Harvested forests provide the greatest ongoing greenhouse gas benefits.

Does current Australian policy support optimal greenhouse gas mitigation outcomes?

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Executive Summary

Australia is acting to reduce greenhouse gas (GHG) emissions principally through the recent introduction, to the Federal Parliament, of the *Clean Energy Future Legislative Package*. Whilst these initiatives are a positive development in addressing climate change concerns, the package ignores the opportunity for multiple use production forests to contribute to low cost greenhouse gas (GHG) abatement. The policy being developed and enacted through the Federal Parliament does not recognise the nature of carbon (C) flows in multiple use production forests and hence does not account for their role in GHG mitigation.

The case studies in this paper illustrate key aspects of GHG outcomes for managed multiple use production forests and conservation forests. These study areas are representative of New South Wales (NSW) production forests. They account for approximately 50% of native forest logs harvested in NSW. Results show:

1. For both case study areas, NSW North Coast and NSW South Coast, the 'harvest' option delivers greater climate change mitigation than provided by conservation forests, particularly as the simulation progresses in time.
2. The GHG abatement of the 'harvest' option after 200 years (excluding use of harvest residues for bioenergy) is 2.0-2.8 Mt C[1] (244-300%) and 1.0-2.0 Mt C (17-39%) greater than the conservation option for the North Coast and South Coast areas, respectively.
3. Accounting for carbon in products and emissions saved by product substitution makes a large difference to the GHG outcome of the 'harvest' scenario. For the North Coast forests, carbon in products contributes 24% and product substitution 61% of the mitigation value.
4. Extraction of 30 – 70 % of available residues for bioenergy generation results in an additional greenhouse benefit in the order of 2.4-3.7 Mt C for the North Coast and 3.8-8.9 Mt C for the South Coast forests.

Managed, multiple use production forests have the capacity to store carbon on site; produce wood products that continue to store carbon off site; provide substitutes for more GHG-intensive building products; minimise the need for GHG intensive imports; and produce residues that can be used to generate renewable energy, displacing fossil fuels. **The data show total GHG emissions abatement and carbon storage from a multiple use production forest exceed the C storage benefit of a conservation forest.**

However, current policy prescriptions support conversion of production forests to conservation forests, provide disincentives for use of native forest residues for energy and discourage the establishment of production focused plantations. Action to reduce logging in Australian forests, with the objective of increased carbon storage, could have perverse global GHG outcomes. Converting multiple use production forests to conservation forests will reduce access to wood and may lead to increased harvesting in other countries where forests are not managed sustainably, with resultant deforestation or forest degradation in those countries. Harvesting of these forests can lead to significant GHG emissions, an example of 'leakage'.

To quantify the climate change impacts of forestry, the entire forestry system should be considered: the carbon dynamics of the forest; the life cycle of forest products; the substitution benefit of biomass and wood products, and the risk of leakage resulting from deforestation or forest degradation in other countries. **Climate change policy should account for whole of life cycle impacts in order to maximise net GHG outcomes.**

[1] Throughout the document values are expressed as t C (tonnes of carbon). To convert to CO_2 equivalent (CO_{2-e}) multiply by 3.776.

The current climate change policy blends policy objectives for GHG abatement with other environmental outcomes (e.g., biodiversity and water) and also discourages the expansion of the managed plantation estate. Specifically:

1. The Carbon Farming Initiative (CFI) encourages biodiverse plantings, that will not be harvested (Australian Government 2011b).
2. The CFI allows for 'native forest protection projects' that 'protect native forest from deforestation'.
3. The CFI discourages production forestry (e.g., plantations in regions with rainfall >600 mm will be required to offset water interception in catchments where interception by plantations is recognised as a risk to water availability).
4. The *current* amendment to the Renewable Energy Target (RET) regulations specifically excludes biomass from native forests being used to generate Large scale Generation Certificates (LGCs)[2] through its use for bioenergy.

This blend of policy objectives that uses only a single policy instrument, developed with the intent to mitigate climate change, is unlikely to maximise those GHG objectives.

