Calver 1998) suggest that more scientific scrutiny is needed to incorporate appropriate climate science. This concern is amplified by participant comments which suggest that a stronger intrusion of climate change into forest management agreements will be seen as a threat to current harvesting entitlements.

5.1.5 Extent to which climate change adaptation is being considered in current planning and management

Preston & Stafford-Smith, (2009) point to: "*the challenge of moving beyond acknowledgement of a changing climate in a general sense into the implementation of context-specific adaptation policies and measures that can have an appreciable influence on vulnerability*." Spittlehouse (2004) argues that adaptation to climate change in forest management calls for a planned response; adopting a risk management approach and taking useful actions now to reduce the risk of unacceptable future losses. He explains many actions necessary to adapt to climate change in the future will benefit the present. There is evidence that some sectors have moved in the direction of planned adaptation. For example, the restoration sector has large scale projects shaped by conscious efforts to reduce the vulnerability of their plantings in the landscape to climate change. Within the plantation sector, some operators have changed species, or moved operations from southern areas to more northern and tropical climates. Managers are seeking to adapt their decision making tools to incorporate the outputs of climate modelling to understand more fully the risks involved. At a government level, action plans and strategies are emerging, and being implemented through policies and programs. Many of these are the subject of ongoing reporting and monitoring.

Monitoring both the effectiveness of climate change adaption actions and progress through the adaptation cycle is required at all scales in Australia. Examples of current adaptation monitoring and review programs from around the world include:

- national scale adaptation monitoring is being implemented in Finland using nationally identified indicators (Finnish Ministry of Agriculture and Forestry 2009)
- in Britain adaptation monitoring is being conducted at a local government scale using specifically identified indicators (British Local and Regional Partnership Board 2008)
- the World Bank reviews adaptation on a project scale (World Bank 2010)

For this project a specific set of indicators has been developed in order to assess progress towards planned climate change adaption for forest management in Australia (Table 12). Three phases have been identified in an adaptation cycle: capacity building, adaptive action and evaluation.

Participants provided evidence of progress towards planned climate change adaptation. In general, climate change adaptation has been widely contemplated, but at best there is inconsistent implementation. The number of people interviewed was limited so this table can only considered a preliminary assessment.

An effective and co-ordinated policy framework is an essential step in capacity building. Participants identified policy and governance as a key area of concern, raising matters in relation to duplication, policy and information silos, conflicting messages and a lack of clear policy direction all of which have the potential to increase vulnerability and act as barriers to adaptation. A supportive policy framework has been contemplated but is seen by participants as being inconsistently implemented across all levels of governance. The IPCC have stressed a risk management approach to climate policy because a focus on using a cost-benefit framework has a tendency to leave out too many relevant factors (Schneider 2004). Policy assessments need to include understanding of the risks associated with delayed responses and unintended consequences or

Table 12 Indicators of progress towards planned climate change adaptation for forest management in Australia

Phase	**Indicators of progress towards climate change adaptation for forest management**	Contemplated		Inconsistent Implementation		Comprehensive implementation	
Building capacity	Co-ordinated and supportive forest policy framework, planning, relevant legislative and statutory requirements						
	Research into levels of exposure, sensitivity, adaptive capacity and vulnerability reduction						
	Investment in skills and resources to facilitate climate resilience in resource management						
Adaptive action	Risked based assessments at all scales						
	Prioritisation of action at all scales						
	Investment in coordinated impact monitoring at all scales						
	Identification of best fit* adaptive responses						
	Adoption of best fit adaptive responses						
Evaluation	Use of standardised criteria to assess the effectiveness of adaptive responses						
	Lessons learned from early adapters are analysed and disseminated effectively						

Conservation Forest = beige; Production forest= green; * Best fit includes an assessment of potential perverse outcomes at all scales.

perverse outcomes of policy implementation. Policy makers need to be aware of the limits to voluntary participation: lessons from land management projects delivered in Australia indicate that having the right attitudes may not necessarily lead to better practices (Hajkowicz 2009).

Most participants discussed research as a need and some offered examples of relevant research already underway. This study shows that research implementation is inconsistent across the forest sectors, with isolated small scale projects identified in both plantation and conservation sectors.

Significantly more targeted research is needed driven from both production and conservation end-user needs.

Participants also recognised an immediate need for people with specific skill sets to facilitate appropriate management responses to climate change. There was some evidence provided which suggests some organisations are seeking to utilise consultants to fill gaps.

Risk based assessments are the first step of an implementation phase for adaption in forest management. Risk based assessments at all scales have been contemplated. Some participants spoke of using specific growth and production tools in their enterprise based assessments. Clear evidence was presented of risk assessments for conservation forests that have been conducted by national agencies. However, this level of implementation was not reflected for other jurisdictions. Some participants questioned whether there was sufficient knowledge available to effectively conduct the types of assessment required.

The need to prioritise action at all scales was discussed by many participants. Relevant national level climate change action plans have been developed, but these were not discussed by participants, suggesting that awareness levels are low. Some participants pointed to state based plans, most frequently linked to mitigation efforts. Evidence was provided by some participants of enterprise level prioritisation. It is clear that effective prioritisation needs adequate levels of information.

Investment in climate change impact monitoring is considered necessary at all scales. Forest health monitoring is implemented in all jurisdictions however; specific climate change impact monitoring is yet to be included. Two examples of long term trials were mentioned as incorporating climate change impacts alongside other priorities. Participants spoke of the need for enhanced remote sensing tools. A priority need is to be able to identify climate signal versus other impacts. Effective long term monitoring may also help to identify instances of autonomous adaptation that can be exploited.

The need to identify best fit adaptation responses is recognised by most participants. Some discussed issues around the need to avoid perverse outcomes from policy and investment decisions. Several participants spoke of genetic and provenance trials and some spoke of the potential need to change management practices, however this represents inconsistent or isolated efforts to identify best fit adaptation.

Some plantation foresters are considering adoption of best fit adaptive response. Participants engaged in large scale regeneration planting provided some indication that their practices had been changed in response to climate change and that this had been incorporated within an adaptive management approach. There is a significant risk if available research is not considered and applied that investment will be wasted and could result in misguided adaptation.

The final phase of an adaptation cycle is evaluation. This phase requires the use of standardised criteria to assess the effectiveness of adaptation responses. This will require systems for measuring and valuing outcomes across the forest estate and will necessarily need to go beyond benefit-cost analysis to incorporate all ecosystem services provided by individual forest types in addition to the ability to link outcomes to expenditure.

The final indicator involves the dissemination of lessons learnt from early adapters. This would also involve lessons from outside Australia being incorporated into current practice where these are applicable.

Some responses may be seen as reactive, driven directly by biophysical drivers such as drought, mass mortality such as large intense fires or disease outbreaks. There is a danger that reliance on reactive adaptation rather than planned adaptation could lead to mal-adaption or the creation of new hardships.

Moves towards an engagement with climate change adaptation is being substantially driven by external factors, notably by governance demands, international agreements as well as community and market expectations. Tompkins et al. (2009), in a recent study of adaptation takeup in the UK also note that: "*many drivers of adaptation are not climate related, even though climate may appear to be a driver. For example, adaptation may be driven by climate change regulations, but not by climate change itself*". These demands frequently drive actions which eventually lead to the building of adaptive capacity and can be viewed as unconscious actions to implement adaptation (Tompkins et al. 2009). The new round of regional forest agreements will focus attention on climate change issues in a more targeted way than in the past. Evidence has emerged from the interviews to suggest that, to some extent knowing this allows some to disengage and defer serious consideration.

5.1.6 Type of information needed by forest managers and policy makers

Stakeholders urgently need information on species thresholds and survival, provenance selection, provenance selection for landscape scale regeneration, genetics and adaptation to climate extremes, translocation trials, water efficiency, pests and diseases, fire regimes for a large gamut of ecosystems and forest types. This includes concerns about how biodiversity can be maintained across large and diverse conservation estates given the knowledge gaps around fire regimes (timing, intensity and frequency) for particular ecosystems. There is also a need for effective long term monitoring of different regimes to identify changes, thresholds, and contributing factors other than climate change. Effectively resourced monitoring provides one of the best means of understanding the biophysical pathways by which climate change impacts on forests, better understanding of critical thresholds and will allow a more thorough understanding of the magnitude of possible future adverse impacts. The detection of impacts may allow time for remediation or provide necessary data for effective adaptive management and resource allocation.

Improved modelling is seen as providing some of the answers in terms of information for future adaptive management and changes to decision making. Many spoke of wanting rainfall and temperature projections that were down-scaled to regional or local levels that would allow "*intensive modelling*" relevant at a farm-scale. The biophysical variables sought in these climate models relate directly to species and productivity thresholds such as soil moisture. Several saw the possibility of incorporating climate projections into integrated decision support systems already in use. Continued monitoring is necessary to keep these calibrated with biophysical changes as they occur. Many decision support tools could be applied to native forest management particularly where they are used in conjunction with "*ecological models*" used to understand the impacts of climate change on regeneration niches and the movement of biodiversity across the landscape.

A critical aspect to reduce vulnerability and facilitate adaptation depends on disseminating information and promoting the uptake of new tools or knowledge. Participants identified an area of need linked to technology transfer and data sharing, suggesting the development of information portals, networks and the use of open source facilities to maximise collaborative information sharing. Accessibility issues were raised in connection to obtaining timely, accurate research outputs, particularly where these are published in journals. Not all organisations have a research budget that will permit subscriptions to all relevant journals. Some saw this need in connection to an effective extension service or brokerage process to deliver required information directly to farmers or forest managers. This link between research and management has been noted in recent forest sector reports (National Farm Forestry Roundtable 2000; URS Forestry 2007) and was raised by workshop participants as a problem citing a perceived disconnect between research and the particular information needs of government and managers. Professional development of forest mangers is needed in terms of climate change impact monitoring. This should also include training in the use of climate change modelling outputs to provide managers with the necessary skills to critically evaluate climate change scenario and projection materials.

Critical knowledge gaps have the potential to inhibit effective adaptation; it was noted by the Research Priorities and Coordination Committee (2008) that the overall knowledge base for Australian forests is poor. Moving beyond the needs articulated by participants, more information is required in developing an understanding of how scale is relevant to adaptive planning for climate change in both conservation and productive forests. This is important for the way in which risk is managed. The management of risk is dependent upon high quality information about the threshold values of key species, the magnitude of adverse impacts from changed climate parameters as well as systematic broadscale and finescale monitoring. Adaptation strategies need to be based on evidence gathered from quality science interfacing with end user knowldege to minimise vulnerability and maximise long term survival and productivity.

Current national targets set out in the National Agriculture and Climate Change Action Plan, the National Climate Change and Commercial Forestry Action Plan and the National Biodiversity and Climate Change Action Plan (see Annex 6 for table of national strategies relevant to the knowledge and information needs raised by participants), if implemented effectively will address many of the key information needs. These plans recognise the need for industry based research, extension services, regional level climate projections, enhancement of data and information flow , diagnositic and monitoring tools and better understanding of the ecosystem services provided by forests. However, no evidence emerged from the interviews of widespread awareness of these specific strategies suggesting implementation has not yet reached effective thresholds or they are subsumed under other measures or there is a failure in dissemination of targeted information. Discussions with key Commonwealth and other stakeholders indicate that an overall reduction in research and development as well as extension services would compromise the delivery and achievement of national targets and strategies for climate change adaptation of Australian forests.

Information needs: The way forward

Investment is required for projects that:

1. bring end users of research together with researchers to generate 'demand driven', products that will address climate adaptation needs such as:
   - regional and local scale climate modelling
   - information about species thresholds and survivability
   - provenance selection
   - climate adaptive genetics
   - water efficiency
   - impacts of climate change on pests and diseases
   - appropriate fire regimes for changed climate and maintenance of biodiverse ecosystems
   - regeneration for climate adaptation
   - translocation trials
   - diagnostic and specific monitoring tools;
2. provide open access to appropriate data through information portals and networks;
3. facilitate the dissemination of information, best practice and the uptake of effective climate change adaptation;
4. target vulnerability at all scales: national, regional and local;
5. monitor synergistic impacts (biodiversity, socio-economic and climate mitigation);
6. will enhance the ability of Regional Forest Agreement reviews to address emerging vulnerability and incorporate greater degress of adaptive management into ongoing decision making facilitate an increase in available extension services;
7. provide opportunities fo collective learning;

8. implement broadscale and finescale monitoring for detecting climate induced change across all forest types; and

9. encourage increased development of national expertise in climate adaptive forest management for both conservation and productive forests.

