



**Forest & Wood
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Knowledge for a sustainable Australia

**INVESTMENT PLAN
FOR CLIMATE CHANGE AND
COMMERCIAL FORESTRY –
IMPROVED DECISION MAKING
AND RISK REDUCTION
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1. SUMMARY

Climate change is a multidimensional issue for the forest industry. It will impact on forest ecosystem functioning and productivity and hence the industry. At the same time forests are seen as part of the solution to climate change as sinks for greenhouse gases and a source of offsets for carbon markets, and thus an opportunity.

The current environment is dominated by uncertainty in terms of the potential biophysical impacts on forests and government policy in relation to climate change, particularly on carbon pricing. At the same time there is recognition of the need to focus on adapting to climate change.

Given the long term nature of forestry and climate change and the need for progressive assessment of adaptation options, the key investment priorities in this plan are those that can assist industry to understand and input to policy development that affects its future, that can improve the predictions of future wood flows and that can allow comparison of carbon values with other forest values. Investment in these areas will reduce the risk and maximize the opportunities for the industry.

2. INVESTMENT PRIORITIES AND BENEFITS

Investment Priority

Short-term policy and economic impact studies that support equitable treatment of forestry investment under GHG emissions reduction policy including carbon pricing/offset arrangements.

Benefits:

- Assist industry to understand and prepare for potential impacts
- Better engagement with other land managers and proactive, informed participation in policy discussions

Investment Priority

FWPA invest in improvements in and testing of process based growth models and the development of linked integrated risk and impact assessment tools that can be applied at the required spatial scale to assist industry decision-making in regards to risks to productivity and profitability.

Benefits:

- Greater confidence in model predictions under various climate change scenarios
- Improved ability to account for and manage risk factors
- Increased capacity to assess impacts and evaluate opportunities in existing or new forestry regions
- Capacity to integrate new information into enterprise and regional planning

Investment Priority

FWPA invest in revised regional (or sub-regional) plantation forest productivity forecasts on a 3-5 year time span.

Benefits:

- Strengthen industry awareness and understanding of likely or evolving climate change impacts on forest productivity
- Progressive improvements in regional forest industry investment decision making

Investment Priority

FWPA invest with other relevant parties to improve accounting for stocks and flows in native forests managed for wood production and ensure the linking of this information to forest management decision making tools.

Benefits:

- Improved understanding of carbon stocks and flows under different management regimes
- Capacity to make informed tradeoffs that maximize desired forest values

Investment Priority

FWPA invest in ecophysiological research that can link physiological traits to drought tolerance in different commercially important species or species groups

Benefits:

- Improved targeting of physiological research to an identified need
- Speed up the identification and selection of drought tolerant species and genotypes

3. INTRODUCTION

Anthropogenically induced climate change is accepted as a basis for policy making for managing greenhouse gas (GHG) emissions internationally and nationally¹. In Australia primary responsibility for climate change related legislation and programmes rests with the Australian Government currently administered through the Department of Climate Change and Energy Efficiency. All States and Territories have also passed climate change legislation, established departments responsible for administering legislation or offices of climate change responsible for government policy and activity coordination.

In addition to Government policy response, economic and environmental sectors are identifying information needs, research priorities and adaptation plans including the primary industries sector. The commercial forest sector is typically aggregated with other primary industries at this broader policy and planning level but is also recognized through specific government research funding initiatives or project funding by a number of organisations.

This plan defines the key research priorities that should be the subject of FWPA investment over the next five years and that will assist the commercial forest sector to remain sustainable in a changing climate.² Whilst this plan stops at the “forest gate” climate change provides both opportunities as well as risks for the forest industry. These opportunities include not only forest based carbon offsets, but bioenergy, biochar and increased substitution of wood products for more energy intensive materials but these latter areas are outside the scope of this plan.

The emerging response to climate change is creating a dynamic policy, programme and coordinating environment that requires regular assessment and engagement with industry, other research funders and policy makers. Policy settings have the capacity to influence the future development of the commercial forest sector whilst climate change will impact on the functioning of forest ecosystems and the productivity of the forests, creating complex decision-making in an environment with high levels of uncertainty.

Given the policy and scientific complexity of the climate change arena, to give context to this plan it was considered necessary to:

¹ IPCC, 2007: *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

² *The sector concerned with the establishment and management of forests for wood production and associated environmental services including forest based carbon offsets.*

- Review the broader international and national policy and coordinating environment as forests are increasingly seen as a part of the solution to rising GHG emissions;
- Assess carbon markets and carbon accounting systems and the impact of climate change on forests;
- Review primary industries climate change research coordination and recent investments specific to forest industries; and
- Develop research priorities based on the literature and consultation.

4. INTERNATIONAL POLICY FRAMEWORKS AND FORESTS

The United Nations Framework Convention on Climate Change (UNFCCC) that came into effect in 1994 is the international framework for intergovernmental efforts to tackle climate change. The Kyoto Protocol, linked to the UNFCCC, is an international legally binding agreement to reduce GHG emissions that came into force in 2005. Australia ratified the Protocol in 2007. The detailed rules for the implementation of the Kyoto Protocol were adopted in 2001 and are known as the 'Marrakesh Accords'. Countries that are signatories to the Protocol have to demonstrate that their agreed GHG reduction targets are met during the first commitment period of the protocol from 2008-2012.

The plan to negotiate and ratify a new international agreement to replace the Kyoto Protocol from 2012 was unsuccessful at the Copenhagen Conference of Parties (15) in December 2009 and hence the scope, targets and mechanisms for any future intergovernmental agreement remain uncertain. The non-legally binding Copenhagen Accord expresses a collective desire to keep the average global temperature increase to less than 2°C.

GHG emissions from deforestation, particularly in the humid tropics, have been a focus of recent international discussions as it is recognised that they are a significant component of overall global emissions and that reducing deforestation is a low cost abatement mechanism as well as delivering a range of other benefits including biodiversity and watershed protection. This has been encapsulated in the REDD (Reducing Emissions from Deforestation and Degradation) concept which aims to provide payments for environmental services (PES) – financial incentives to achieve forest conservation. This has now been extended to REDD+ to include incentives for enhancing carbon storage through forest restoration, rehabilitation and afforestation/reforestation (Campbell, 2009).

REDD or REDD+ faces many implementation and carbon market difficulties and it will be a number of years before it can be determined a success or otherwise in the face of expanding populations and economic development in the main target (developing) countries. Australia is a significant contributor in this sphere through its International Forest Carbon Initiative (www.climatechange.gov.au). International agreements and concerns about emissions from deforestation and degradation will influence the development Australian forest management policy under climate change and the opportunities for Australian forest industry.

5. AUSTRALIAN POLICY FRAMEWORKS AND FORESTS

The Australian Government response to reducing GHG emissions is guided by its commitments under the Kyoto Protocol and agreed national targets for reducing emissions (currently 5% reduction on 2000 emissions by 2020). Australia has a legislated Renewable Energy Target and voluntary offsets will be available from July 1 2010 under the new National Carbon Offsets Scheme (see Section 5).

There is currently considerable discussion on implementing a price on carbon in the Australian economy in order to drive emission reductions consistent with our international obligations. A proposed cap and trade emissions trading scheme (Carbon Pollution Reduction System-CPRS) has been postponed until at least 2013. More recently developments include a possible carbon tax and abatement purchasing programmes, and there is the potential for the emergence of a mixture of carbon pricing mechanisms. Forest based carbon offsets are elements of proposed emission trading and abatement purchase schemes.