By ignoring the mitigation value of forest products and limiting incentives for expansion of plantation forests, the current policy, (including the CFI Act, the Renewable Energy (Electricity) Act and regulations to both Acts), fails to provide support for production forestry activities that could generate substantial abatement. Abatement through reforestation has lower marginal cost than most other measures (McKinsey & Company 2008), and generates additional economic benefits. Therefore the likely contribution to emissions mitigation through land sector action will be less than could otherwise be achieved. Either GHG mitigation targets will not be met, or the cost of achieving them will be higher, or both.

Conclusions from the case studies presented include:

1. GHG outcomes can vary for forest types and due to management for the production of different product mixes.
2. Business as usual (BAU) in managed multiple use production forest provides greater GHG mitigation benefit compared with conservation.
3. Cessation of logging in some native forests will give no additional mitigation benefits over BAU.
4. The focus of the CFI on achieving GHG mitigation benefits through conservation measures is narrow.

These case studies show that converting production forests to conservation forests will not provide additional GHG benefit. Incentives for expansion of plantations are limited due to concerns over water use and biodiversity impacts. The current policy will potentially lead to reduced national GHG benefits and higher costs of abatement. There is a significant risk of perverse GHG outcomes: domestic and international leakage may lead to increased global GHG emissions. The current policy will mean that potential mitigation through multiple use production forests will not be realised and emissions may instead increase. **A long term, evidence-based, whole of life perspective is required to meet climate change objectives.**

[2] previously called Renewable Energy Certificates

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Abbreviation	Detailed information/definition
ACCU	Australian Carbon Credit Unit
C	Carbon
CCC	Carbon carrying capacity
CDM	Clean Development Mechanism
CFI	Carbon Farming Initiative
ETS	Emissions trading scheme(s)
GGAS	Greenhouse Gas Reduction Scheme (NSW)
GHG	Greenhouse gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
KP	Kyoto Protocol
Mha	Millions of hectares
MIS	Managed Investment Scheme
NC	NSW North Coast case study region
ppm	Parts per million
SC	NSW South Coast case study region
UNFCCC	UN Framework Convention on Climate Change

Glossary

Additionality	Additionality refers to the requirement that an activity provide abatement that would not have occurred in the absence of the activity. Under the CFI, abatement is additional if it is not required by regulation and is deemed to go beyond common practice in the industry or in the environment in which the activity is carried out.
Biochar	Biochar is made by heating biomass under oxygen-limited conditions (e.g. slow pyrolysis). Biomass feedstocks can include forestry and agricultural residues, biosolids, animal manures etc. The thermo-chemical conversion drives off the volatile components of the biomass and stabilises the remaining carbon into a black, highly aromatic solid.
Carbon carrying capacity	The mass of carbon able to be stored in a forest ecosystem under prevailing environmental conditions and natural disturbance regimes, but excluding anthropogenic disturbance (Gupta & Rao, 1994).
Carbon dioxide equivalent (CO_2-e)	Unit for comparing the radiative forcing of a greenhouse gas to carbon dioxide. The mass of GHG emissions in terms of CO2-e is calculated by multiplying the mass of a given greenhouse gas by its global warming potential.
Conservation forest	The management of forest land, by maintaining ecological processes that sustain forest ecosystems; conserve biological diversity associated with forests and protect water quality and associated habitat, with the objective of ensuring an extensive and permanent native forest estate.
Global warming potential (GWP)	Characterisation factor describing the mass of carbon dioxide that has the same accumulated radiative forcing over a given period of time as one mass unit of a given greenhouse gas. Global warming potential is a function of the atmospheric lifetime and radiative properties of a greenhouse gas (Forster et al, 2007).
Leakage	A decrease in carbon stocks or an increase in emissions external to a project that results from the project activities.
Life Cycle Assessment	A systematic method used to quantify and evaluate the environmental impacts of a product or service across all the stages of its life. In respect of global warming impact, this would be the net emissions of greenhouse gases over the product/service life cycle, expressed in terms of mass of carbon dioxide equivalent (CO_2-e).
Multiple use production forest	The management of forest land for production of wood or non-wood products as well as other purposes. Examples include conservation of biodiversity, management of water quality and quantity, carbon sequestration, livestock foraging and grazing, ecosystem and landscape maintenance and recreation.
Permanence	The maintenance on a net basis (allowing for the reversibility of greenhouse gas removals by sinks) of sequestered carbon. Permanence requirements of the CFI sequestration require sequestration to be maintained for a period of not less than 100 years.
Substitution	The use of products with low greenhouse gas intensity in place of equivalent goods with higher greenhouse gas intensity.