The CSIRO have been engaged in the development of a scenario planning tool which deals with the performance of tree crops under historical (1975-2005) climates as well as incorporating future scenarios (2030 and 2070) for the Avon wheat belt region of Western Australia and South Western regions of Victoria (CSIRO 2009). This tool uses climate change scenario outputs from the CSIRO MKIII climate model (SRES A2). The tool is designed for landholders, NRM and extension services under a licence agreement with the CSIRO. This tool offers users the ability to zoom into their farm and access information about growth rates and generate economic outputs based on user created scenarios. The latest version of this Scenario Planning Investment Framework (SPIF) tool has been released in May 2010 and can be obtained from CSIRO Forestry. Participants spoke of the need to make "*knowledge useable at farm scale*"; it is tools like this one which will fill perceived gaps.

6 Conclusion

This report provides stakeholder insights into climate change adaptation and forest vulnerability for all forest types and focuses on stakeholder issues, needs and responses driven by climate change impacts on Australian forests. These views will inform the creation of a national forest vulnerability baseline through the other Work Packages involved in the overall FVA process. The FVA is expected to help shape future research directions.

This project engaged with stakeholders from across the national forest estate. All jurisdictions were represented in the process. Participants were drawn from a broad cross section of forest management and policy areas, including government and private organisations, forestry industry bodies, non-government organisations in industry and conservation, managers from native and plantation forests, researcher organisations and policy makers.

The report provides national scale information about the key issues which were raised as concerns by participants, explores the extent to which climate change adaptation is being considered in current planning and management and determines the type of information that is needed by forest managers and policy makers.

Participants expressed vulnerability in terms of a range of biophysical, socio-economic and governance issues at all scales and across all forest types.

Changes to fire, pest and disease disturbance pathways were identified by participants as significant issues. Concerns about rainfall patterns, soil moisture, drought and the ongoing availability of water were also prominent. Linked to these issues are concerns about species and provenance tolerances, tree survival, growth rates, the supply and quality of timber within a context in which a narrow range of species are grown commercially. Biodiversity issues raised involve concerns about species loss and changes to diversity within ecosystems, potential for future extinctions and the limits which will prevent movement of biodiversity across the landscape, such as the availability of suitable land.

Participants voiced concerns about the continuing economic viability of production forestry. Connected to these concerns are issues related to water availability and regulation. The availability of suitable land for the expansion of production, biosequestration and conservation forests was also raised and linked to the potential for land use conflicts. A lack of qualified staff emerged as a significant issue along with concern about reductions in funding for research, development and extension services.

Policy and legislative uncertainty impacting on decision making in forest management was an issue which emerged strongly from the interviews. The impact of the proposed Carbon Pollution Reduction Scheme on both plantation and conservation forests was raised repeatedly. Across all groups there was a consistent call for clarity on the Carbon Pollution Reduction Scheme (CPRS) policy and legislation.

Responses from stakeholders indicate that climate change adaptation is being considered both in terms of planning and management but implementation is inconsistent. Some organisations have a specific action plan or similar initiative for climate adaptation, either in use or currently being prepared. Others did not have a specific plan, but referenced a broader strategy document within their sector that incorporated climate change, such as a national climate change action plan. Some organisations had minimal or no plans to develop adaptation measures. Some forest managers described specific trials and changes to operational procedures, for example, tests of genetic material, managing risks by planning across eco-tones, and moving operations to regions perceived to have lower climatic risk potential.

For select groups, other concerns such as the economic viability of forest operations, land use and resource conflicts, and changing management policies and practices may be seen as more important than the potential threats of changing climatic conditions.

The need for adaptation is recognised. Forest managers are beginning to assess potential threats and opportunities. There is a general awareness at a qualitative level of the indicative impacts of climate change with a mindfulness of the uncertainty that is inherent in current scenario development. Some adaptation measures have been implemented, and others are under consideration however, adaptation is not yet widely incorporated into regular decision making processes.

Participants identified key information needs in the areas of modelling for decision making, research and appropriate dissemination of knowledge. In particular, many participants expressed a strong need for local and regional scale climate models to aid decision making. There was a consistent call from forestry managers and conservation managers from all jurisdictions for down-scaled climate change scenarios and related risk analysis information. Participants also voiced needs for basic scientific knowledge on forest species and their response to climate change, including monitoring, translocation trials, carbon fixation, and water use efficiency, mixed species plantations, response of weeds to climate change, vegetation dynamics; and how to source seeds for plantings that will cope with climate change. A need for better communication and dissemination of knowledge, research and best practice across the sector was expressed strongly and consistently across the stakeholder groups. This was coupled with an appeal for a more highly trained and skilled workforce to cope with climate change.

Progress towards climate change adaptation in the Australian forest sector can be enhanced through investment in a suite of measures outlined to address the issues and information needs raised by participants. Vulnerability needs to be targeted at at all scales (national, regional and local) and across all forest types.

An increase in the applied research effort for forest and climate science is essential. The development of climate-proof genetic stock is urgently required to ensure ongoing supplies of quality timber and other wood products. A better understanding of species tolerance is also needed for both plantation and conservation forests. Research is required into the cumulative and interacting effects that can occur between pre-existing issues and climate change (e.g. changes in predator host relationships). Climate change-based decision-making tools need to be improved with capacity for integration with regional and local scale climate modelling.

Investment in response to existing issues such as weeds, pests and disease, fire, and drought needs to be increased to improve the resilience of both conservation and production forests. In addition this should be supported by broadscale and finescale monitoring to detect climate-induced change across all forest types.

Land-use management systems that recognise the ecosystem services values of forests are needed at all scales. This could be enhanced by stewardship payment systems that reward landowners with significant forest holdings, particularly those identified as climate change refugia, for the ongoing provision of ecosystem services. Investment in ex-situ conservation efforts is necessary to support conservation efforts. Bio-sequestration plantings, particularly those that maximise biodiversity, have the potential to add substantially to buffer zones and to create temporary migration corridors.

Legislative clarity is needed at all governance levels to provide stability for investment and reduce wasted effort within sectoral organisations. This should include efforts to minimise perverse policy outcomes at all scales. Adaptive governance cycles which incorporate current research and reflect the needs of forest managers are required at all governance scales. Bio-sequestration achieved through biodiversity plantings should be recognised within incentive schemes. National accreditation for operators in the bio-sequestration market needs to be centrally managed.

Investment is required for projects that generate 'demand driven', products that will address the climate adaptation needs of forest managers. This should include projects which will facilitate the dissemination of information and best practice; increase the available extension services; facilitate the uptake of effective climate change adaptation; provide opportunities for collective learning; and increase the development of national expertise in climate adaptive forest management for both conservation and productive forests. Reviews of Regional Forest Agreements must address emerging vulnerability and incorporate greater degress of adaptive management into ongoing decision-making.

Box 5 Notes for policymakers

Vulnerability and adaptive capacity can be enhanced or constrained by the activities of policy makers. Climate change imposes new and escalating threats to Australian forests. Participants in this research project identified key concerns about the policy environment which they perceived as constraints.

Policy measures that need to be considered:

- Greater policy clarity which will enhance investment security within the forest sector;
- Review of the impact of funding cycles on adaptation efforts;
- Recognition for tax incentives of bio-diverse plantings that prioritise the establishment of climate change buffer zones;
- Stewardship payments to landowners for the protection of refugia, remnant vegetation and buffer zones in recognition for the ecosystem services these provide to the community;
- Increased investment in climate change adaptation extension services for the forest sector;
- Investment incentives which target adaptation research and management experiments for all forest types;
- Establishment of open source information sharing portals;
- Investigate means of shortening policy cycles to allow for the incorporation of findings from rapidly developing science; and
- Review land management processes to reduce conflict and allow movement of forest production.

New opportunities are likely to emerge from the establishment of new stakeholder alliances and the establishment of non-regulatory networks which prosecute social expectations and initiatives.

Box 6 Notes for Forest Managers

Changed rainfall and temperature patterns with the possible escalation of extreme events pose significant threats to existing forests.

Climate change is likely to significantly impact on production forests and may result in changes in productivity and the species which can be grown in some areas. Climate change will increase the vulnerability of existing conservation forests which are already impacted by multiple issues. Participants recognise current limitations such as a lack of resources, knowledge and the availability of land for expansion of the conservation estate. Options for adaptive response are likely to be constrained by high levels of endemism, general aridity of most of the landscape, rainfall variability, infertile soil types, and fire as a key determinant of forest structure.

Interim and transitional measures that need to be considered include:

- Increased efforts to identify and effectively protect refugia;

- Increasing community involvement in management and creation of climate buffer zones;
- Use of stewardship payments to landholders to protect and enhance the biodiversity and ecosystem services provided by remnant forest;
- Identification and protection of forest areas with specific microclimates that would serve as potential niches to facilitate climate migration;
- Use of regional scale climate models to predict risks to production from climate change;
- Selection of plantation species more tolerant of climate change based on available information and science;
- Improvements to water use efficiency in plantation forests;
- Adoption of management practices that account for changed climate conditions;
- Increasing the level of investment in skill and knowledge development;
- Increased efforts to eradicate known invasive weeds and pests;
- Use of the tools and lessons from plantation forestry to enhance reforestation and management experiments;
- Encouragement of plantation forestry to help create temporary migration corridors and buffer zones; and
- Greater investment in fire management experiments to determine appropriate fire regimes for all forest types and ecosystems under climate change
- Investment in ex-situ plantings of genetic stock
- Broad and fine scale monitoring for the impacts of climate change
- Investment in risk planning that incorporates non-linear shifts in climate variables

New opportunities are expected to emerge from increasing community value placed on forest ecosystem services in response to climate change threats and impacts. The biodiversity, amenity and sequestration values provided by conservation forests are expected to become increasingly important.

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Annex 1 List of key documents

Australia's State of the Forests Report 2008 (Montreal Process Implementation Group for Australia, 2008)

Provides a baseline synthesis of all issues impacting on production and conservation forests in Australia. Socio-economic and biophysical issues are comprehensively covered. The document is structured to facilitate reporting against Montreal criteria and indicators. A report is prepared every five years, effectively providing a means for monitoring and assessing change, for determining the direction of change in a regular set of parameters which include climate change and for reporting on the implications for forest sustainability.

Nitschke, C. R., & Hickey, G. M. (2007). *Assessing the Vulnerability of Victoria's Central Highlands Forests to Climate Change. Technical Report*.

This report outlines the findings of an Australian vulnerability assessment conducted for Victoria's Central highland Forests using TACA-OZ, a mechanistic model. The vulnerability of 22 tree species in their regeneration niches to projected climate change was modelled.(Nitschke and Hickey 2007)

National Forest Policy Statement 2nd Edition 1995

A statement of policies and objectives for the national forest estate produced as an intergovernmental response to a set of earlier reports on forest issues from:

i. Ecologically Sustainable Development Working Group on Forest Use
ii. National Plantations Advisory Committee
iii. Resource Assessment Commission's Forest and Timber Inquiry
iv. 1983 National Conservation Strategy for Australia

The statement covers conservation, wood production and industry development, intergovernmental arrangements, private native forests, plantations, water supply and catchment management, tourism and other economic and social opportunities, employment, workforce education and training, public awareness, education and involvement, research and development and international responsibilities (Commonwealth of Australia 1995).

National Biodiversity and Climate Change Action Plan 2004-2007

Outlines a three year plan designed to coordinate the activities focused on the impacts of climate change on biodiversity across all jurisdictions. It sets out the principles and rationale for integrated action within existing governmental structures utilising a risk management approach that is cognizant of critical thresholds for species and ecosystems. (National Resource Management Ministerial Council, 2004)

Climate Change in the Wet Tropics Impacts and Responses – 2008

The report covers the impacts of climate change on the Wet Tropics Queensland World Heritage Area. Management responses are considered. (Wet Tropics Management Authority 2008)

Australia's Biodiversity and Climate Change – 2009

A national assessment of the vulnerability of Australia's biodiversity to climate change with a focus on terrestrial biodiversity (Steffen et al. 2009). The approach is based on ecological principles. These principles are used to examine current and projected changes to biodiversity. Current biodiversity management (including the institutional and policy context) and socio-economic trends are also reviewed. The responses of biodiversity to climate change are also considered. Chapter 7 focuses on means of enhancing adaptive capacity. Two other documents have been produced to accompany this large report: a *Technical Synthesis* and a *Summary for Policy Makers2009.*

Australian Forests at a Glance 2009

An easy to read summary of national, state and territory forestry statistics prepared by Department of Agriculture, Fisheries and Forestry (Includes maps, tables and simple graphs). (Bureau of Rural Sciences 2009)

Implications of Climate Change for Australia's World Heritage Properties – 2009

A comprehensive report which examines potential impacts of climate change on natural and cultural heritage properties and values. Each property is covered with a synthesis of the implications. Adaptation and management issues are also featured. In addition the report explores flow on effects for communities and considers needs as well as knowledge gaps. (Australian National University 2009)

Independent Review of the Environment Protection and Biodiversity Act 1999 – 2009

The review, fact sheets and submissions are available online. Covered in the document are sections on current and emerging threats which include climate change, regional forest agreements, and ecosystems of national significance and governance arrangements. Among the submissions submitted in response to the draft review there are some that have been made by key stakeholders for this project. (Hawke 2009)

National Climate Change and Commercial Forestry Action Plan 2009-2012.