Australia has developed a National Greenhouse Gas Inventory and monitors and accounts for its greenhouse gas emissions from land based sectors in its national inventory through the Australian Greenhouse Emissions Information System (AGEIS) and the National Carbon Accounting System (NCAS). The AGEIS currently accounts for the methane and nitrous oxide emissions from livestock and crop production while the NCAS is currently designed to account for carbon emissions from agriculture, deforestation and forestry (www.climatechange.gov.au).

All State/Territories have Ministers with climate change responsibilities and most have as a minimum established a whole of government

coordinating mechanism for analysis of regional climate change scenarios, information provision and policy development within their respective jurisdictions e.g. Queensland Centre for Climate Change Excellence. Some states have passed or intend to pass climate change related legislation. For example the NSW Department of Climate Change and Water administers legislation such as the Carbon Rights Act, the Native Vegetation Act and the NSW Greenhouse Gas Abatement Scheme. In Victoria, the recently released White Paper - Taking Action on Climate Change, proposes the establishment of a Victorian Carbon Exchange that will include offsets from reforestation. Proliferation of State carbon trading initiatives in the absence of national action creates potential conformity issues for industry.

In addition to information gathering and synthesis activities, States support to varying extents climate change adaptation research and seek to coordinate climate change research within their jurisdictions e.g. the Victorian Climate Change Adaptation Research Centre that fosters a collaborative research effort between Victorian Government agencies and Victorian universities.

In terms of Commonwealth-State coordination the National Climate Change Adaptation Framework was endorsed by the Council of Australian Governments in April 2007 with the Australian Government providing \$126million over five years to implement the Framework. The most important research initiative flowing from the Framework has been the establishment of the National Climate Change Adaptation Research Facility (NCCARF) at Griffith University in November 2007. The purpose of NCCARF is to generate information needed by policy and decision makers in governments and vulnerable sectors and communities, to manage the risks of climate change. NCCARF claims to be distinct from other programmes in that it focuses entirely on generating the knowledge required for Australia to adapt to the physical impacts of climate change (www.nccarf.edu.au).

The emerging response to climate change is creating a dynamic policy, programme and coordinating environment that requires regular FWPA assessment and engagement with relevant agencies.

6. CARBON MARKETS

Carbon sequestered by forests, subject to qualifying criteria, is increasingly accepted as part of carbon trading schemes and this is expected to increase in importance. Carbon markets are therefore an opportunity for forest growers. There are essentially two kinds of carbon markets: compliance markets that cover activity associated with

carbon commodities eligible under a mandatory emissions trading scheme; and voluntary markets that cover activity associated with voluntary commitments or exchanges of carbon commodities.

The carbon market is complex and evolving. There are international markets, such as the European Union Emissions Trading Scheme and the Kyoto Protocol (compliance markets), and the Chicago Climate Exchange (CCX) and Portuguese Carbon Fund (voluntary markets). In Australia there are both compliance and voluntary markets. The NSW Greenhouse Gas Reduction Scheme (compliance scheme) for example has been operating since 2003 that include forest based carbon offsets, although globally most forest based carbon offsets are traded in voluntary markets (Clarke 2010).

In addition to the more 'formal' voluntary markets, there is the ability for any two (or more) individuals or organizations to trade carbon, as you would any other commodity between a buyer and seller. The value of a carbon commodity is generally determined by the credibility and integrity of the product, which is in turn normally governed by the methodology that supports their creation. Where there is no formal market, the buyer and seller should agree as to what constitutes the carbon product. Several models, some accredited and some not, are being used commercially by abatement providers e.g. Greenfleet, CO2 Australia.

Within a formal market the methodology that creates the carbon commodity will usually need to address the following issues:

- Ownership – who actually owns the carbon stock or the right to it;
- Additionality – demonstration that the project would not have occurred under business-as-usual;
- Permanence – for how long and by what mechanism will the offset be secured;
- Leakage – consideration of emissions that are indirectly attributable to the project and which occur outside the project boundary; and
- Quantification, monitoring, reporting and verification – detailing how the carbon is proven to be secured.

The Australian Government has recently introduced the National Offset Carbon Standard (NCOS), effective from July 1, 2010 that the voluntary market can use to gain credibility and integrity for carbon commodities. This scheme in part replaces the previous Greenhouse Challenge Plus scheme. In reality, NCOS is not a 'standard', rather a scheme. There remains some confusion about what is eligible under NCOS and when. As it stands, all Kyoto-compliant activities, including forestry, are not eligible for offset accreditation without the CPRS in place. However, there is discussion within policy circles as to how to

ensure forest based carbon offsets are available in the interim until the CPRS or some other carbon price signal is operational, as it is recognized that these will provide significant opportunities to reduce Australia's net emissions. It remains unclear as to how the NCOS will relate to the Australian Standard for forest carbon accounting (see Section 5: AS 4978.1- 2006 Carbon Accounting for Greenhouse Sinks. Part 1. Afforestation and Reforestation).

Future carbon markets are important for the forest industry and industry will need to understand the opportunities as they evolve. The commencement of the New Zealand Emissions Trading Scheme from 1 July 2010 provides a case study for analysis of the impact of such a system on commercial tree growing. However, it is likely carbon markets will be an add-on rather than a driver for traditional forestry and are most likely to influence rotation lengths and net rates of reforestation.

The extent of the market opportunity for 'carbon only' forestry in Australia and the sustainability of the business model will be driven by many factors including government policy, competition for land, the price of carbon and the long term costs of maintaining forests grown specifically for generating offsets. A number of businesses focused on generating forest-based carbon offsets have been established in Australia in recent years. Business development and opportunities in this area were reviewed by Dargush et al (2010). They concluded that carbon markets could be a "catalyst for broader industry change that supports better climate mitigation outcomes".

7. THE NATIONAL CARBON ACCOUNTING SYSTEM (NCAS) AND CARBON ACCOUNTING STANDARDS

Carbon accounting at both the national and project level is critical to underpinning mitigation strategies. Under various schemes and markets, there is a range of accounting methodologies and standards by which to measure, monitor and verify the carbon commodity. These methodologies go to the heart of the credibility and integrity of the carbon commodity, and therefore the value, and the ability to track and report emissions.

The Australian Government established the National Carbon Accounting System (NCAS) in 1998 to provide a complete accounting and forecasting system for human-induced sources and sinks of greenhouse gas emissions from Australian land-based activities. It is the system by which Australia reports its emissions to the international

community and verifies its performance in meeting agreed emission reduction targets.

The NCAS estimates emissions through a system that combines:

- satellite images used to monitor land use and land use change across Australia;
- monthly maps of climate information;
- maps of soil type and soil carbon;
- databases containing information on plant species, land management, and changes in land management over time; and
- ecosystem modeling using the Full Carbon Accounting Model (FullCAM).

The NCAS has and will continue to undergo significant development to improve its accuracy and capability. For example, the NCAS team is currently developing its capacity to do whole of landscape accounting (as opposed to just Kyoto-compliant lands), and the addition of the nitrogen cycle into the system.

The NCAS is considered one of the best in the world for national level land-based accounting. However, it is also considered less accurate in undertaking project or location specific accounting. Investment is being made to improve FullCAM's capabilities to account for forest management impacts (including fire), production native forests, environmental plantings and oil mallees.

Parties wishing to use the same modeling framework as the Australian Government uses for generating the national accounts, can do so through the publicly available National Carbon Accounting Toolbox (NCAT): it provides a relatively simple interface to NCAS for project developers to undertake project level accounting. An updated, more user friendly version of NCAT will be released in 2010.