1 Introduction

Atmospheric concentration of the greenhouse gas carbon dioxide (CO_2) has risen rapidly over the last century. The currently reported CO_2 concentration of 389 parts per million (ppm) in 2010 (Blasing 2011) is much higher than the pre-industrial level (in 1800) of 280 ppm, and is currently increasing at nearly 2 ppm per year (CSIRO, 2011).This increase in atmospheric carbon dioxide level represents a risk to the long-term climate stability, over and above the inherent climate variability, under which the ecosystems and biota that comprise the NSW landscape have developed. These projected long-term changes to the climate have the potential to impact on both conservation and primary industry enterprises via the natural resource base on which they depend.

The clearing of forests primarily for agriculture has contributed approximately one third of the increase in CO_2 in the atmosphere over the last 200 years (Figure 1.1), with the burning of fossil fuels contributing the other two thirds. In the last decade deforestation has contributed less to increases in atmospheric CO_2. This is due to a decrease in the rate of deforestation in the tropics and an increase in the consumption of fossil fuels (Friedlingstein et al 2010).

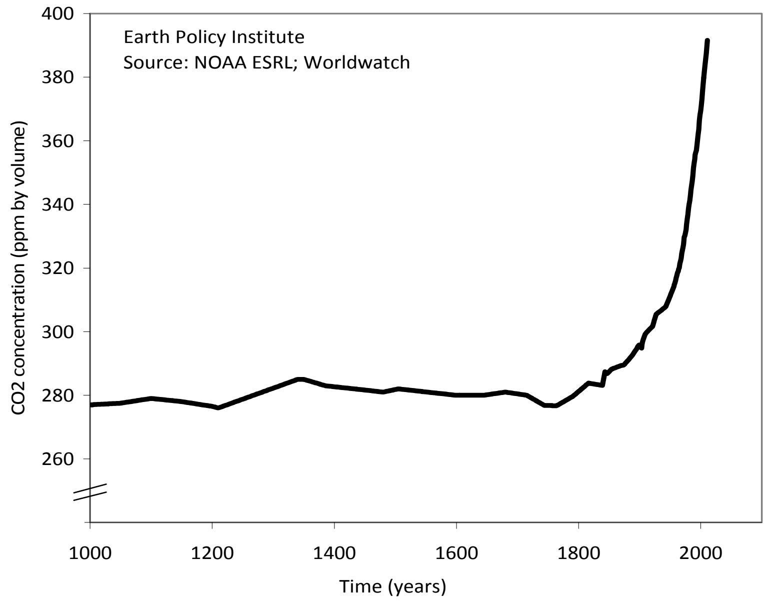

Figure 1.1 Atmospheric CO_2 concentration from 1000 – 2009 (Earth Policy Institute 2010).

Climate change is deemed to be 'dangerous' if globally, average temperate increase by more than 2ºC above pre-industrial temperatures (Schellnhuber et al 2006). Stern (2006) and Garnaut (2008) further discuss the impacts and risks of global temperatures exceeding this 2ºC threshold. Managing the risk of 'dangerous' climate change requires a proactive response. The large time lag between emissions of greenhouse gases (GHG) and response of the earth's climate systems means action is required before significant impacts are clearly observed.

Forests can play both a once-off, and importantly, an ongoing contribution to climate change mitigation. A one-off opportunity exists through reforestation on previously cleared lands and through reducing disturbance in existing forests. Both changes will allow forests to sequester carbon from the atmosphere and store it in the landscape in a non-greenhouse active form, for example, as carbon in wood. However, forests' role in sequestration goes beyond the one-off landscape benefit of carbon in standing stock. Wood products from forests also make an important ongoing contribution to climate change mitigation. Wood products continue to store carbon off-site; are substitutes for more GHG-intensive building products; produce residues that can be used to generate renewable energy, displacing fossil fuels; and minimise the need for

GHG-intensive imports and those that have high transport associated emissions. Over time these ongoing greenhouse gas benefits accumulate and can contribute significantly to the GHG mitigation effort.