A three year strategic document produced in consultation with stakeholders. The Department of Climate Change were involved as a stakeholder through the steering committee. The document is endorsed by the Natural Resource Management Council and the Primary Industries Management Council. The document outlines strategies and actions developed to facilitate responses to the apparent risks and opportunities for commercial forestry that are linked to climate change impacts. The focus areas are : adaptation, mitigation, bioenergy and supporting actions.(Commonwealth of Australia 2009)

Forest Research Strategic Directions 2008 – 2011

Prepared by the Forest Research Priorities and Coordination Committee of the Primary Industries ministerial Council. It outlines the key research and development themes for sustainable forests: mitigation of an adaptation to climate change in Australia; water quality and yield; forests for multiple objectives; health and biosecurity of Australia's forests; product development and use (Research Priorities and Coordination Committee 2008)

National Agriculture & Climate Change Action Plan 2006 – 2009

A strategic document designed to assist natural resource managers and farmers to address issues of climate change adaptation. Four focus areas are covered through a set of strategies and actions: adaptation, mitigation, research and development, awareness and communication. The action plan was developed from an assessment of scientific, economic and environmental issues. This plan was developed to complement a similar action plan for biodiversity(Natural Resource Management Ministerial Council 2006)

Annex 2 Verbatim survey sheet used for interviews[8]

National Climate Change Adaptation Research Facility
WP1 Forest Vulnerability Assessment (FVA)
Introduction

- Introduction to the project and the subject areas that we will ask about.
- We will ask questions in 5 stages:
  1. Major issues for your organisation
  2. What is your knowledge of /awareness of climate change
  3. What is your organisation doing about climate change
  4. Demographic and background data
- How would you define your responsibility with respect to forest management in Australia within your organisation?

1. Major issues for your organisation

a) What are the most pressing issues for your organisation for forest policy or forest management?
NB. If participant indicates that their role is within policy, frame subsequent questions around policy, same with management.

2. Knowledge/awareness of climate change

a) Describe briefly what words/images come to mind when you hear the phrase "Impacts of Climate Change".
b) Which of these impacts (if any) are likely to influence the way in which forests need to be managed? Please elaborate.
c) Open – see what issues are raised from the above question and follow up on those in the first instance. If none mentioned, then prompt with those listed below.
d) On a scale of 1-5 (with 5 being very important) how important are these issues (list one by one) with respect to forest policy or management (Likert 1-5)?

List those mentioned by participant, and then prompt further if necessary with those from list below that they have not mentioned "What about the following?"
Prompts:

- Rainfall variability
- Fire frequency
- Drought
- Weather extremes
- Weeds/pests

e) How do you currently manage these issues – repeat list above?

3. What is your organisation doing about climate change?

a) Do you have an action plan or are you aware of climate change adaption strategy? (Perhaps use a Likert scale 1-5 (5 very familiar))
b) Where on this scale?
c) Have you changed any of your management strategies (or policy approaches) in response to what you understand the impacts of climate change to be?

If yes, please explain how.

If not, do you plan to change any of your management strategies (or policy approaches) in response to what you understand the impacts of climate change to be?

Why or why not?

[8] These questions were approved by USC HREC and participants signed a statement of consent according to HREC guidelines.

d) What types of constraints are there on your capacity to change any of your practices?

If required, prompt with constraints such as:
- Financial/economic
- Legislative/policy
- Knowledge – what types? (financial, scientific, time management)
- Conflicting priorities / organisational needs

Ask for specific examples.

e) What types of strategies are affected by these constraints?

If none mentioned, prompt with the following management strategies:
Modification of any of the following:
- Species selection
- Fire regime
- Weed control practices
- Grazing patterns
- Off-site conservation
- Pest management strategies

f) What specific government policies influence your organisation's response and planning for climate change?

g) What steps has your organisation taken to get involved in:
- carbon sequestration
- carbon credits
- carbon trading

Please give details.

If asked, provide the pre-determined definition of these.

h) What other types of opportunities do you perceive to be available to plan or respond to climate change?

Query perceived effectiveness of these opportunities.

4. Demographics/background data.

a) Title of position
Make a note of gender

If participant is a forest manager – ask the following:

b) How big is the area of forest you manage (e.g. in hectares)
c) What type of forest do you manage?
e.g. national park, plantation forest, grazing lease, state forest, restoration forest, other
d) What is the land usage of the forest that you manage?
e.g. grazing, timber production, conservation, carbon credits, recreation, heritage values
e) What is land tenure
e.g. leasehold , freehold, national park, reserve, crown land, other
f) How many people are involved in forest management in your organisation?

If the participant has a policy role within their organisation – ask the following:

g) How many people involved in forest policy in your organisation?

General

h) Age category – [<25, 26-34, 35-44, 45-54, 55-64, 65 or over]
i) Person how long have you been involved in the forestry industry?
j) How long have you been in your current position?
k) What was your previous position?
l) What is the size of your organisation?
   e.g. How many people are employed/involved in your organisation?
m) What are your formal educational qualifications?

Note: Prior to commencing the process, all interviewers received training from Dr Anne Roiko, who has considerable experience in conducting social research and community-based research, and data analysis.

Annex 3 List of Audio and transcript files from participant interviews

Document Code	State	Minutes
A1	**WA**	47
A2	**QLD**	57
A3	SA	69
B1	QLD	65
B2	QLD	39
B3	National	40
C1	QLD	42
C2	TAS	90
C3	SA	55
C4	SA	39
C5	National	30
G1	SA	68
E1	National	41
E2	Qld	33
E3	NSW	43
E4	Vic	33
E5	NT	30
E6	NSW	39
E7	NT	30
E8	National	42
E9	VIC	31
E10	SA	57
F1	TAS	61
F2	National	42
F3	WA	50
F4	Vic	53
F5	TAS	46
F6	WA	37
G2	NSW	42
G3	QLD	41
G4	National	67
G5	VIC	70
G6	QLD	42
G7	National	63

Annex 4 The Scenarios of Climate Change: Tools, Methods, Data and Outputs

Richard Warrick and Yinpeng Li (CLIMsystems Ltd)

This section describes the tools, methods and data used to generate the scenarios of climate change for the NCCARF Forest Vulnerability Assessment (FVA) project. The scenario development was overseen by the University of the Sunshine Coast and carried out by CLIMsystems Ltd. using its *SimCLIM* modelling system.

Deliberations with FVA stakeholders pointed to a need for specific, customised scenarios of climate change (e.g. scenarios pertaining to selected seasons and geographic locations; spatial patterns of days exceeding critical threshold values), which were not readily available from other off-the-shelf material. The range of GCM climate model outputs (i.e. from IPCC AR4) and methods (pattern-scaling of normalised climate change patterns) in SimCLIM are similar to those employed by CSIRO in producing regional scenarios of climate change for assessment purposes. SimCLIM was used to produce the required outputs quickly without employing additional or alternative climate models. The difference, and a key strength of SimCLIM, is the flexibility that it affords in being able to customize the modelling system by adding data, creating new areas, adding overlays, linking to impacts models as well as being able to generate outputs rapidly.

This section contains a general description the SimCLIM system, and an overview of the approach used for generating scenarios of monthly, seasonal and annual-mean changes in precipitation and temperature for the FVA project. It then describes in more detail the technique of *pattern-scaling* in which these customized scenarios are constructed from outputs of General Circulation Models (GCMs) and Simple Climate Models. The last section describes the additional steps required to generate scenarios of changes in the frequency of days of extreme temperatures based on gridded sets of time-series of daily data.

Tools: SimCLIM and the Approach to Scenario Generation

SimCLIM is a software modelling system used to link and integrate complex arrays of data and models in order to simulate (both temporally and spatially) bio-physical impacts and socio-economic effects of climate variability and change, including extreme climatic events. SimCLIM is the generic name of the “open-framework” system developed from CLIMPACTS, an integrated modelling system developed specifically for New Zealand at the University of Waikato (Warrick, 2009), and its various “clones” (for example, the Australian version, OzCLIM; http://www.csiro.au/ozclim/home.do).

The “open-framework” features of SimCLIM provide the flexibility for importing data and models in order to customise the system for specific applications – much like a GIS. There are tools to allow the user to import spatially-interpolated climatologies and other spatial data (e.g. elevation surfaces), site time-series data and patterns of climate and sea-level changes from General Circulation Models (GCMs). The geographical size is a matter of user choice (from global to local), as is the spatial resolution (subject to computational demands and data availability and quality). For the FVA project an Australian version of SimCLIM was used that contained Australia-wide observed monthly-mean values of precipitation and mean, maximum and minimum temperature derived from the 1961-1990 baseline period and interpolated to a 0.025 lat/lon resolution, as well as spatial patterns of change for these same variables from GCMs.

Every SimCLIM contains a “climate scenario generator”. In using SimCLIM, there are three major areas of uncertainty in the generation of scenarios which are treated independently and for which ranges of uncertainty can be taken into account:

- The **climate sensitivity** (which determines the *magnitude* of global warming for a given change in GHG concentrations). The “climate sensitivity” refers to the responsiveness of the climate system to changes in atmospheric concentrations of greenhouse gases. Conventionally, the climate sensitivity is defined as the *equilibrium* change in global-mean temperature for a doubling of CO_2. Different GCMs produce different values for the climate sensitivity due to differences in the way in which climate feedbacks – e.g. changes in snow and ice cover, clouds – enhance or dampen the direct radiative forcing from GHGs. The SimCLIM user can select from a low, “best estimate” and high climate sensitivity, a range of uncertainty corresponding to the 90% confidence interval in accordance with that used by the IPCC Fourth Assessment Report;
- **GHG emissions** (which determine the *rate* of change of GHG concentrations and associated radiative forcing). The six key IPCC SRES marker scenarios, spanning low to high emissions, can be chosen individually in scenario generation within SimCLIM;
- **Spatial patterns of change from GCMs** (which determine the *regional differences* in changes in temperature, precipitation and other climate variables). SimCLIM has sets of results from 21 GCMs (see below), which can be used either individually or in *ensembles* (combinations of GCMs). For the latter, the user can select the “best estimate” (median value) or select a percentile range to represent the uncertainties.

The SimCLIM user interface provides considerable scope for choosing amongst emission scenarios, model sensitivity values, GCM patterns, regions, seasonal aggregations and future time horizons, and thus for examining the range of uncertainties involving future greenhouse gas emissions and scientific modelling. For the FVA project, the following specifications applied:

- Climate sensitivity: **HIGH**
- Emission Scenario: **SRES A1FI (highest)**

- GCM: **the median value of an ensemble of equally weighted 21 GCMs**

Using “pattern scaling” techniques, these three factors can be combined to generate scenarios of climate change, as described below.

Methods

SimCLIM uses a variation of the *pattern scaling* described originally by Santer et al. (1990) to generate regional patterns of climate change for user-selected years between 1990 and 2100. In pattern-scaling, the global-mean and spatial patterns of future change are treated separated. Spatial patterns of climate change (monthly-means) from GCMs are “normalised” (i.e. expressed as changes per 1°C change in global-mean temperature) and scaled up to a projected global-mean temperature change for a given year. As stated by Kennett and Buonomo (2006), “...pattern scaling method offers a possibility of representing the whole range of uncertainties involved in future climate change projection based on various combinations of emission scenarios and GCM outputs, which makes the cross model sensitivity analyses and uncertainties examinations can be easily conducted (TGICA 2007)”. Pattern scaling may be described as follows:

For a given climate variable *V*, its anomaly ΔV^* for a particular grid cell (*i*), month (*j*) and year or period (*y*) under an emission forcing scenario is calculated as:

$$\Delta V_{yij}^* = \Delta T_y \cdot \Delta V_{ij}^' \qquad (1)$$

ΔT being the annual global-mean temperature change.

For SimCLIM, the local “normalised” (i.e. the change per 1°C of global temperature change) pattern value ($\Delta V_{ij}^'$) is calculated from the GCM simulation anomaly (ΔV_{yij}) using linear least squares regression, that is, the slope of the fitted linear line.

$$\Delta V_{ij}^' = \frac{\sum_{y=1}^{m} \Delta T_y \cdot \Delta V_{yij}}{\sum_{y=1}^{m} (\Delta T_y)^2} \qquad (2)$$

where *m* is the number of future sample periods used, in this case a 10 year average was the period.

The anomaly ΔV^* is then used to perturb the baseline *observed* values, V_{obs}, in order to generate a "new" climate scenario for the future year.