The Australian Standard for forestry (AS 4978.1- 2006 Carbon Accounting for Greenhouse Sinks. Part 1 Afforestation and Reforestation) "sets out the process for estimating and reporting greenhouse gas removals and emissions from forest projects over a set period of time as a result of afforestation and reforestation activities. The Standard is intended to facilitate the consistent estimation and reporting of greenhouse gas emissions and removals from forest projects, and the verification of estimation and reporting processes." The NSW GGAS requires a party to be accredited under GGAS as a 'Sequestration Pool Manager' by being able to apply Australia Standard AS4978.1 for maintaining, measuring and monitoring carbon stock changes in their sequestration pool.

Growth and yield models underpin carbon accounting and are an essential mechanism for achieving accreditation and demonstrating the integrity of the carbon product. Australia has invested significantly in the development of process-based growth modeling for mainstream plantation species over the last 30 years. Such models will be central to predicting future growth and yield under different climate change scenarios and understanding and managing risk and uncertainty (Battaglia et al. 2009).

In terms of accounting for GHG emissions in forestry operations in Australia results from a detailed life cycle inventory are summarised in Tucker et al. (2008). Total GHGs emitted in producing a cubic meter of log is a very small percentage of the CO₂ sequestered during the growth phase.

8. PRIMARY INDUSTRIES COORDINATION BROAD R&D PRIORITIES IN CLIMATE CHANGE RESEARCH

Australian agricultural and resource industries are likely to be affected profoundly by climate change (Garnaut 2009). This recognition has stimulated analysis of mitigation and adaptation options, increased R&D efforts and better coordination of R&D activities.

The first attempt to develop a more coordinated and collaborative approach to research in areas of common interest in the primary industries sector was the National Climate Change Research Strategy for Primary Industries (CCRSPI) established in 2007. This initiative is between State, Territory and Commonwealth government agencies, RDC's, CSIRO and Universities and has been endorsed by the Primary Industries Ministerial Council.

The first phase of CCRSPI was completed in 2008 and key products included:

- A database on recent and current research projects across primary industries including forestry;
- 'Adapting Agriculture to Climate Change': a comprehensive assessment of the likely impacts of climate change in agriculture, fisheries and forestry (Stokes and Howden 2010); and
- 'Knowledge Gaps and Opportunities for Research to Inform and Position Australian Primary Industries to respond to a Future National Greenhouse Emissions Trading Scheme' that contained a summary of research priorities for forestry, including farm forestry (Keogh (2008), Table 1).

The establishment of National Climate Change Research Adaptation Research Facility (NCCARF) resulted in the development of eight National Adaptation Research Plans (NARPs), and eight associated Adaptation Research Networks (ARNs). The consultation draft NARP for the Primary Industries (Terrestrial) sector was released in February 2010(www.nccarf.edu.au). Forestry is treated as a sub-sector in this NARP.

Both CCRSPI and the Primary Industries Adaptation Research Network (PIARN) were managed by Land & Water Australia and have now been transferred to the University of Melbourne. Both are being revised to maximize alignment and complementarities, and re-activated following the transition to the University of Melbourne.

The climate change response priorities of the forest sector are specifically addressed in the National Climate Change and Commercial Forestry Action Plan 2009-2012 (www.daff.gov.au) endorsed by the Natural Resource Management and the Primary Industries Ministerial Councils. This sets out 17 actions under the headings of adaptation, mitigation, bioenergy and support. Some of these actions represent research priorities.

In 2009 the Forests and Forest Products Committee of PISC (FFPC 2009) endorsed research priorities for the forest industries including those related to climate change. The latter were broadly stated but included demonstrating the benefits of forests as part of the climate change solution, carbon accounting tools, risk management for pests, fire and drought, alternative forest management options and alternative species. The importance of climate change adaptation research was also recognized in the recently completed Forest Industry Sector National R, D&E Framework (www.daff.gov.au).

Given the investment in climate change R&D in the primary industries, initiatives such as CCRSPI and PIARN to promote collaboration and coordination will continue and probably expand. The forest industries will need to be integrated in a cost effective manner with such initiatives both for research efficiency, knowledge sharing and funding leverage.

Table 1.

Forestry related research and knowledge gaps associated with responding to a future national emissions trading Scheme
Information about the greenhouse accounting rules associated with forest harvesting to create timber and wood products, and the use of forestry wastes as alternative energy sources.
Information about emission trading scheme rules as they relate to forestry plantations, in particular rules associated with accreditation, verification and inspection requirements, and legal and other administrative requirements for saleable offsets.
Information about the rates of tree growth occurring in native tree plantations in areas that are not currently utilised as forestry plantation areas, but where land costs are relatively cheap and marginal returns per hectare for plantations may be competitive with existing landuses.
Information about transitional measures linking existing state-based emission mitigation schemes with the proposed national ETS.
Information about possible mechanisms for pooling small-scale forestry plantations to create more efficient volumes for sale as emission offsets to ETS participants.
Research into soil carbon changes under different landuses, and in particular the net impacts of different plantation establishment and management systems on soil carbon levels.
Detailed information about ETS market rules for offsets, including allocation of long-term responsibility for management of fire, pests and weeds, and any associated planning and natural resource management requirements.

(Keogh, 2008)

9. IMPACT OF CLIMATE CHANGE ON FORESTS

Seppala et al. (2009) provides an extensive analysis on a global basis of the potential impact of climate change on forests and the capacity and options for adaptation. A key message from the report was that “available information, however, is insufficient to support a quantitative assessment of the ecological, social and economic consequences of recent forest responses to climate change.”

In Australia a number of studies exploring potential impacts have been completed or are nearing completion for plantations and native forests. These studies provide, collectively, a good knowledge base of the likely impacts and the probable interactions between biotic and abiotic effects based on our current scientific understanding. They also highlight knowledge gaps and point to research priorities.

Battaglia et al. (2009) applied the process-based growth model CABALA and predicted the impact for productivity in hardwood and softwood plantations across all major plantation regions under several climate change scenarios, up to 2070. The report indicated varied impacts for plantation productivity depending on the region. Whilst Battaglia et al. focused on likely biophysical impacts, Pinkard et al. (2009) analysed the potential impact of a defoliating pest (*Mycosphaerella* leaf disease) for *Eucalyptus globulus* across a range of sites using different climate change scenarios. Simioni et al. (2009) examined carbon budgets in *Pinus radiata* plantations in Western Australia using the CenW model that predicted reduced productivity under climate change.

Pinkard (2010) reviewed the potential impacts of climate change on Australian plantations recognizing the likely biophysical impacts as well as changes in exposure to risks such drought, pests and fire. This analysis was then used to examine options for adaptation.

Medlyn et al. (2010) have comprehensively reviewed the likely biophysical impacts of climate change on Australia’s forests (both natural and planted) and the associated uncertainties. The key knowledge gaps identified in the review were:

- the quality of climate projections, particularly in relation to water availability and frequency of extreme events;
- the availability of forest ecosystem scale data to assess vulnerability of forests to climate change;
- deeper understanding of physiological processes; and
- research integration and modeling to make quantitative projections for climate change impact on forests and woodlands.

The Bureau of Rural Science (Clancy pers.comm.) is undertaking a project utilizing the 3PG model to estimate regional forest productivity and potential wood flows under climate change scenarios that can then be utilized in economic modeling of the effects of climate change on regional forest industry.

Studies of impacts of climate change on New Zealand plantation forests are relevant to Australia given common species such as *Pinus radiata*. Watt et al. (2008) undertook a comprehensive assessment of the effect of climate change on New Zealand's planted forests. This work has continued to develop plantation productivity surfaces for major plantation species across New Zealand using the CenW process based model. Whilst this work has not yet been published it has obvious parallels with the approach of Battaglia et al. (2009).