Internationally there is general support for sustainably managed multiple use production forests for carbon mitigation (Lippke et al 2011). The Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (IPCC 2007) concluded that: "*In the long term, a sustainable forest management strategy aimed at maintaining or increasing carbon stocks, while producing an annual sustainable yield of timber, fibre, or energy from the forest will generate the largest sustained mitigation benefits*". The same report also notes that policies are limiting the implementation of these options: "*Forestry can make a very significant contribution to a low-cost global mitigation portfolio that provides synergies with adaptation and sustainable development. However, this opportunity is being lost in the current institutional context and lack of political will to implement and has resulted in only a small portion of this potential being realised at present*".

In this paper the Australian Federal Government's policies on climate change and renewable energy are reviewed with respect to the potential impact and opportunities for forests. Through two case studies on native forests in NSW, this paper compares the potential GHG outcomes from multiple use production forests with those of conservation forests. The implications of current policy are discussed in light of the results of this study. A manuscript which expands the discussion included here was submitted to the "Forests" journal for publication, and will hopefully be available from http://www.mdpi.com/journal/forests.

2 .Treatment of forests in Australia's climate change and renewable energy legislation

2.1 Existing emissions trading schemes

Emissions trading schemes (ETSs) are increasingly being introduced to assist countries to meet their emissions reduction targets. ETSs create an economic incentive for businesses to reduce their emissions, by requiring them to purchase offset credits if they cannot meet imposed emissions reduction targets through internal actions. The NSW Greenhouse Gas Reduction Scheme (GGAS) is the longest-running mandatory ETS in the world. Other examples include the European and New Zealand ETSs, and state-based schemes in the US (on the east coast, the Regional Greenhouse Gas Initiative, and on the west coast, the Western Climate Initiative), (Tuerk et al 2011).

Most ETSs give credit for reforestation/afforestation, as defined under the Kyoto Protocol to the Nations Framework Convention on Climate Change (the European Union ETS is a notable exception), but they do not give credit for managing existing forests to increase carbon stocks.

2.2 Clean Energy Future legislative package

The Australian Government introduced a series of Bills through the Federal Parliament in 2011 (grouped and known as the Clean Energy Future Plan (Australian Government 2011a)). A national carbon pricing mechanism will commence in Australia from 1 July 2012, implemented through the *Clean Energy Act 2011*. The carbon price will be initially fixed, commencing at AUS$23 per tonne of CO_2, then rising at 2.5 % each year for the following two years. From July 2015 a 'cap and trade' ETS will commence, with the price determined by the market. The scheme will cover all sectors, except agriculture, although processors of agricultural products are covered. The carbon price will not apply to household transport fuels, light vehicle business transport and off-road fuel use by the agriculture, forestry and fishing industries. Liable businesses are those with emissions greater than 25,000 t CO_2-e.

2.3 Carbon Farming Initiative

The Carbon Farming Initiative (CFI) which commenced in December 2011 allows for abatement activities, undertaken as offsets projects, to produce Australian Carbon Credit Units (ACCUs). These units can then be traded to enable liable parties to meet their obligations (emissions targets) established under the Clean Energy legislation. Under the CFI, reforestation and reduction in livestock emissions are some of the activities that could generate ACCUs. Only activities that count towards Australia's emissions target under the Kyoto Protocol can be used to offset emissions of a business with a liability under the *Clean Energy Act 2011*.

However, a second element of the CFI allows for credits to be generated through activities that reduce emissions or sequester carbon, but are not counted by Australia towards its Kyoto Protocol target. The Clean Energy Future policy introduced the 'non-Kyoto carbon fund' through which the Government will purchase credits from these activities, which could include soil carbon management, forest management and biochar application.

Sequestration offset projects in the CFI are defined in the Act as projects to: (1) sequester carbon in living biomass, dead organic matter or soil; or (2) to maintain carbon stored in biomass, organic matter or soil. Some carbon sequestered in biomass or soil is vulnerable to future release. In recognition of this risk, all sequestration projects (i.e., projects to maintain or increase carbon stores) are subject to permanence obligations. The CFI Act contains provisions for three measures to manage permanence:

- A risk of reversal buffer, through which 5% of abatement remains unsold to ensure against temporary loss;
- A requirement to relinquish credits if sequestration is reversed; and
- Carbon maintenance obligations that require future land owners to maintain the sequestration.