Pattern scaling is based on two key assumptions: Firstly, that a simple climate model can accurately represent the global responses of a GCM, even when the response is non-linear (Raper et al. 2001); and, secondly, that a wide range of climatic variables represented by a GCM are a linear function of the global annual mean temperature change represented by the same GCM at different spatial and/or temporal scales (Mitchell 2003; Whetton et al. 2005).

Data

ΔT projections contained in SimCLIM were produced by the simple climate model, MAGICC (Wigley 2008), using emission scenarios and a set of climate model parameters (in SimCLIM, represented by the "climate sensitivity" value) which produce temperature projections consistent with those of IPCC AR4. In SimCLIM, there are thus 18 possible projections of global-mean temperature change from which to select (3 climate sensitivities X 6 emission scenarios).

The GCM data were obtained from the experiments of 21 models from research groups around the world (see **Table 2**). The data were obtained from the Coupled Model Intercomparison Project 3 (CMIP3) database (http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php), produced for the IPCC AR4. The models in the CMIP3 database represent the current state-of-the-art in climate modelling, with generally more sophisticated representations of physical and dynamical processes and finer spatial resolution. The CMIP3 database provides monthly mean temperature and precipitation data for all 21 models. The simulations of 20th century climate were driven by observed changes in greenhouse gases and aerosols and were used as the simulated baseline calculating change values. For the 21st century, simulations were driven by various emission scenarios; the patterns obtained for SimCLIM were driven by the SRES A1B forcing. The global patterns are generated in 0.5 degree latitude * longitude grids interpolated from the GCM's original resolution, using a bilinear interpolation method. These were further interpolated to a 0.025 grid for Australia.

Using a multi-model ensemble of all 21 GCMs is an accepted methodology. In recent years, especially around the time of IPCC AR4, it became evident that, in general, multi-model ensembles of GCM outputs actually tended to "validate" better as compared to single GCMs. One reason may be that the singularly odd behaviour of an individual GCM tends to get "washed out" when included in an ensemble of outputs (like taking a statistical sample of 21 to estimate the central tendency). Thus, while some experts argue that individual GCM pre-selection or weighting should be performed prior to "ensembling", others argue that there it makes little difference to the end result. For the sake of simplicity, transparency and expediency, we chose to use a comprehensive non-weighted approach. The major assumption is that the "outlier" GCMs have minimal effect on the resultant median value.

Whether or not to "handpick" GCMs or to weight them is a contentious issue within the field. It necessarily involves evaluating the individual models, either by how well the control run outputs match observations (e.g. observed vs. predicted precipitation patterns), by how well specific processes are simulated (e.g. cloud, precipitation processes), or both. The problems include decisions about which type of evaluation should be given greater reliance for scenario selection; *which* quantities or processes should be used for evaluation; and at what scale (e.g. is a model "better" if it performs well at the regional scale but relatively poorly at the global scale, given that climate is a global system?).

This is a general problem when measures of central tendency are presented without any notion of the variation or scatter of results. One graphical way of doing this is to include "model agreement" map, which can easily be interpreted by a range of readers. Such maps were presented, for example, in the last IPCC AR4. A model agreement map for annual precipitation change was generated (Figure 7) for the FVA project indicating normalised spatial agreement patterns for the 21 GCMs used.

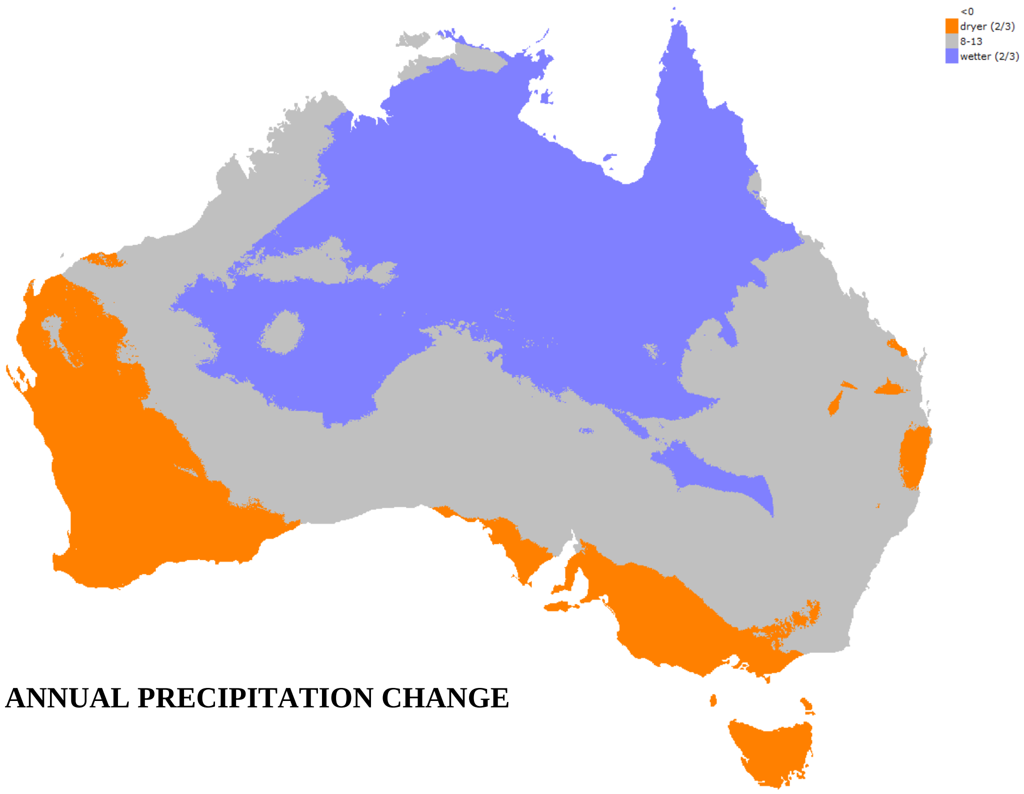

Figure 7 Model agreement map for annual precipitation change for 21 GCMs. Orange: 14-21 models agree it is getting drier, blue: 14-21 models agree it is getting wetter, grey: model disagreement

Stage 1 Outputs

Using the methods and data described above, the first tranche of climate change scenarios were generated for the FVA project. Two time horizons were specified, 2030 and 2070 for the model specifications noted above and for the following variables, regions and seasons:

Variable	**Area**	**season**
Rainfall	Northern	Wet
Rainfall	Northern	Dry
Rainfall	Southern	DJF
Rainfall	Southern	MAM
Rainfall	Southern	JJA
Rainfall	Southern	SON
Rainfall	Australia	Annual
Tmax	Australia	Annual

Table 13: GCMs used in SimCLIM Precipitation and Temperature Patterns

No.	Originating Group(s), Country	Model	SimCLIM name	Horizontal grid spacing (km)
1	Bjerknes Centre for Climate Research, Norway	BCCR	BCCRBCM2	~175
2	Canadian Climate Centre, Canada	CCCMA T47	CCCMA-31	~250
3	Meteo-France, France	CNRM	CNRM-CM3	~175
4	CSIRO, Australia	CSIRO-MK3.0	CSIRO-30	~175
5	CSIRO, Australia	CSIRO-MK3.5	CSIRO-35	~175
6	Geophysical Fluid Dynamics Lab, USA	GFDL 2.0	GFDLCM20	~200
7	Geophysical Fluid Dynamics Lab, USA	GFDL 2.1	GFDLCM21	~200
8	NASA/Goddard Institute for Space Studies, USA	GISS-E-H	GISS—EH	~400
9	NASA/Goddard Institute for Space Studies, USA	GISS-E-R	GISS—ER	~400
10	LASG/Institute of Atmospheric Physics, China	FGOALS	FGOALS1G	~300
11	Institute of Numerical Mathematics, Russia	INMCM	INMCM-30	~400
12	Institute Pierre Simon Laplace, France	IPSL	IPSL-CM40	~275
13	Centre for Climate Research, Japan	MIROC-H	MIROC-HI	~100
14	Centre for Climate Research, Japan	MIROC-M	MIROCMED	~250
15	Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA, Germany/Korea	MIUB-ECHO-G	ECHO---G	~400
15	Max Planck Institute for meteorology DKRZ, Germany	MPI-ECHAM5	MPIECH-5	~175
17	Meteorological Research Institute, Japan	MRI	MRI-232A	~250
18	National Center for Atmospheric Research, USA	NCAR-CCSM	CCSM—30	~125
19	National Center for Atmospheric Research, USA	NCAR-PCM1	NCARPCM1	~250
20	Hadley Centre, UK	HADCM3	UKHADCM3	~275
21	Hadley Centre, UK	HADGEM1	UKHADGEM	~125

Stage 2 Outputs

The second tranche of scenarios produced for the FVA project focused on daily extremes of temperature. As before, two time horizons were specified, 2030 and 2070 for the same model specifications noted above and for the following variables, regions and seasons:

Variable	**Area**	**Season**
days >35 deg	Australia	Annual
days >40 deg	Australia	Annual
Frost days	Australia	Annual

Because these analysis were spatial and involved daily time-series data, the datasets and computational requirements were large. Therefore most of the "number-crunching" was done outside the SimCLIM environment. However, the scenario generation that produced the change values was done within SimCLIM following the same methods as described above, and the results were entered into SimCLIM for purposes of further manipulation and graphical display. The steps followed for analysing ***extreme hot days*** were:

1) The observed gridded daily maximum temperature data with 0.05 latitude longitude degree spatial resolution were obtained from BOM Australia. For each grid cell, the number of days where the maximum temperature exceeded 35 ºC and 40 ºC was calculated on an annual basis for the observed period. The results were then averaged over the observed period 1961-2000 to form the baseline data.
2) For each grid cell, the monthly climate change projection values were obtained from the ensemble median value of 21 GCMs for the defined years (2030 and 2070) under the A1FI high storyline and climate sensitivity. For each site, GCM monthly projected temperature change values were added to the corresponding daily observed temperature values to create the future temperature time series.
3) For each grid cell, the average number of days in which the maximum temperature was >35 ºC and >40 ºC were re-calculated for the projected climate change year of 2030 and 2070 using the perturbed maximum temperature times series
4) The data on the number of days with maximum temperature >35 ºC and >40 ºC were interpolated to 0.025 resolution grid cell using bilinear interpolation method in order to consistent with other climate variables generated from SimCLIM.
5) The *change* in the number of days with maximum temperature >35 ºC and >40 ºC was the difference between projected period and the baseline.

For ***frost days***, the steps were similar, except that daily gridded time-series data of minimum temperatures with a threshold value of <0 ºC were used.

Annex 5 Scenario Summary and Outputs

The climate changes, depicted as both absolute and relative changes, are contained in the assemblage of maps provided below. From the maps, four major patterns of change are evident:

- ***Annual rainfall increases in the tropical north and decreases elsewhere***. In general terms, this portends an exacerbation, not alleviation, of problems associated with drought and water shortages and their effects on vegetation being experienced through non-tropical parts of Australia.

- ***In northern Australia, the wet season gets wetter, the dry season gets drier.*** Although in terms of the annual average large areas of Northern Australia are projected to get wetter, the seasonal distribution may suggest that the additional rainfall may come when it is least needed, and decline when it is most needed by vegetation.

- ***In southern Australia, widespread decreases in rainfall occur during winter and spring. The west and southern coasts show decreases in rainfall in all seasons.*** In general, this pattern would appear to add considerable stress to an already stressed part of Australia and, along with temperature increases, would surely worsen the risks of bush-fires.

- ***Mean maximum temperature in February increases by 3.5-4.5 degrees over most of Australia***. By 2070, vast areas of interior Australia in particular would be facing <u>*average*</u> daytime temperatures in February in excess of 39 deg C. Questions arise regarding the survival of species and the breakdown of ecosystems under those sorts of temperatures.

The number of days of daily temperature extremes, depicted as both absolute and relative changes, are contained in the assemblage of maps provided below. From the maps, three major patterns of change are evident:

- ***The increase in number of days exceeding both >35 ºC and >40 ºC is greatest in the interiors of Northern Territory and northern Western Australia***. These are areas where the number of days exceeding the threshold values is already high. The increases may be greatest where the central value of the distribution is already near the threshold values. This is illustrated by the example of Derby Post Office data shown below: the effect of increasing the daily maximum temperatures by a couple of degrees is to shift a large portion of the distribution over the respective thresholds.