10. KEY RECENT INVESTMENT IN FOREST AND FORESTRY RELATED CLIMATE CHANGE RESEARCH

Many organisations undertake research directly or indirectly relevant to forests and forestry. Evidence from the consultation phase of this work indicated a degree of fragmentation, lack of coordination or rebranding of research that might be considered typical of a rapidly expanding research area. For climate change the boundaries are also diffuse in terms of interfacing with other research areas such as hydrology and genetics. Hence more recent efforts to improve networking and coordination are welcome (Section 7). This report did not involve an audit of research in progress for climate change and forests but some initiatives are worthy of highlight.

Active research up until 2008 related to climate change and forests was summarized in a CCRSPI publication-covering climate change relevant R&D in the primary industry sector (CCRSPI 2008). For forests and forestry, 28 projects were listed that covered:

- carbon accounting and decision support systems;
- quantifying emissions associated with forests operations and landuse change including soil carbon stocks the biophysical response of eucalypts to changing temperature and CO² level;
- plantation productivity and risk management in plantations in response to climate change;
- potential new biomass crops for environmental benefits including alterative plantation species;
- forest ecological research; and
- the impact of climate change on fire weather.

CCRSPI will update the database of research in progress by the end of 2011.

The most important recent project funding initiative has been the Forest Industries Climate Change Research Fund (FICCRF) managed by DAFF (www.daff.gov.au) that has committed approximately \$5million to new projects. These include projects on:

- genetic resources;
- allometrics/carbon accounting;
- better risk prediction models for fire and drought,
- quantifying soil carbon stock;
- bioenergy crops including biomass harvesting for bioenergy from existing plantations; and
- using permanent growth plots to understand the possible effects of climate change on the growth of native forests.

The CSIRO Climate Change Adaptation and Sustainable Agriculture Flagships are significant loci of R&D pertinent to forests with forest relevant R&D distributed within the Adaptive Primary Industries, Species and Ecosystems and Managing Carbon in Forests sub programmes. Some of the research capability is shared with the CRC for Forestry.

In terms of research infrastructure the most significant recent investment has been the \$40 million Education Investment Fund (DIISR) to develop climate change research infrastructure at the University of Western Sydney(UWS) at Richmond NSW. This includes support to establish a Free Air CO₂ Enrichment Facility (FACE), rainout shelters and upgrading of the existing whole tree chambers to provide humidity control. This infrastructure is linked with the significant ecophysiological and modeling expertise available through UWS, Macquarie University, University of NSW and University of Technology Sydney.

FWPA past and current climate change related projects are summarised in Appendix 1. Over the last 5 years there has been approximately \$3.24 million invested or committed in projects broadly related to climate change. About 35% of this investment is related to research on understanding carbon stocks and flows in managed forests, likely response of production forests to changing climate and decision support systems and 65% in better understanding the greenhouse footprint of forest products in construction and reuse, the potential impact of an emissions trading system on the wood products industry and treatment of wood products in an emissions trading system. This distribution of investment in part reflects the past mandate of FWPA (as the FWPRDC), the limited Australian knowledge available around the carbon footprint of forest products and the need to understand the threats and opportunities of the proposed emissions trading system for the forest industry.

11. RESEARCH PRIORITIES

Climate change research priorities for the forest sector have been addressed at varying levels of comprehensiveness and specificity in primary industry or sector publications such as the National Climate Change and Commercial Forestry Management Plan, CCRSPI (Keogh 2008, Table1) and reviews (Medlyn et al. 2010), as noted in Sections 7 and 8. Battaglia et al. (2009), Booth et al. (2010) and Pinkard (2010) list adaptation options for the plantation forestry sector some of which can be interpreted as research priorities (Appendices 3 and 4). These sources were used to test views of priorities during the consultation phase to define R&D priorities for FWPA investment.

10.1 Policy and economic analysis

The impact climate change and climate change policy can make on the forest industry is significant and FWPA investment in policy and economic analysis will be important in specific circumstances. The current dynamic environment requires that FWPA be able to respond to emerging policy developments in a timely fashion. There is a need for ongoing assessment of priorities in consultation with Government and industry bodies, in particular in the areas of integration and synthesis of research results that may inform policy including the development of forest based carbon offset policy, interaction between forestry and other land uses under carbon pricing, and the impact of changing land uses on the natural resource base (Keogh, 2008, Manley and McLaren, 2010, Salvin, 2010, and GHD Hassall 2010).

Investment Priority

Short-term policy and economic impact studies that support equitable treatment of forestry investment under GHG emissions reduction policy including carbon pricing/offset arrangements.

Benefits:

- Assist industry to understand and prepare for potential impacts
- Better engagement with other land managers and proactive, informed participation in policy discussions

10.2 Assessing and monitoring the impacts of climate change on forests

The potential impacts of climate change on Australian forests have been reviewed (see Section 8). Whilst there is confidence that in the future there will be higher levels of CO₂ in the atmosphere and temperatures are likely to be higher, there remains considerable

uncertainty about the direction and extent of other biophysical changes and their interactions.

Monitoring the condition of forests in a changing climate is an important national priority because of the ecosystem services forests provide. For native forests there has been a strong shift to an ecological focus rather than a wood production focus and hence key management and stewardship responsibility in this area has shifted to State and Commonwealth conservation and climate change agencies.

There are efforts underway in native forests to better define carbon stocks and fluxes, to better correlate remote sensing data with forest condition or parameters such as leaf area index and develop new in-forest remote sensing technology to monitor forest condition (Culvenor pers. comm.). The second phase of the National Collaborative Research Infrastructure Strategy funded Terrestrial Ecological Research Network (TERN) includes an Australian National Flux network in forest and woodland sites that will expand information on carbon sequestration and other changes in forest systems.

Investment in forest monitoring studies or technology to assess native forest condition is not seen as a priority for FWPA investment at this time, given responsibility for the stewardship of native forests increasingly lies with government conservation agencies and the current level of resourcing in monitoring through programmes such as TERN.

Plantations are a more intensively managed resource the general condition and productivity of which are monitored through remote sensing and ground truthing, networks of growth plots, pest surveillance surveys and sampling of nutritional status. Impacts of climate change/variability will be detected through such surveillance and measurement and longer-term impacts predicted through improved forest growth modeling and risk assessment capability (see below).

10.3 Predictive capability and risk assessment

Under any climate change scenario, the key R&D priority is to improve the predictive or forecasting capacity of forest productivity that can assist the forest industry in decision-making and hence adaptation. There are two main aspects to this – the regional climate predictions at an appropriate scale and models to predict productivity within acceptable confidence limits.

Outputs for climate models are key inputs to regional analysis of potential impacts. There are often substantial differences between

Global Climate Models and simulated regional climates derived from them and there are no standard methods for producing probabilistic projections to apply in impact studies (Whetton and Hennessy 2010). Land managers will continue to seek resolution at appropriate scales for use in decision making and it is important that regional scale predictive capacity is improved, particularly in relation to temperature and rainfall. These models will be developed by organisations such as CSIRO and the Bureau of Meteorology.

Process (ecophysiological) based growth models represent the best method for predicting the effects of simultaneous changes to rising CO₂, increasing temperatures and changing water availability and the interactions between these factors although the results depend on the quality of the inputs. There is a need, however, to test such models either through backward projection or predicting productivity for regions where plantations are known to have failed (Medlyn et al. 2010) to increase confidence in the predictions from them. The hybrid modeling demonstrated in such tools as Blue gum Productivity Optimisation System (BPOS) and Forest Productivity Optimisation System (FPOS) linking process based model data and empirical data on landforms, site factors and management history is a complementary approach to both refine and give greater confidence to predictions from process based models.