The concept of 'additionality' is important in understanding the prospects for different activities to earn credits through the CFI. Participants need to consider a fundamental question: *Would the activity have occurred anyway, in the absence of the Carbon Farming Initiative?* If the answer to this question is "yes", the activity is not additional and therefore not considered to be a legitimate offset activity. The argument is that if an emitter buys offsets from someone who would have planted trees or burned landfill gas anyway, there is no extra abatement. They are merely subsidising an activity that would have happened anyway.

Offset schemes usually require individual projects to demonstrate that they are additional. For example, projects under the Clean Development Mechanism (CDM) must demonstrate that they are not common practice, and are not financially viable in the absence of abatement credits (UNFCCC 2011).

The CFI will be the first carbon offset scheme to use a more efficient streamlined 'Positive List' to assess additionality. Under the Positive List approach, additionality is assessed for activity types, rather than individual projects. Those activities that are determined to go beyond common practice, are included in the positive list and therefore deemed to be additional.

The CFI also includes a 'Negative List' to exclude offset activities that are considered to adversely impact one or more of the following: the availability of water; the conservation of biodiversity; employment; the local community; and land access for agricultural production. Both the positive and negative lists will grow over time as new activities are submitted and assessed, and risks identified. The current positive and negative lists, key instruments in defining which activities can generate credits through the CFI, are included in Appendix A.

2.3.1 Native forests and the CFI

Native forests receive specific treatment in the CFI Act[3]. The Act defines native forests, (see Appendix A) and contains two elements of significance for native forest management. Firstly, the Act specifically excludes offset projects which use “material obtained as a result of the clearing or harvesting of native forest” [*Part 3, Division 2, Section 27, clause 4(j) (ii)*]. This effectively excludes any GHG benefits obtained from wood products or residues from harvested native forests being recognised under the CFI. This would also prevent clearing of low-density native forest to establish a higher-density carbon sink plantation or biochar projects that make use of materials from native forests.

Secondly, the Act defines a “native forest protection project” as a project to:

1. remove carbon dioxide (CO_2) from the atmosphere by sequestering carbon in trees in one or more native forests; and
2. avoid emissions of GHGs attributable to the clearing or clear-felling of one or more native forests.

This definition of a “native forest protection project” indicates that cessation of harvest in multiple use production native forests, not currently part of the nature conservation reserves, will be eligible for an offset credit under the CFI. And the Act then details (Part 2 Division 3 Section 17) the process to determine the ACCU entitlement.

Native forest protection projects, as defined in the Act, include a mix of sequestration and avoided emissions. The exact nature of these projects will be defined if and when they are included on the positive list. The CFI Explanatory Memorandum has also flagged methodological and crediting requirements as follows: ACCUs will be issued on a pro rata basis over 20 years, to “reduce the risks that forests will be cleared after all the ACCUs have been issued, and ... (to) provide a revenue stream to fund ongoing management of the forest”.

While native forest protection projects are specifically defined in the legislation, they must be included on the positive list and an offset methodology must be approved before credits for native forest protection projects can be generated. As at 8 December 2011 native forest protection was not included on the positive list. Likewise, no specific native forest activities have been excluded via inclusion on the negative list.

2.3.2 Leakage

Native forest protection projects which involve cessation of logging could lead to leakage. That is, forests could be harvested elsewhere to supply the timber. Under the CFI, potential leakage from forest protection projects is addressed by including indirect emissions within the project boundary. Indirect emissions may result if a forest owner increased harvest intensity on one site while another is protected. These emissions are captured because all forested lands under the operational control of a project proponent are accounted for, irrespective of whether those lands participate in the sequestration project.

Of concern is the potential for leakage to occur between forest companies and across national boundaries. Under the CFI leakage that occurs at a domestic level is to be addressed “at a program level”, though it is not yet clear how this will be implemented. Furthermore, any loss in carbon stock in forests elsewhere in Australia will be reflected in Australia’s national inventory, but leakage across national boundaries could be undetected. Thus leakage across national boundaries is the most significant issue, and it is not considered under the CFI.