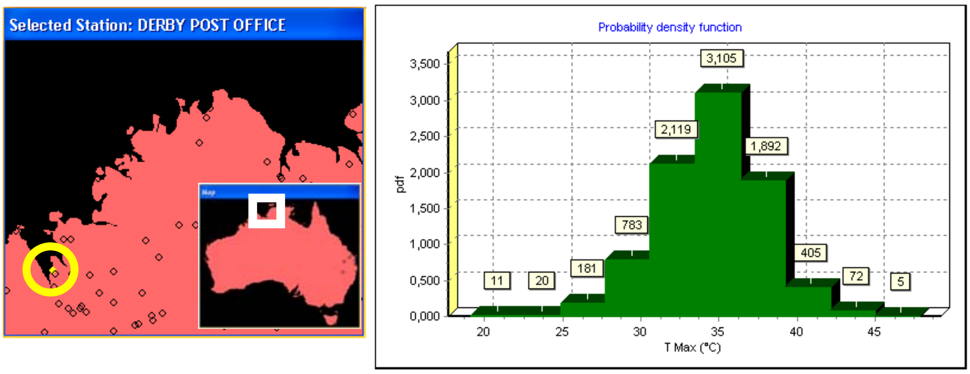

Figure 8 Derby Post Office location map and probability density distribution for T_{Max}

- ***From many coastal areas to the interior, there may be large spatial shifts in the number of days exceeding the designated maximum temperature thresholds.*** These areas currently exhibit steep horizontal temperature gradients. The effect of increasing maximum temperatures would be an advance coastward of given numbers of exceedance days.

- ***The decrease in the number of frost days may be most evident as large elevational shifts over short distances as minimum temperatures increase***. The areas presently exhibiting the most frost days are those in inland mountainous areas of Victoria and NSW and in western Tasmania. This may have large implications for narrow ecotones occupying these areas.