Medlyn et al. (2010) regard the report of Battaglia et al. (2009) on plantation productivity in a changing climate as "state of the art" but note that CABALA could have overestimated future productivity through the manner in which the effect of elevated CO₂ was treated, that mortality was not accounted for and indirect effects of climate change such as changes in fire frequencies or pest activity were not incorporated.

Some of the physiological parameters in process-based models will be sensitive to changed environmental conditions. The source of revised physiological parameters for process based models for Australian species will primarily be the whole tree chamber or FACE experiment at UWS. The planned FACE experiment is unlikely to deliver useful results in less than 8-10 years and is in a forest type of limited relevance to industry. The whole tree chambers are likely to generate more useful results in the near term, albeit with young plants, and FWPA may consider selective investment in experiments in these facilities to obtain better estimates of physiological parameters or at least a better indication of directional change in such parameters.

Medlyn et al. (2010) also highlighted predictive differences between process based models and bioclimatic modeling – the latter indicating many Australian species have narrow ranges and are vulnerable to

climate change while process based models generally predict increases in forest productivity. From a forest production viewpoint this is not considered a priority issue for FWPA given the strong field trial (empirical) base for many species used or likely to be used in plantations.

Linking predictions of productivity with assessment of risk from indirect effects of climate change on the incidence and severity of drought, fire, pests and wood properties into an integrated risk and impact assessment tool for industry use is a key priority for future investment given the potential impacts of these indirect effects on productivity and wood properties. The development of such decision support systems must be closely linked to user needs and to ensure they can fit within industry decision-making frameworks.

10.3.1 Drought

Current projections of future rainfall suggest possible increases in northern Australia and decreases in southern Australia, particularly in winter and spring (CSIRO 2007). Evapotranspiration and drought occurrence is expected to increase over most of Australia and these changes are likely to be accompanied by an increase in the number of extreme hot days.

Medlyn et al. (2010) note that the physiological mechanisms for drought mortality in trees remain poorly understood and the thresholds for drought mortality are poorly quantified. As noted earlier the latter are particularly important for improving the predictions from process based models for commercially important species. Initial development of drought mortality functions for plantation species is being undertaken via a FICCRF project although it is likely further investment will be required.

10.3.2 Fire

Fire is ongoing threat to Australian forests and plantations and is a factor that needs to be incorporated into risk management models within management decision support systems. While reducing the risk may have a strong operational component – fuel reduction burning, planning and location of plantations, extent of firebreaks etc – application of remote sensing techniques to give better spatial representation of fuel loads and fuel moisture content will progressively improve predictive capacity.

This research will be undertaken by fire research organisations such as the Bushfire CRC and CSIRO and translated into decision support

systems by these organisations or fire management agencies. FWPA needs to ensure that its risk assessment and decision support systems link to the latest developments in the bushfire risk prediction.

10.3.3 Pests, pathogens and weeds

Increased impacts from pests, pathogens and weeds (pests for short) are a possible consequence of climate change. These may include expanding the range of existing pests, intensifying the effects of existing pests or the emergence of new pests. In some cases the opposite may occur. The effects are likely to be less with exotic species with fewer pests compared with native species being grown in the presence of their indigenous pests. The risk of introductions of new pests may not necessarily be higher as climate changes introductions being more related to trade pathways and people movements. If increasing pest impacts do occur they will need to be managed and that may require new approaches to plantation management including changed genetics, silviculture or new control methods.

The population dynamics of particular pests can be modeled if epidemiological information is available and predisposing factors understood. At present this is the case for only a limited number of pests (Medlyn et al. 2010). Some modeling work on individual pests and pathogens has been done using a bioclimatic approach to generate scenarios for pest prevalence that were linked to a process based growth model to make predictions on growth across a rotation (Pinkard et al. 2010). There is a FICCRF project that seeks to expand the predictive modeling approach further. There is, however, the need for case studies to gather the basic information that can improve modeling for some key pathogens such as Californian pine aphid, leaf beetles in eucalypt plantations and root rot fungi such as *Phytophthora cinnamoni* that may already be present in plantations and will be influenced by rising temperatures.

10.3.4 Wood Properties

The impact of climate change on wood properties can also be incorporated into decision-making frameworks via a modeling approach. For key commercial plantation species in Australia it is known that for approximately every 50mm reduction in rainfall wood density may increase by up to 50kg per m³ (Downes pers.comm.) although the impacts of climate change on wood properties have received limited attention. There have been experimental studies with elevated CO₂ in young trees (e.g. Kaakinen et al. 2004, Kilpelainen et al. 2005) but it remains unclear how much effect climate change will have on wood properties in trees subject to slowly rising CO₂. The most likely

effects may be on patterns of ring development and the balance of early to late wood depending on interactions between temperature and rainfall although the studies referred to also illustrated differences in chemical composition of wood laid down under different CO² concentrations.

There are several approaches to partially addressing the issue including studying wood formation and properties in the same species across an altitudinal or latitudinal gradients, examining wood formation in whole tree chamber or FACE experiments, or examining wood formation for trees exposed to different environmental conditions at one or more sites. It would, however, be necessary to integrate data from a variety of sources via a modeling approach that can be calibrated to predict variation in wood properties in response to the environment and management. A wood formation model can be linked to process based growth models providing expanded information for forest managers.

FWPA is already investing in wood formation modeling in relation to environment and management and this is supported as a priority. Future investment in wood property modeling can be evaluated based on the outputs of the current project but as noted above there is likely to be an industry demand for this type of information and good opportunities to link prediction of wood properties into decision support systems and regional forecasts. As such wood properties modeling fits within the investment priorities listed below.

Investment Priority

FWPA invest in improvements in and testing of process based growth models and the development of linked integrated risk and impact assessment tools that can be applied at the required spatial scale to assist industry decision-making in regards to risks to productivity and profitability.

Benefits:

- Greater confidence in model predictions under various climate change scenarios
- Improved ability to account for and manage risk factors
- Increased capacity to assess impacts and evaluate opportunities in existing or new forestry regions
- Capacity to integrate new information into enterprise and regional planning

The centrality of productivity estimates, the continuing development of regional climate models, improvements in process based growth models and assessment of indirect effects of climate change, support

the need for regular updating of plantation productivity forecasts along the lines of Battaglia et al. (2009). Updated forecasts could be produced approximately every 5 years with the interval being determined by the rate of advancement in regional climate and productivity prediction capacity. Improvements in methodology and computing capacity make this a more cost effective exercise than in the initial developmental study (Battaglia pers.comm.). Such forecasts will highlight issues and problems for species and regions and will inform future research priorities. The work on productivity forecasting in New Zealand (Watt and Kirschbaum pers.comm.) will also feed into improved methodology and understanding. Such forecasts can then be linked to regional economic models (as is being attempted in the current BRS project noted in Section 8) for analysis and planning.

Investment Priority

FWPA invest in revised regional (or sub-regional) plantation forest productivity forecasts on a 3-5 year time span.

Benefits:

- Strengthen industry awareness and understanding of likely or evolving climate change impacts on forest productivity
- Progressive improvements in regional forest industry investment decision making

10.4 Mitigation

Mitigation involves actions that are intended to reduce the magnitude of anthropogenic contribution to climate change. It includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks. (www.nccarf.edu.au).