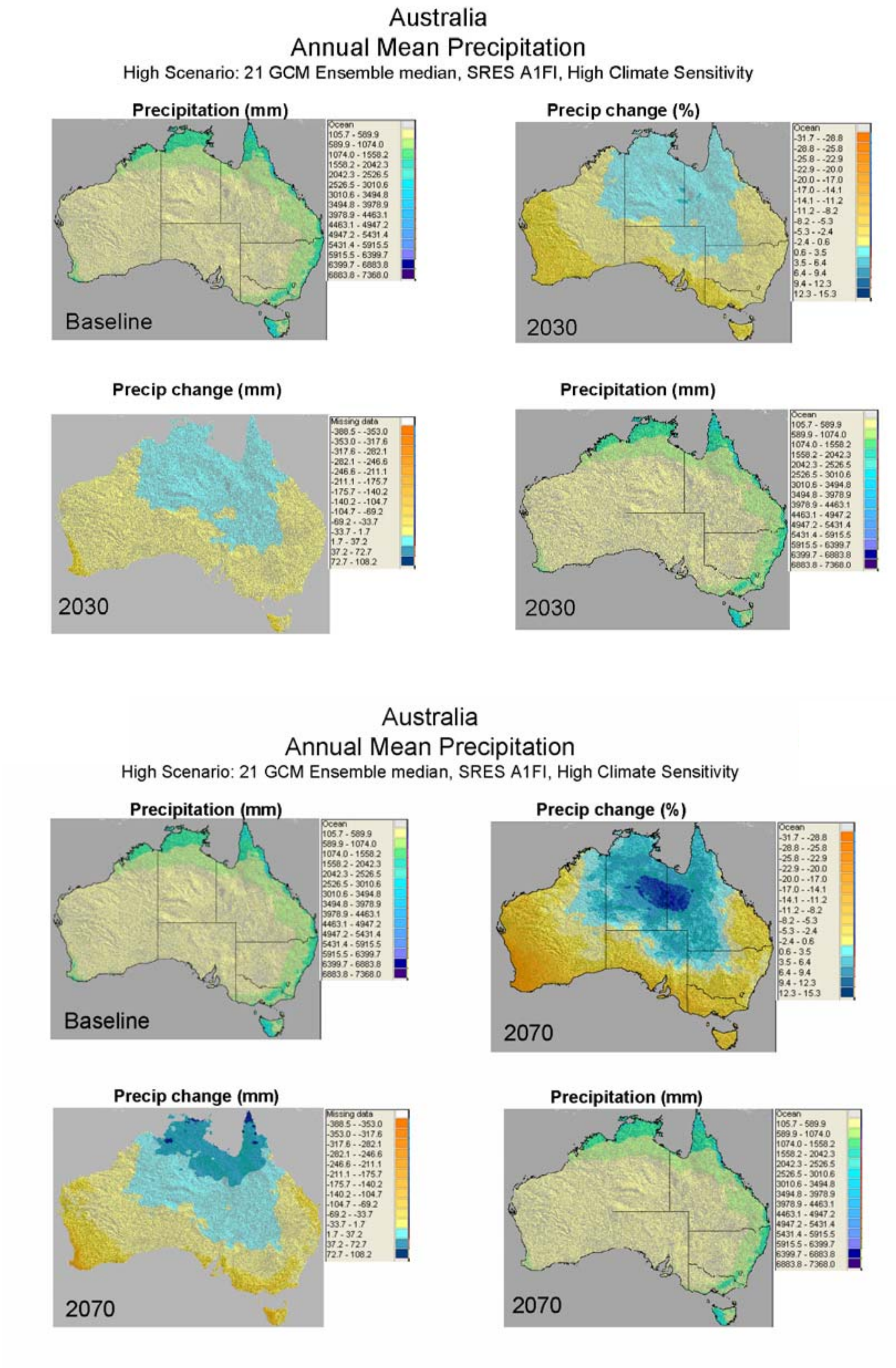

Figure 9 Change in annual mean precipitation for Australia

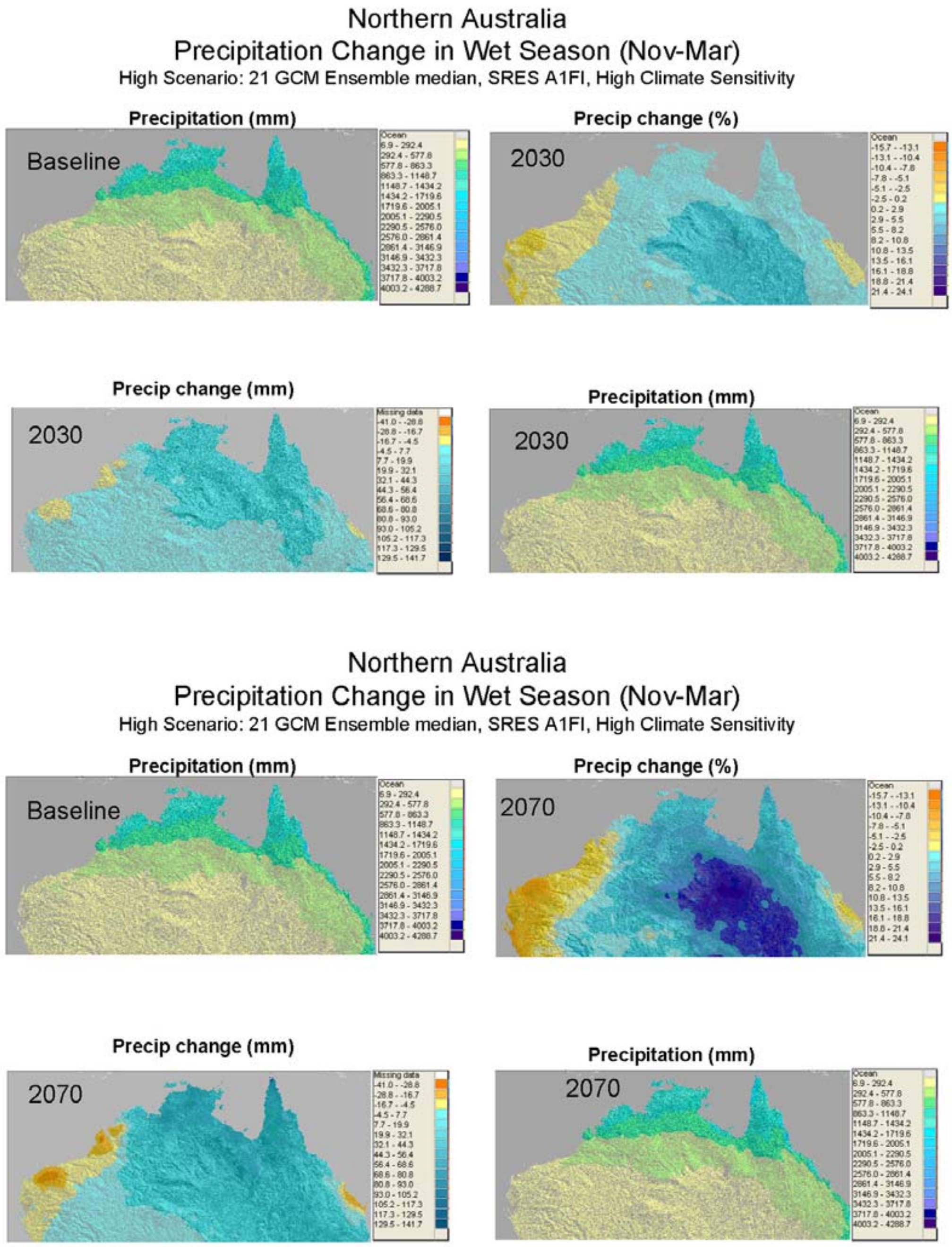

Figure 10 Change in precipitation in wet season for Northern Australia

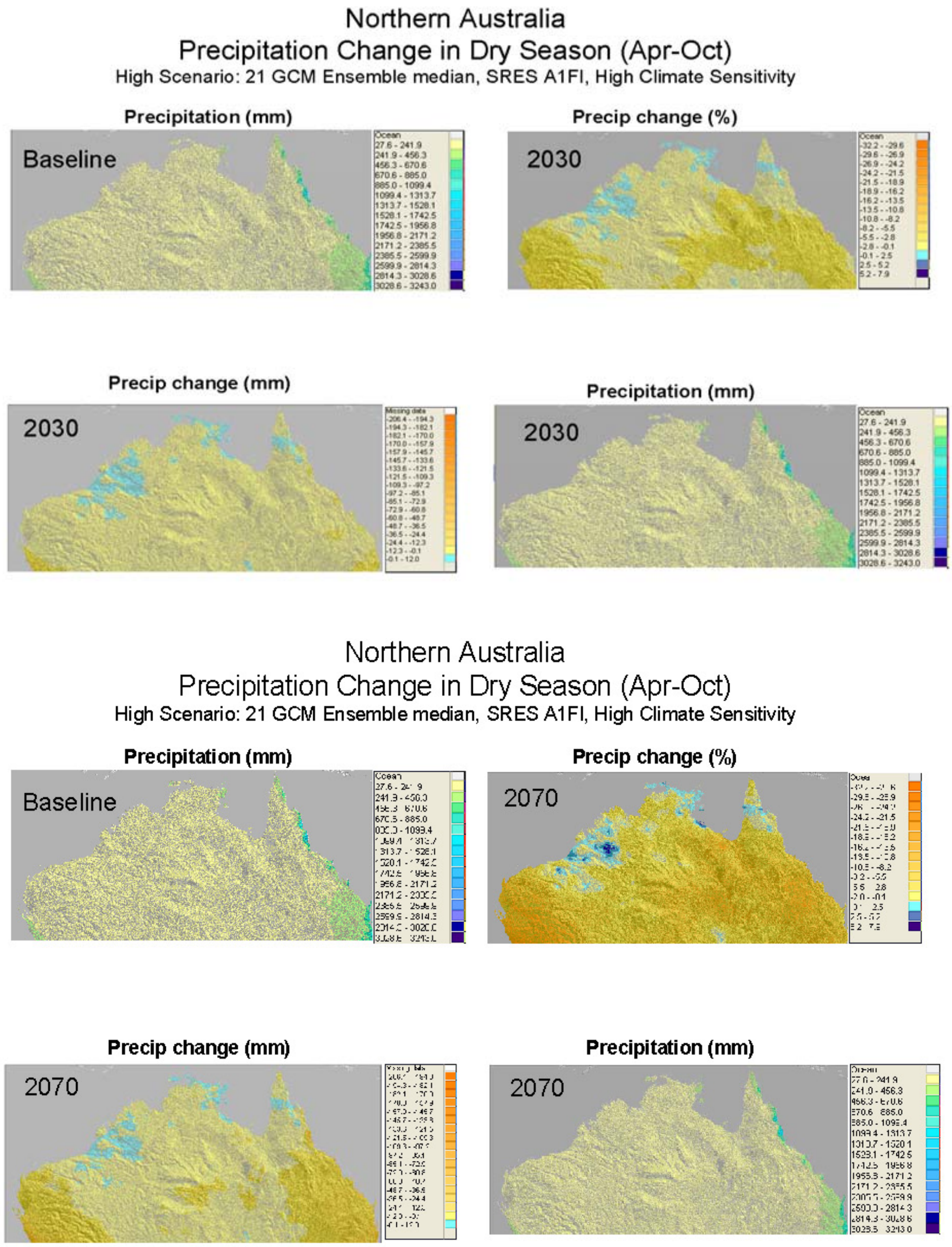

Figure 11 Change in precipitation in dry season for Northern Australia

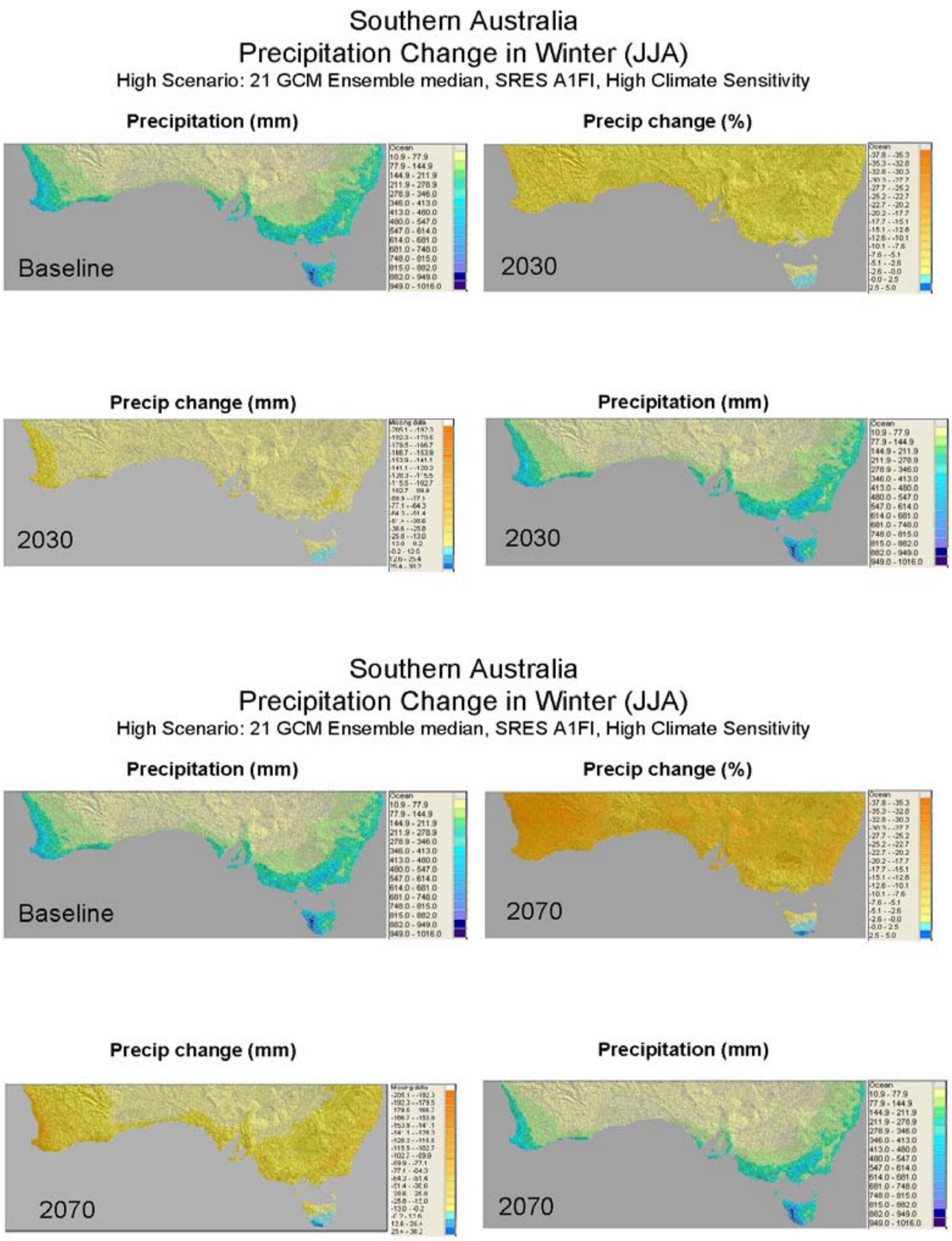

Figure 12 Change in precipitation in winter (JJA) for Southern Australia

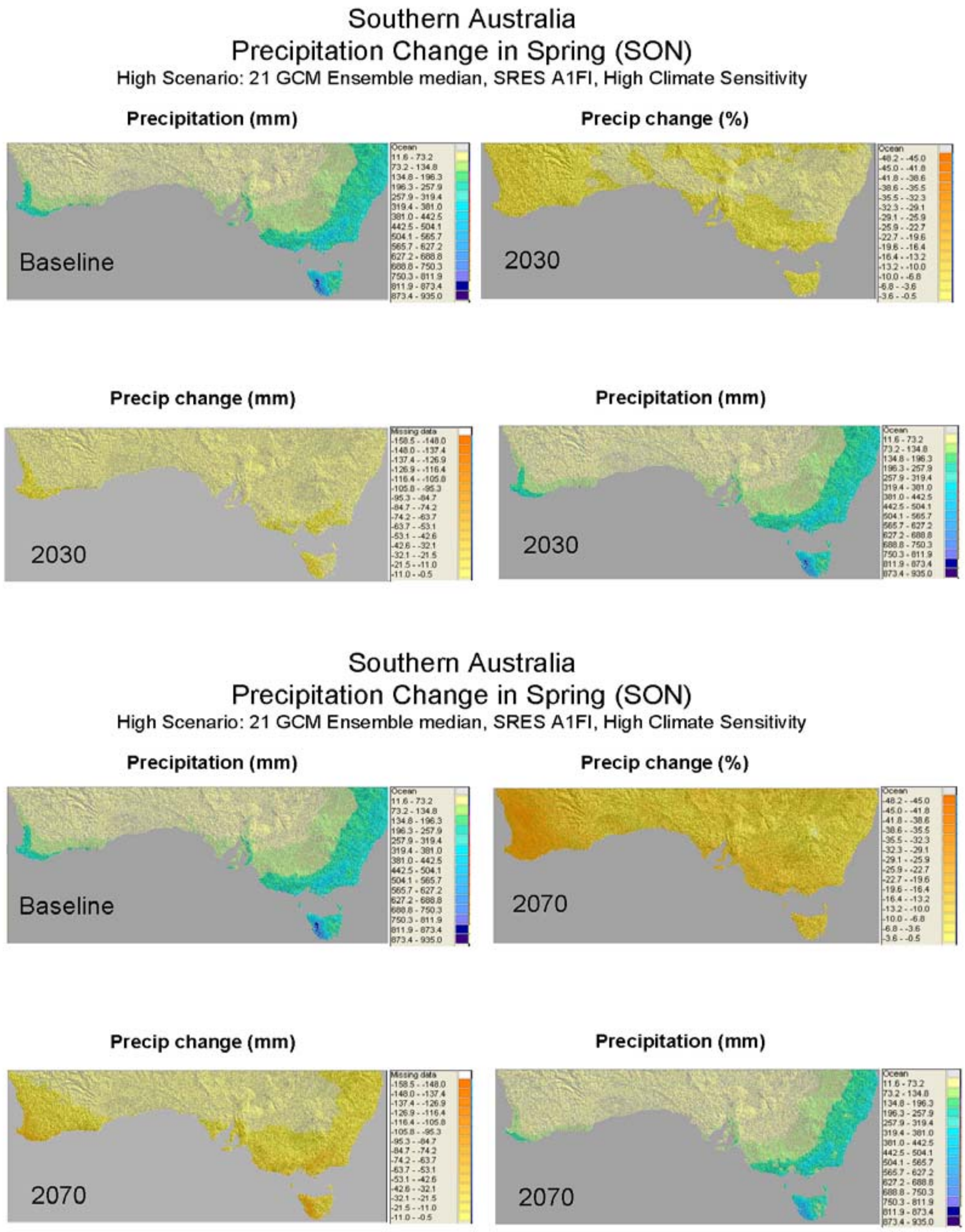

Figure 13 Change in precipitation in spring (SON) for Southern Australia

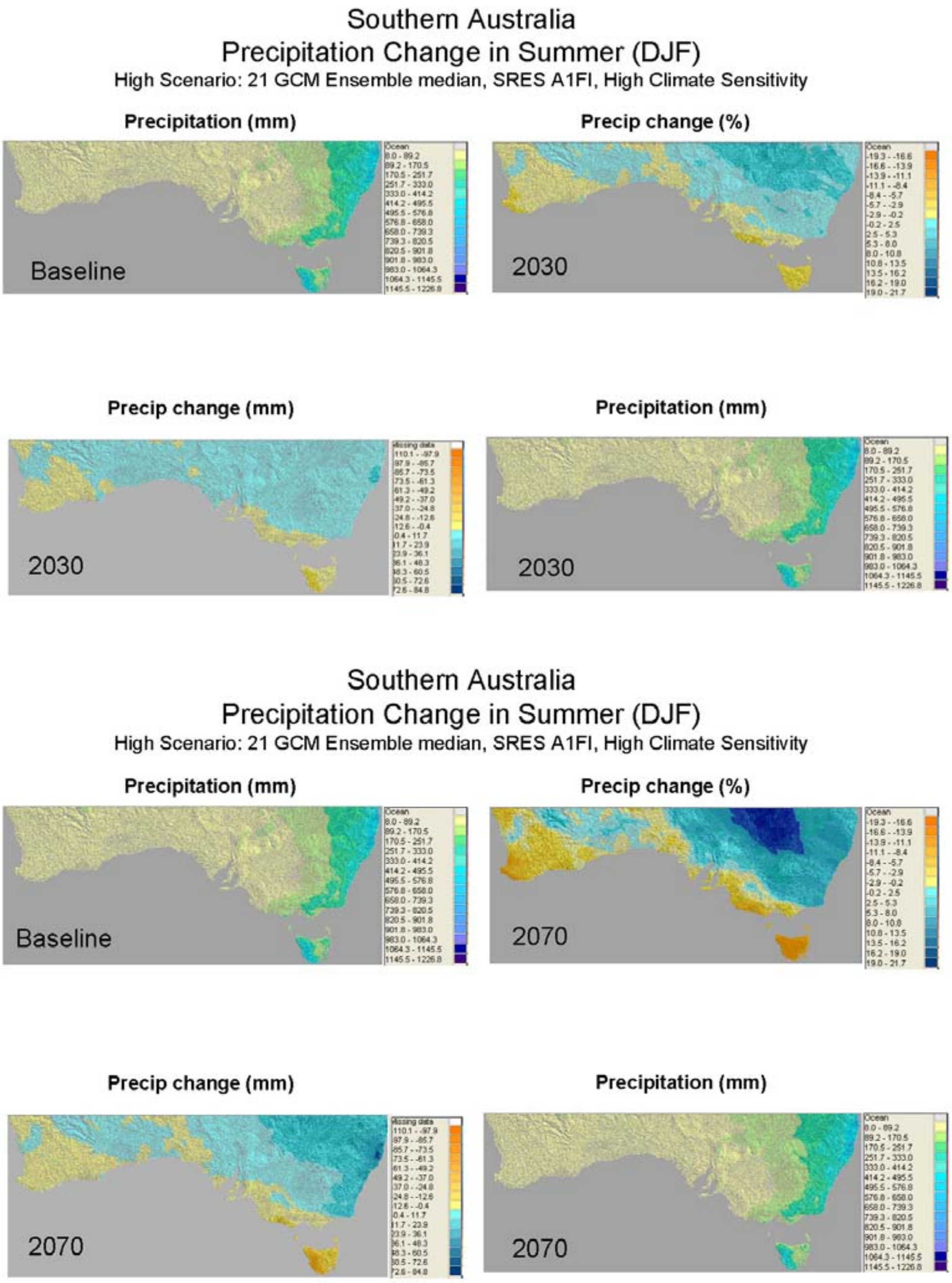

Figure 14 Change in precipitation in summer (DJF) for Southern Australia

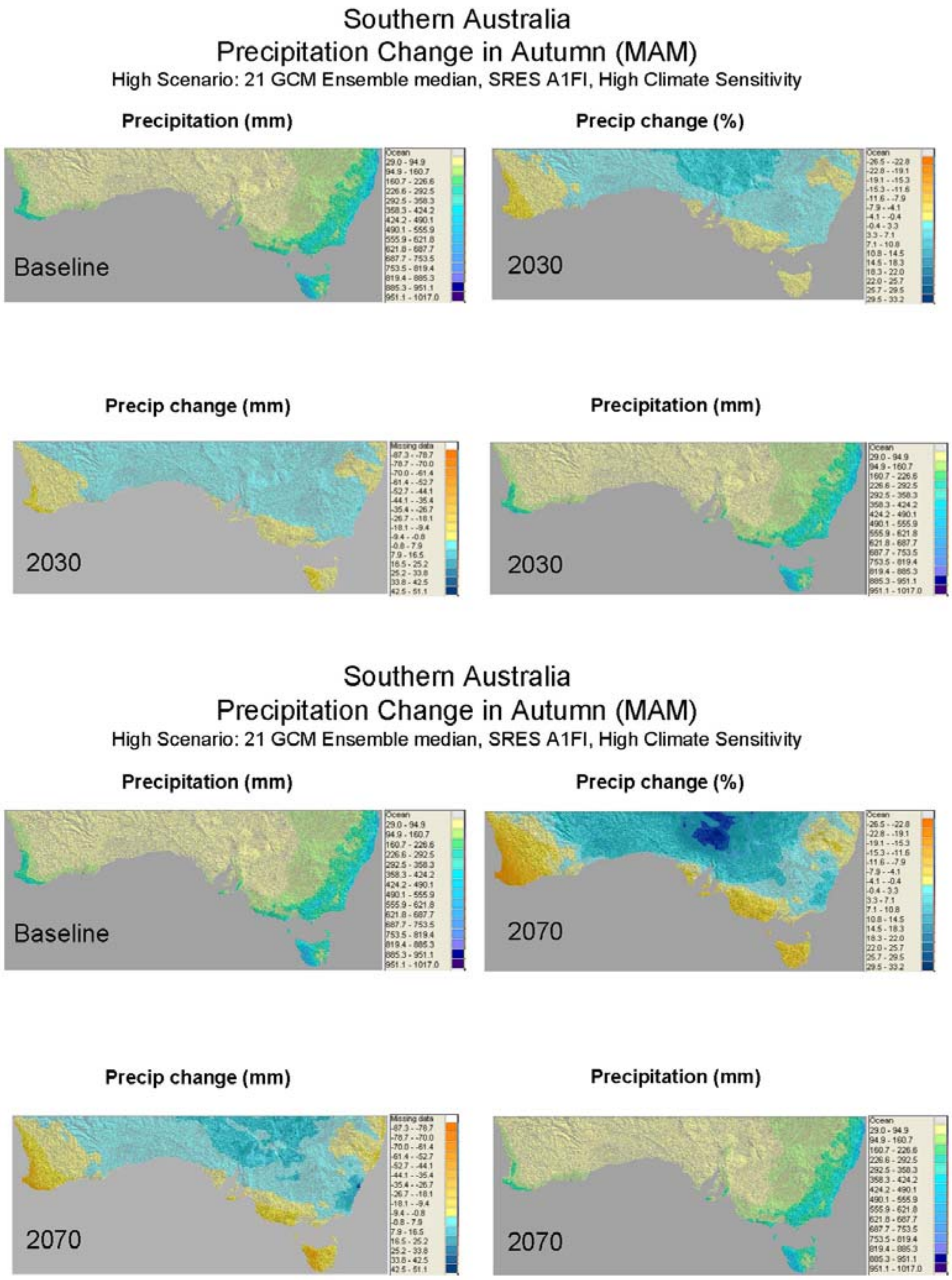

Figure 15 Change in precipitation in autumn (MAM) for Southern Australia

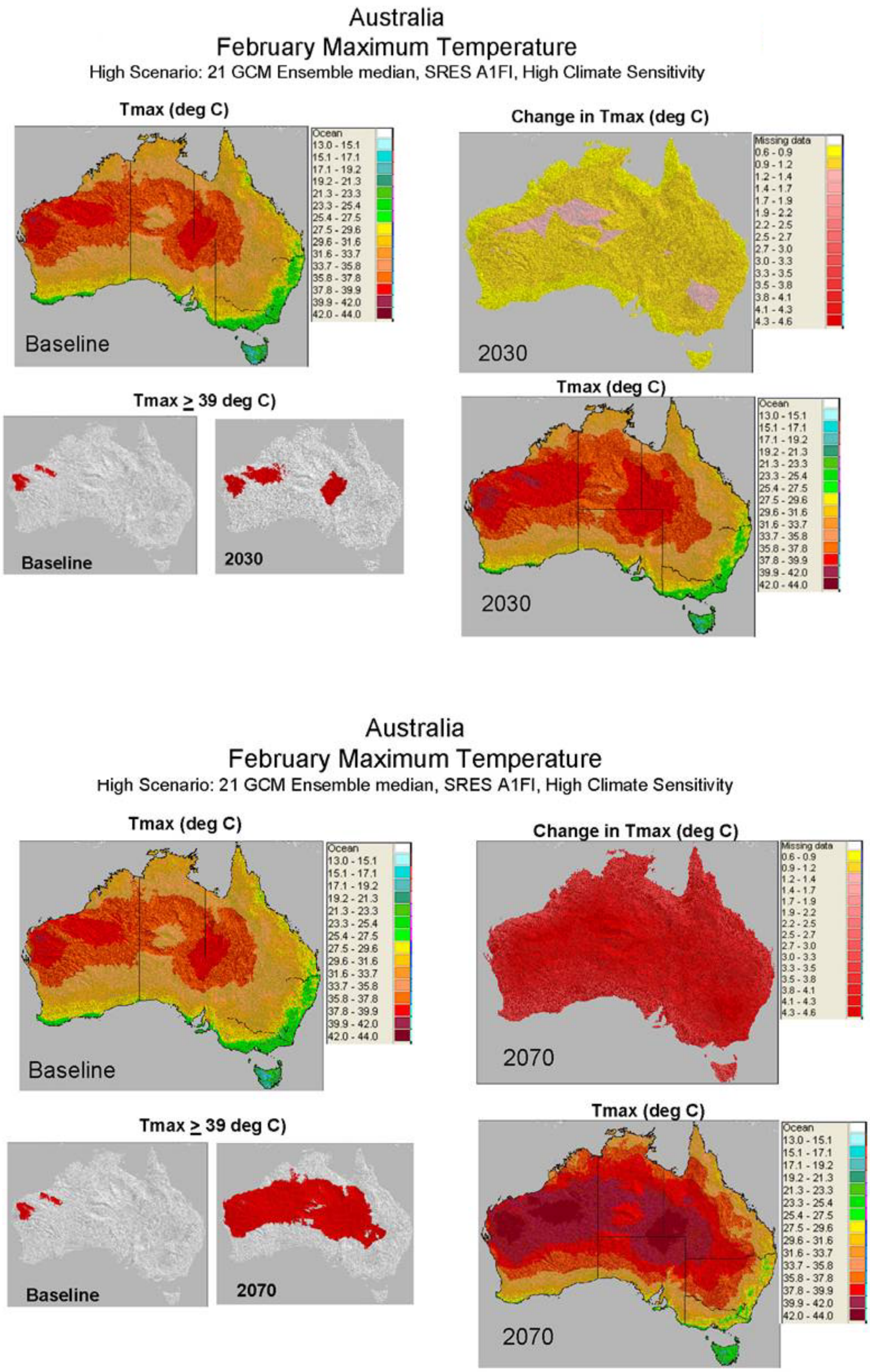

Figure 16 Maximum temperatures in February

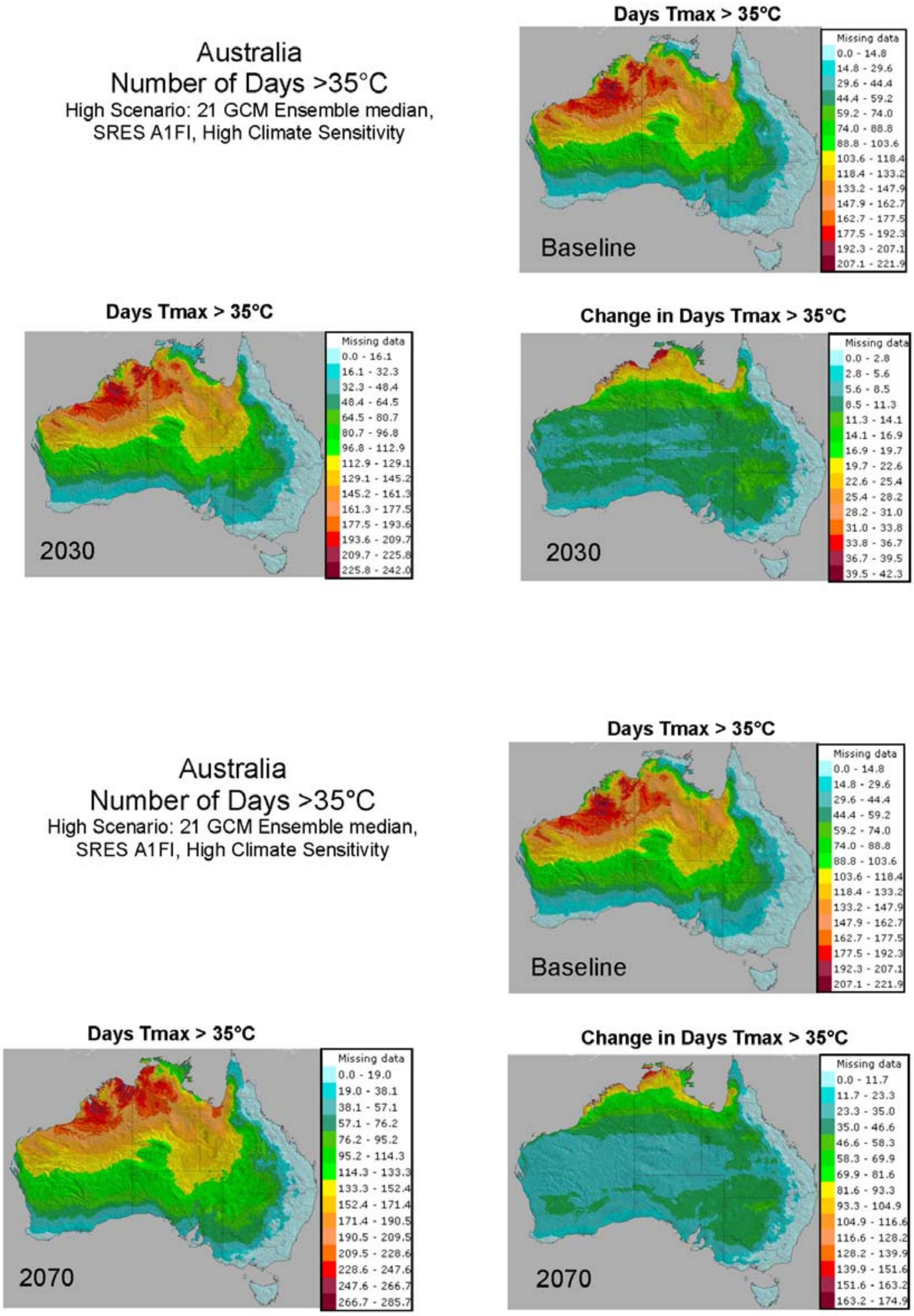

Figure 17 Number of days above 35° C

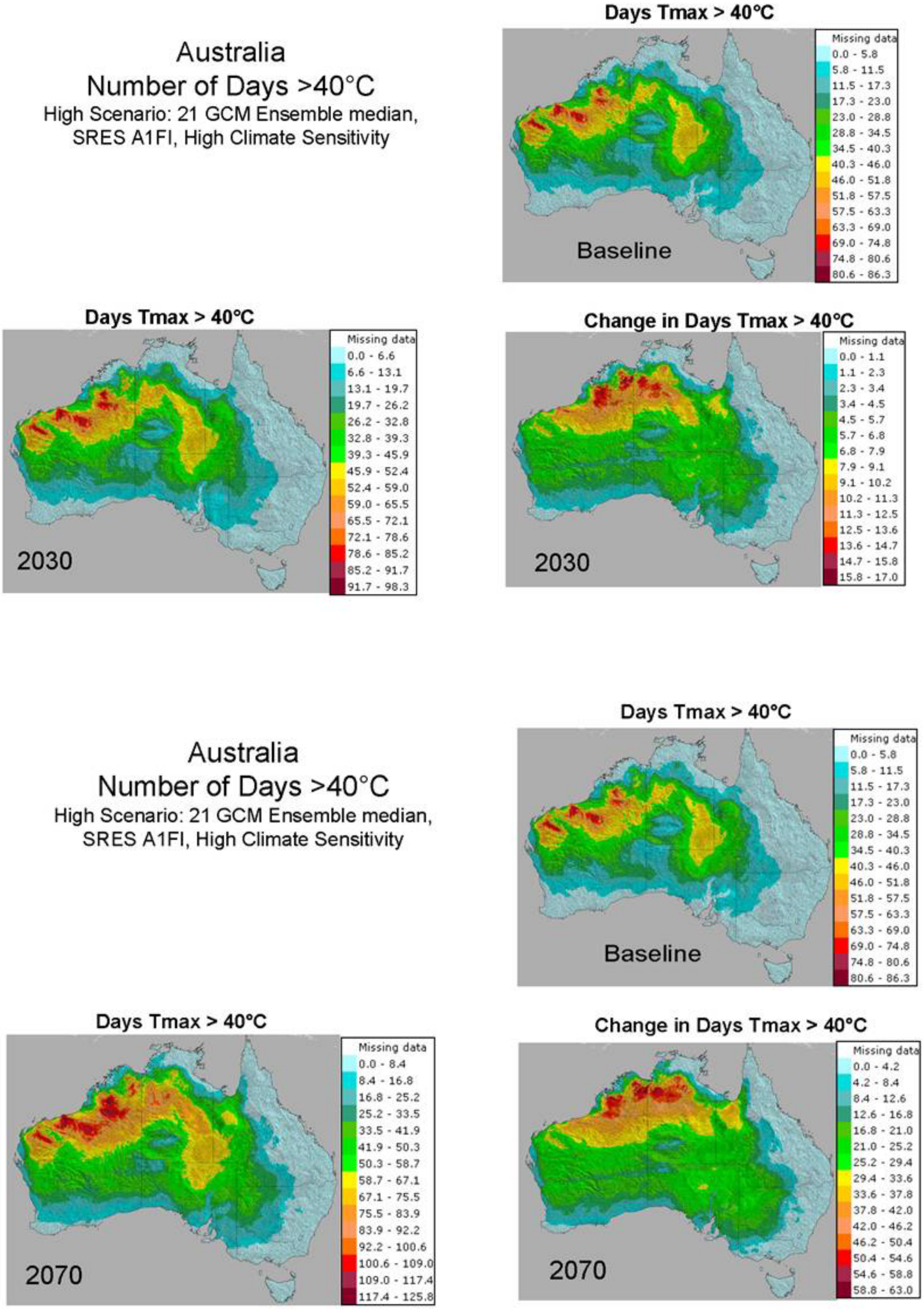

Figure 18 Number of days above 40° C

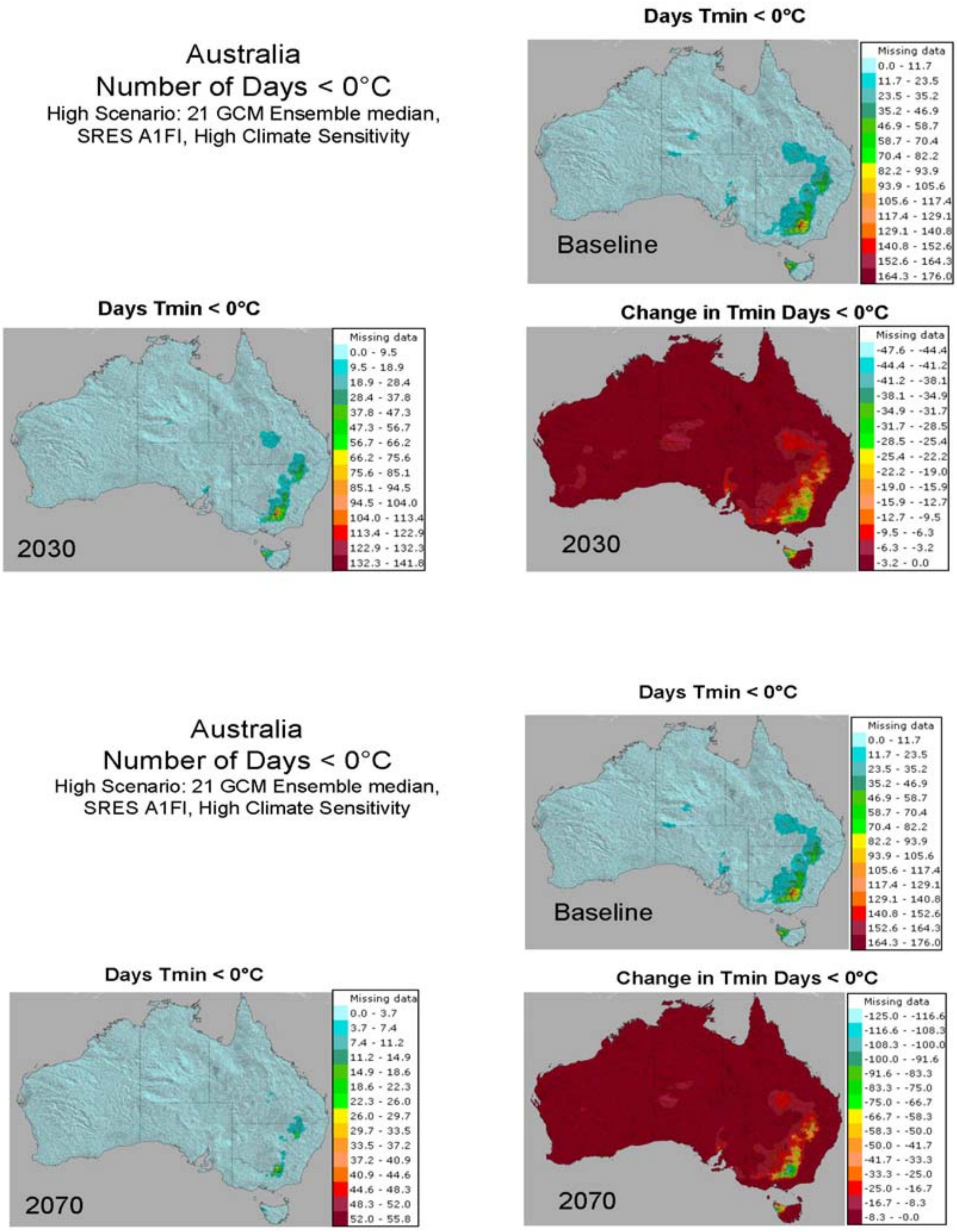

Figure 19 Number of days below 0° C

Annex 6 National Climate Change Action Plans[9]

Table 14: National climate change action plan strategies relevant to biophysical issues raised by participants

National Action Plan or Strategy	Identifier	Action, Strategy or Outcome
National Agriculture and Climate Change Action Plan	Strategy 1.2	Integrate climate adaptation into agricultural adjustment and natural resource management (NRM) programs through risk a management approach, including progressively building considerations of climate change into existing national natural resource management programs such as the National Action Plan for Salinity and Water Quality and the Natural Heritage Trust, and any successor future programs
	Strategy 1.3	Integrate pest, weed and disease implications of climate change into strategies that minimise the impact on agricultural and natural resource systems
	Strategy 3.4	Support the development and maintenance of observational networks and systems to monitor climate changes and agricultural systems response to better understand climate change variability
National climate change and Commercial Forestry Action Plan	Action 2	Assess all forest regions, forest types and forest values to determine risks from climate change
Forest Research Strategy Directions	Outcome 1.4	Forest and water resource managers can predict and manage the impact of climate change on water yields from forested catchments
	Outcome 1.5	Fire management systems are adapted to changed climate conditions
	Outcome 1.6	Landscapes are designed and managed for resilience
	Outcome 2.1	A balanced and equitable basis for allocating water that does not unfairly impede growth of the forestry sector and recognises the economic and environmental benefits that forest provide
	Outcome 2.2	Native and planted forests are managed in a sustainable manner using information based on knowledge of limitations within a changing climate
	Outcome 4.1	Australia's natural and planted forests are included in national and state biosecurity plans jointly supported and implemented in a proactive and integrated manner by governments and industry

[9] (Commonwealth of Australia 2009; Research Priorities and Coordination Committee, 2008; Natural Resource Management Ministerial Council, 2006; Natural Resource Management Ministerial Council, 2004)

	Outcome 4.2	Forest managers are equipped with biologically, economically and environmentally effective tools for managing pest and disease threats within Australia
National Biodiversity and Climate Change Action Plan	Strategy 1.2	Maintaining and improving capacity to predict climate change impacts on biodiversity
	Strategy 5.1	Identifying and incorporating into vegetation management strategies across all tenures, ongoing activities to improve the opportunity for species at risk from climate change to adapt
	Strategy 5.2	Reviewing reserve acquisitions to strengthen reserve system to act as refuges for vulnerable terrestrial species and integrate reserve planning and management with broader landscape protected area networks to allow the movement of species across bioclimatic gradients
	Strategy 5.3	Conserving threatened species that have the potential to become extinct as a result of climate change impacts
	Strategy 6.2	Considering implications of native species becoming invasive, and incorporating this information as appropriate into invasive species and threatened species programs
	Strategy 6.3	Preventing the establishment of new alien invasive organisms in Australia, which could be attributed to climate change
	Strategy 6.4	Reviewing priority alien invasive organisms for management action and re-evaluating alien invasive organism managements strategies, taking into account the potential effects of climate change on their distribution
	Strategy 7.1	Incorporating consideration of climate change impacts on biodiversity into NRM/biodiversity policies, strategies and programs, consistent with ecologically sustainable development (ESD) principles.
	Strategy 7.3	Incorporating consideration of the impacts of climate change when listing threatened species and ecological communities and, in planning for the recovery of these species and ecological communities, ensure prioritisation.

Table 15: National climate change action plan strategies relevant to socio- economic issues raised by participants

National Action Plan or Strategy	Identifier	Action, Strategy or Outcome
National Agriculture and Climate Change Action Plan	Strategy 2.4	Enhance biosequestration opportunities in agriculture
National climate change and Commercial Forestry Action Plan	Action 4	Develop methods to identify risks to infrastructure and processing facilities
	Action 5	Develop, provide and facilitate integrated regional scale tree planting and sustainable forest management options which can be used in the business models of other land use sectors as a means of adaptation, while enhancing and protecting

		land, water and biodiversity outcomes
	Action 6	Encourage greenhouse mitigation through: • Promoting investment in reforestation and bioenergy systems
	Action 16	Facilitate changes in forest management to lower risk and identify new forest growing opportunities by disseminating information on forestry and climate change
Forest Research Strategy Directions	Outcome 3.2	The contribution of active forest management to biodiversity conservation at different scales is understood by communities, governments and industry
	Outcome 3.3	Forest management is physically, economically and environmentally integrated into agricultural production systems
	Outcome 5:1	Timber resources are of sufficient quantity and quality for profitable value adding within Australia
National Biodiversity and Climate Change Action Plan	Strategy 7.2	Incorporating consideration of climate change impacts on biodiversity into land-use planning and land-use change programs