In the Australian forestry context mitigation could involve attempts to increase the soil carbon store in forest estates, manage forests for maximum carbon storage or plant new forests on already cleared land for sequestration and storage of carbon. In production forests the greatest long-term mitigation benefits are obtained through harvesting and incorporating the wood into long service life products (FWPRDC 2006).

There is a limited amount work examining other GHG stocks and fluxes from forests in Australia. However, it is generally considered that these fluxes will be relatively minor – forests soils are typically a sink for methane (Fest et al .2009, Arndt pers.comm.) and emissions from nitrogen fertilizers are likely to be minimal (May et al. 2009).

For native forests, particularly in the wetter environments, it has been argued eliminating human disturbance and allowing forests to reach older age classes will allow maximization of carbon storage in these forests (Mackey et al. 2008, Keith et al. 2009). This work on actual and potential carbon stocks in native forests is used to argue for further restrictions on logging in native forests, but this does not incorporate any broader life cycle assessment of forest management and storage of carbon in wood products, that fire is the major factor influencing carbon stocks in many Australian forests, and that under environmental stress such as severe drought, native forests may move from sinks to sources (Polglase pers.comm.).

Overall it is considered that the capacity to account for carbon stocks and flows in traditional plantation systems is adequate but that this is less so for native forests where carbon pools such as dead standing and fallen woody debris and below ground carbon pools in biomass and soil are less well quantified. There are projects to improve estimates being undertaken (DCCEE, Mackey pers. comm.). FullCAM is being applied in public forests in Victoria to estimate carbon stocks in the various pools in response to management and fire. This work is also highlighting the need for improved carbon accounting in native forests (Vic LandCarbon project: www.climatechange.gov.vic.au/landcarbon). Given the tenure of native forests and the international reporting requirements, improved carbon accounting in native forests per se is not a primary responsibility or research priority for FWPA.

However, if forest agencies are to continue to manage native forests for wood production then a better understanding of the carbon stocks and fluxes in managed forests under the influence of climate change and a capacity for carbon value to be incorporated in forest management scenarios, is a high priority for managers and industry. FWPA PRC1622009/2010 Parameters for describing sustainable landscape carbon stocks and for integrating the impact of forest and timber utilization into overall carbon dynamics will review and recommend a research framework but a key priority is the capacity to link carbon accounting models with forest management systems which support decision making and tradeoffs amongst multiple criteria. The CRC for Forestry is developing a project in this area.

Investment Priority

FWPA invest with other relevant parties to improve accounting for stocks and flows in native forests managed for wood production and ensure the linking of this information to forest management decision making tools.

Benefits:

- Improved understanding of carbon stocks and flows under different management regimes
- Capacity to make informed tradeoffs that maximize desired forest values

Maintaining adequate soil organic matter is important in terms of sustained productivity and soil organic matter will be affected under climate change as a consequence of changed growth rates, water availability and temperature particularly. Attempts to increase soil carbon stocks for use in carbon trading is unlikely to be a priority for production forestry in the short to medium term. O'Brien (2010) noted "Soil carbon is generally a relatively small component of the balance sheet when estimating carbon sequestration in forestry projects. As such, we either estimate changes in soil carbon using generic models rather than doing detailed measurement of soil carbon, or ignore soil carbon entirely (assuming no net loss over the project life). The key barrier to having a greater emphasis on soil carbon in forestry projects is the cost-benefit return - changes in soil carbon are slow, relatively expensive to measure accurately, particularly in comparison to estimation of changes in tree carbon stock. Implementation of new technologies (at low cost) is critical in gaining greater focus on soil carbon."

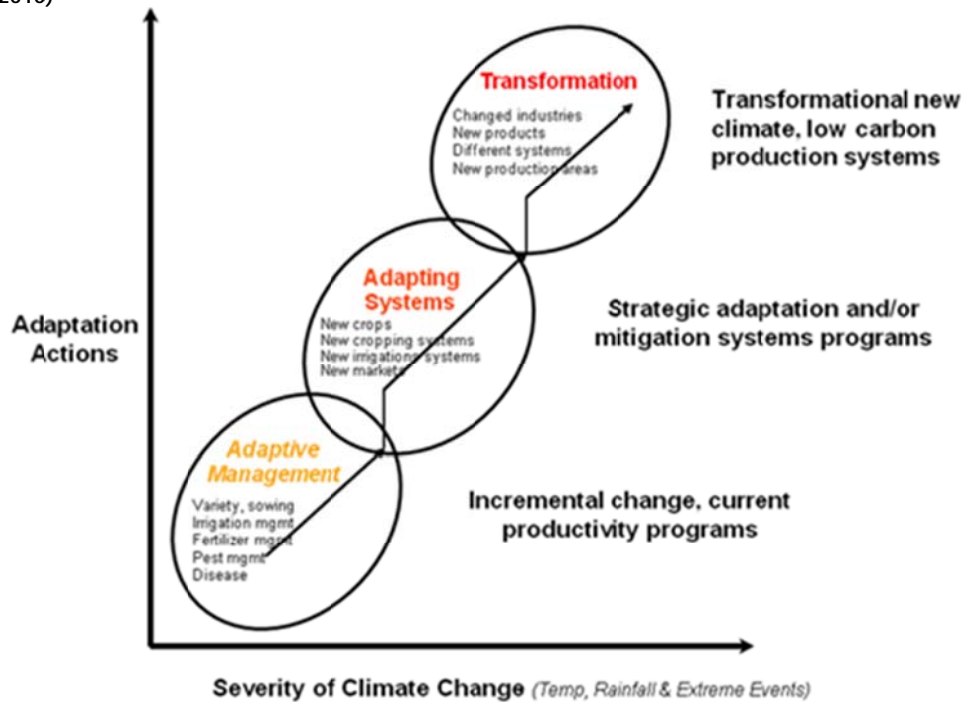
Carbon (tree) farming is already established on a moderate scale particularly through the planting of oil mallees in south west Western Australia and parts of eastern Australia and is likely to increase as most proposed programmes for mitigation include a forestry component e.g. Climateworks (2010). These plantings may be purely for carbon storage/environmental purposes (e.g. Greenfleet www.greenfleet.com.au) or be subject to periodic harvest for products that may substitute for fossil fuel derived products e.g. oil mallees. These offset programmes appear to be using either empirical or process based growth models as the basis for the carbon accounting required. However, investment in allometrics and improved carbon accounting tools for these non-traditional species is not seen as a priority for FWPA.

10.5 Adaptation

Given the warming trend already evident, climate change adaptation is rapidly assuming centre stage in both policy and research for primary industries. However, it should be recognized that these industries have a long and ongoing history of adaptation to climatic variability. Adaptation involves actions undertaken to reduce the adverse consequences of climate change, as well as harness any beneficial solutions. Adaptation aims to reduce the impacts of climate stresses on human and natural systems (www.nccarf.edu.au).

A number of classifications of adaptation actions have been developed for primary industries (CCRSPI, NARP) and an example is provided in Figure 1. These frameworks are useful for thinking about the range of actions that might be required but for forestry the boundaries between Adaptive Management, Adapting Systems and Transformation may not always be clearly defined given the time scales involved in forest management.

Figure 1. A contextual framework for adaptation in the primary industries (adapted from Howden et al. 2010)



The adaptive management options available to the current commercial plantation forest industry were detailed in Battaglia et al. (2009) and cross all three of the categories shown in Figure 1 (Appendix 4). A further assessment of adaptation options and tools is by Wilson and Turton (2010). Adaptation will require a regional approach linked to regional climate models and research given likely differences in climate change impacts (Battaglia et al. 2009).