Table 16: National climate change action plan strategies relevant to governance issues raised by participants

National Action Plan or Strategy	Identifier	Action, Strategy or Outcome
National Agriculture and Climate Change Action Plan	Strategy 4.1	Ensure climate change issues are integrated where relevant in policy and program communications
Forest Research Strategy Directions	Outcome 1.2	The forest industry is adequately prepared for a carbon trading environment at local and national levels
	Outcome 3.1	Better informed policy decision to meet the multiple demands on forests

Table 17: National climate change action plan strategies relevant to the knowledge and information needs raised by participants

National Action Plan or Strategy	Identifier	Action, Strategy or Outcome
National Agriculture and Climate Change Action Plan	Strategy 3.1	Develop approaches, tools and improved participatory engagement to assist Australian agriculture to manage risks from climate change
	Strategy3.3	Encourage industry-based research and development organisations, including research and Development Corporations (RDCs) to work together, and with research

		providers and industry, to develop a coordinated approach to climate change research and development in agriculture and natural resource management
	Strategy 3.5	Improve capacity of models to predict climate impacts on agriculture at scales relevant to farmers and natural resource managers
	Strategy 4.2	Increase understanding and integration of scientific knowledge of climate into farm management decisions
	Strategy 4.3	Incorporate issues of climate change into education and training packages directed at agricultural industries
National climate change and Commercial Forestry Action Plan	Action 1	Collaborate with the climate community to understand the impacts of recent climate variability and change on forestry and develop regional level climate projections in forested areas to establish where intervention is critical and necessary
	Action 3	Develop diagnostic tools and techniques to determine when (and what) specific management intervention is required to respond to the threats and opportunities of climate change
	Action 15	Enhance and add value to the existing body of forest industry data and monitoring so that better quantitative analysis to support climate change responses can be undertaken in the future
National Biodiversity and Climate Change Action Plan	Strategy 1.1	Addressing important gaps in our knowledge about climate change impacts on biodiversity, and on the cumulative effects of other threatening processes whose impacts on biodiversity will be exacerbated by climate change, at scales relevant to adaptive planning
	Strategy 1.3	Increasing capacity to monitor impacts on biodiversity and evaluating the effectiveness of adaptation strategies and action
	strategy1.4	Addressing information needs of NRM managers and decision makers involved in developing and implementing strategies to minimise the loss of biodiversity due to climate change
	Strategy 1.5	Improving and increasing capacity to assess environmental, economic and social costs and benefits of taking action
	Strategy 2.1	Improving information systems and flows between key groups
	Strategy 2.2	Developing a targeted communication strategy to promote awareness in the broader community
	Strategy 2.3	Increasing capacity of NRM and environmental planners and decision makers to manage dynamic systems

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