From a research priorities perspective a number of issues arise from the listings of topics and actions in Tables 1 and Appendices 3 and 4 that have been grouped under a small number of research relevant headings. Many of the adaptive actions suggested in the publications are not new, require the application of existing knowledge and practice and do not require further research or minimal applied research only.

10.5.1 Species selection and breeding

Species selection and breeding interfaces with the recently published FWPA Investment Plan for Genetic Improvement to Increase Wood Quality and Manage Risks. The first investment priority in that plan is *'FWPA will invest in research that facilitates deploying the most appropriate genetic stock for a particular environment and silviculture. This will include research aimed at optimizing productivity in drier environments and may include the evaluation of alternative species.* This recommendation recognised climate uncertainty and that tree selection and breeding has an important but sometimes over-emphasised contribution to reducing risk.

Species and genotype selection has been an ongoing activity for several decades in Australia and this continues through various agencies or projects around the country (e.g. Southern Tree Breeding Association, the Australian Low Rainfall Tree Improvement Group and Flora Search). Agri-Sciences Queensland, for example has an extensive programme of selection and breeding for hardwood species (native and exotic) particularly (Lee pers.comm.). Extensive trials have been established on north-south and east-west transects with the objective of selecting species or genotypes adapted to the likely more stressful environments of the future. This is a sound strategy but operational selection programmes are not a priority for FWPA. Breeding for climate change adaptation per se is problematic and also not a priority for FWPA. While there is variation in water use efficiency within species it is uncertain if this confers adaptive value or reflects different stomatal behaviour of different genotypes. As well water use efficiency can be more readily managed at the stand level through management of stand stocking rather than potentially expensive and not necessarily successful breeding.

From an ecological perspective in native forests where the survival of some key species may be threatened in the long term, a conservation genetics approach including identification of the most genetic diverse populations may be justified. In the longer-term development of genomics and understanding of genetic diversity in relation to past climate events may help tree breeding for adaptation but this is long-term strategic research and beyond the resources of FWPA.

An investment priority for FWPA in this species selection and breeding area is the opportunity to more effectively use ecophysiological information to assist species /genotype selection. There is strong evidence of functional convergence amongst tree species for drought tolerance and identifying the associated physiological traits could speed up and improve the cost effectiveness of selection programmes particularly for new species that might be deployed in new

environments or in traditional forestry environments that are becoming marginal for traditional species due to climate change.

Investment Priority

FWPA invest in ecophysiological research that can link physiological traits to drought tolerance in different commercially important species or species groups

Benefits:

- Improved targeting of physiological research to an identified need
- Speed up the identification and selection of drought tolerant species and genotypes

10.5.2 Stand management and water use

Managing plantations in stressful environments has been a matter of attention in Australia for many years. Potentially decreasing water availability and increased drought incidence is perhaps the major concern for forest managers and managing stand stocking across a rotation will become more important if drought and rising temperatures become even stronger features of our climate. Stressed forests are also more likely to be susceptible to pests, pathogens and fire. This extends to native forests where declining water availability will affect catchment yields and changes in forest structure will impact conservation values. More active management may be required to protect existing values including water yields and quality. In over-allocated catchments plantations may be subject to water licensing. Forests and water use is subject of another FWPA Investment Plan: Water use efficiency, access to resources and balanced policy outcomes and research priorities pertinent to stand water management, offsite impacts of forests on catchment water balances and climate uncertainty will be dealt with in that plan.

10.5.3 Nutrition

Increasing CO² will at least initially increase water use efficiency and potentially runoff from reduced water demand. Maintenance of any CO² fertilisation effect will require adequate nutritional resources: FACE experiments typically show a CO² fertiliser effect which diminishes over time as the trees become nutrient limited, particularly by nitrogen supply. Medlyn et al. (2010) concluded there was likely to be a strong interaction between CO² fertilisation and nutrition with above ground productivity increases only likely on the most fertile sites. With declining

fertility productivity may still increase but is likely to be diverted below ground.

The productivity of the overall Australian plantation estate could be improved by at least 10% by adoption of existing knowledge (Nambiar pers.comm.). Under climate change nutritional management will become increasingly important in terms of adaptation, although in Australian soils it may also be phosphorus as well as nitrogen that could be limiting. An indication of future likely effects is that whilst first rotation blue gum plantations on ex farmland typically do not respond to nitrogen fertiliser application, consistent responses are observed on second rotation sites (White pers.comm.). Operational methods of monitoring for plantation nutritional status will need to be improved. Mixed plantings with nitrogen fixers has also been proposed as a plantation management strategy for climate change adaptation (Appendix 4). There is a reasonable experimental base for mixed species plantings and cover crops in Australia that would need to be reviewed before any further research in this area and is not seen as an FWPA priority at this time.

The potential for harvesting residual biomass from wood production plantations for bioenergy has been proposed in a number of regions. This activity will require evaluation of the impact on site resources give the potential nutrient losses that could occur.

In summary the nutritional status of plantation forests on their productivity and adaptability is an important area. The capacity to adapt current knowledge and best practices is such that new research investment from a climate change perspective is not seen as a priority at present.

10.5.4 Communication and technology transfer

In the short term, adaptive management is an ongoing operational issue that can be enhanced by more effective adoption of existing knowledge. In the longer term climate change has the potential for significant social and economic effects through its impacts on the commercial viability of wood production. Transformational change – new species and new environments may be required.

At a government level there are concerns that industry needs to be more engaged with the climate change issue but this is difficult with the current policy uncertainty with limited incentives to change. Good information and decision-making tools, however, support longer-term adaptive management.

Pinkard et al. (2010) provided a discussion around adaptation and potential barriers to adaptation and Wood et al. (2010) set out an even more detailed analysis for FWPA and industry to consider. That latter study indicated an underlying need for better communication, dissemination of knowledge and best practice across the forest sector. FWPA will need to respond and work with other partners with targeted investment in this area as new knowledge becomes available, as part of its ongoing communication and technology transfer work.

10.6 Guidelines for investment

Climate change mitigation and adaptation in the primary industries sector will be guided by the ongoing evolution of national strategies. The forest industry needs to ensure it plays an active but differentiated role in the development of the strategies and plans that will guide the allocation of R&D funding in the future (e.g. CCRSPI, NARP, the Rural Research and Development Council, other special or specifically targeted programmes).

It is likely the climate change arena will be characterized by new and typically short term funding programmes e.g. Forest Industries Climate Change Research Fund (2009-2011) and industry needs to ensure it is able to capitalize on such funding with well-developed priorities that research providers can take up i.e. more focus on demand rather than R&D supply.

It is understood FWPA will invest approximately \$250k per annum in climate change research related to forestry. Whilst FWPA will be a small funder it can help leverage additional resources for forest industry relevant research through co-investment. It should also be prepared to take broader industry climate change research priorities to Government to help them with their investment decisions.

The small number of investment recommendations made in this report are those that are identified for FWPA to consider as a primary investor, or a significant co-investor with other partners, and reflect the small amount of funding available. It recognizes there are other funding streams, including from land management, policy agencies and research providers that have a responsibility and investment priorities. A risk factor for the implementation of this plan is the decline in forest research capacity and capability in Australia. There are currently good skills available to the forest sector in this particular area. The industry will however need to engage in this area to assist in the maintenance of this skill base.

10.7 Outcomes and indicators for success

The key outcome from climate change research should be greater preparedness and capacity for better decisions on reliable predictions and capacity to qualify risk.

As indicated through this plan there are high degrees of uncertainty in relation to climate change and forests but investment in predictive capacity and risk management will serve the commercial forestry sector well no matter how the climate might change. Good predictive capacity also allows the sector to interface with policy and other competitive landuses on a sounder footing.

Benefits will be difficult to measure in the short to term given the long time frames involved although matters such as policy will be dealt with on shorter time frames. In due course benefits should be measurable through conventional cost benefit analysis. Improved decision making based on sound science in response to climate change will help deliver the benefits of other R &D investment.

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APPENDIX 1: CONSULTATION

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APPENDIX 2: FOREST AND WOOD PRODUCTS AUSTRALIA CLIMATE CHANGE AND CARBON RELATED PROJECTS OVER THE LAST 5 YEARS

Project No	Title	Researcher	FWPA Budget (\$)	Total Budget (\$)	Project status
Climate Change and Forests					
PNC068-0708 (PN07.4021)	Climate change and Australia's plantation estate: risks and management to mitigate impacts	CSIRO - Mike Bataglia	180,711	432,538	Complete
PR06.1041	Forests, wood, and Australia's carbon balance	Michael Robinson	11,500	23,000	Complete
PNC168-0910	The Forest Productivity Optimisation System - A decision support tool for enhancing the management of planted forests in southern Australia under changing climate	CRC Forestry - Daniel Mendham (CSIRO)	482,207	29M+	Active
PRC162-0910	Parameters for describing sustainable landscape carbon stocks and for integrating the impact of forest and timber utilisation into overall carbon dynamics	CRC Forestry – M. Moroni	82,000	97,500	Active
Carbon trading					
PRA021-0809 (PR08.1066)	Carbon in timber within a national emissions trading scheme - methodologies and mechanisms	(A3P) - Miles Prosser	43,203	58,203	Complete
PR07.1059	Impact of carbon trading on timber products	Monash University - Alison George	68,000	73,000	Complete
Recycling, re-use and disposal					
PN05.1017	Recycling and End-of-life Disposal of Timber Products	CSIRO –Joely Taylor	80,000	160,000	Complete
PN07.1060	Wood recovery and recycling - a source book for Australia	CSIRO Joely Taylor	61,558	232,645	Complete
Building performance, carbon stocks and wood products in service					
PNA001-0405 (PN04.1009)	Determining means of improving the thermal performance of light-weight domestic construction while validating the regulatory thermal performance model, AccuRate, against test buildings, particularly those with light-weight timber floor construction	University of Tasmania – Greg Nolan	286,000	586,000	Complete
PNA008-0708 (PN07.1044)	Life cycle assessment of timber products - phase 2	CSIRO - Mike Syme	729,000	1,221,000	Complete
PNA016-0708 (PN07.1058)	Dynamics of carbon stocks in timber in Australian housing	University of Melbourne -Rod Keenan	210,000	384,852	Complete

PR07.1047	Comparative service life assessment of window systems	BRANZ- Nigel Howard	148,200	44,800	Complete
PR08.2046	Economic benefits from sawmill residues	Carnot Group - Malcolm Peck	49,140	49,140	Complete
PGD103-0809	Optimising Timber Use in Residential Building to Reduce Environmental Impact: A Life Cycle Assessment Approach	RMIT (Hamidul Islam)	90,000	90,000	Active
PNA147-0809	Comparative life cycle assessment study of various residential buildings	RMIT – Andrew Carre	70,200	70,200	Active
PR06.5044	Carbon Storage in Wood Products in Australia - a Review of Current State of Knowledge – CARBON BROCHURE	Michael Robinson	7,000	7,000	Complete
PNA161-0910	Development of an embodied CO2 emissions module for AccuRate	CSIRO - Mike Syme	97,000	139,000	Active
PRA026-0809 (PR08.1071)	Development of an Australian life cycle assessment methodology for building products	TDA-Andrew Dunn	73,000	73,000	Active
PR06.1030	Life cycle assessment of timber products - Phase 1	CSIRO – Selwyn Tucker	65,000	92,000	Complete
Additional – Contributions					
PNC066-0607 (PN06.4018)	Joint Venture for Agroforestry Program (JVAP) provides knowledge to underpin profitable, sustainable and resilient agroforestry within Australian farming systems and landscapes in the light of the dramatically changing contexts of climate change (a small component relevant to climate change)	(JVAP 2005-2009)	400,000	4,200,000	Complete

APPENDIX 3: ADAPTATION OPTIONS FOR FORESTRY

Options	Priority
Policy Level	
Use bioclimatic analysis to identify plantations of key species already going under extreme climatic conditions. Monitor these sites to provide early warning of potential problems	1
Support studies of impacts of increased levels of CO ₂ on key exotic and native species and incorporation of results into simulation models to assist adaptation planning	1
Undertake further adaption studies which include costs/benefit analyses	2
Support continuing commitment from all levels of government for pest, disease and weed control	2
Promote introduction of climate change adaptation into routine forest management	2
Forest Management	
Take climate change into account when planning establishment of new plantation	1
Use updated fire behaviour prediction systems to plan for a changing fire regime	1
Use tree growth models and permanent sample plot (PSP) records from existing plantations to plan alternative management strategies	1
Use improved tools to assess risk of weed, pest and disease problems under climate change	2
Provide advice on opportunities to use nutritional adjustments as an adaptation to climate change	3
Climate information and use	
Improve regional level climate change modeling to provide more reliable scenarios to assist decision-making	1
Give greater weight to more recent climatic data when planning	2

(Source- Booth et al. 2010)

APPENDIX 4: MANAGEMENT ADAPTION OPTIONS FOR PLANTED FORESTS

Species
Species substitution: Use species better adapted to expected climates
Species selection/breeding/hybridization/GM: Tree improvement for existing/new species for adaptation to expected climates
Sites
Climate: Use expected climates as site selection criteria
Rooting zone plant-available soil water storage: Use selection specifications consistent with expected climates.
Planting location: Use biophysical stratification of planting sites to facilitate intra-site-specific management
Silviculture
Soil cultivation: To increase soil rooting volume and thus plant-available water. Use site cultivation to reduce run-off and conserve water
Weeding: Use spatial weeding patterns and/or cover species that minimize non-crop and soil evapotranspiration and/or provide other benefits (e.g. N-fixation)
Watering-in, Hydrogels: Use strategically or tactically to ensure/improve survival after planting
Irrigation: Only a niche application in Australia using wastewaters (see Baker et al. 2005)
Stocking (planting density): Use lower stockings to reduce stand leaf area development and to increase resource availability to planted trees
Thinning (waste/commercial): To (temporarily) reduce stand leaf area, to increase resource availability to retained trees, and for stand vigor/hygiene. Note that pruning solely to reduce stand leaf area is costly and not relevant to pulpwood production; if simply reactive to drought probably would be undertaken too late to capture solid timber wood quality benefits.
Nutrition and nutrient conservation, fertiliser application, biological N-fixation: Strategically manage site fertility (nutrient supply capacity/intensity) and tree nutrition consistent with crop (age-dependent) demand under expected climates. Use short term weather outlook in decisions for tactical application of N. Control leaf area by withholding fertiliser to reduce drought stress.
Forest health: Timely/enhanced surveillance/monitoring for pests and diseases, and early intervention where required. Species selection and breeding (see Species). Adopt IPM principals, including biological control to provide continuous base-level control/resilience.
Fire protection: Fuel reduction burning in some species/environments. Wider firebreaks and break-tree management zones.
Rotation length: Shorten to decrease period of vulnerability (drought, pests and diseases, fire) and to facilitate species/germplasm changeover. Balance estate structural/age class-distribution to reduce risk. Adjust harvest schedules according to stand vulnerability.