Protection of native forests in Australia is likely to increase hardwood timber imports. In NSW native forests currently supply around 146,000 m^3 of finished sawn product annually while

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[3] Carbon Credits (Carbon Farming Initiative) Act 2011 Act No. 101 of 2011

eucalypt plantations supply only 55,000m^3 (see Appendix B). This is insufficient to meet the demand for high quality hardwood products. Approximately 60% of the imported sawn tropical hardwoods come from Indonesia and much of this is likely to be from illegally logged forests (Jaakko Poyry Consulting 2005). Illegal logging is a leading cause of deforestation and forest degradation in Indonesia (Ministry of Environment 2010; Blaser et al 2011). The rate of deforestation in Indonesia is about 1.1 Mha^{-1} yr^{-1} (and is increasing) resulting in 850 Mt emissions annually (Ministry of Environment, 2010). Further reductions in native forest harvesting could increase Australia's reliance on imports from forestry activities that are not managed under a sustainability framework (which is applied in Australia).

There is an assumption that the current plantation estate will be able to meet the demand for wood products currently supplied from native forests if harvesting of native forests ceases. Although the plantation estate expanded between 1994 and 2006, the bulk of the planted area is not high-quality sawlog producing species. To produce the sawlog products that currently come from native forests managed by Forests NSW an additional 65,000 ha plantations managed for high quality log production would be required. Forests NSW currently has less than 20,000 ha of plantation land suitable for high-quality log production. Purchasing and establishing a plantation resource to replace the existing native forest production would need an investment greater than $300M at current land prices and establishment costs, and it would take at least 30 years before they could fill the gap.

2.3.3 Plantations in the CFI

The current positive and negative lists (Appendix A) specify restrictions on the types of tree-planting activities that are eligible under the offset provisions of the CFI. Permanent plantings (that is, not for harvest) established since July 2007 are specified on the positive list. Plantations (defined as forests established for harvest) could be eligible under limited circumstances. Through the negative list, the CFI restricts the eligibility of plantations in areas receiving >600mm long-term average rainfall per annum. In this zone, eligible projects are limited to:

- Environmental plantings, defined as plantings of mixed native tree species that will not be harvested;
- Plantings established for salinity management;
- Plantings in areas where policy measures are in place to manage water impacts; and
- Plantings for which a quantified water access entitlement of between 0.9-2.1ML ha^{-1} yr^{-1} has been acquired (Appendix A, Table A1).

In addition, cessation of harvest of plantations is specifically excluded from the CFI, as is establishment of forests under a MIS.

Plantations are the only land use required to account for changes to water interception by the purchase of high security water entitlements. Environmental plantings or other agricultural changes in land use do not have the same requirement.

As a result of the restrictions on eligibility of plantations it is probable that very few plantation offset projects will occur in areas suitable for forestry, as the costs of securing the required high security water entitlements is likely to impair the economic viability of such projects.

Any project to maintain or increase forest carbon stores is subject to permanence obligations outlined above. Under the CFI regulations permanent (i.e., non-harvest) plantings accredited under the New South Wales Government's GGAS would be eligible as specified offset projects (not requiring further additionality test). As most GGAS offset projects were established with intention to harvest, their eligibility is unclear, since cessation of harvest of plantations is specifically excluded from the CFI. However, the conversion of GGAS offset projects to permanent plantings may be accepted if a case can be made that with suitable environmental improvement actions, this would effectively constitute permanent environmental plantings, which is a permitted activity under the CFI.

2.3.4 Implications of CFI for forestry

In order for Australian carbon to be in an international tradeable form, an offset methodology must recognised by both the Australian government and the UNFCCC. The CFI is the only instrument currently used by the Australian government to assess the eligibility of a method for creating international carbon trading units. Under the CFI, carbon sequestration activities in the harvested forest estate are largely ineligible as offset projects. As yet there are no methodologies that have been internationally recognised and there is currently no recognition at the national level under the CFI. Current eligible forestry activities are limited to native forest protection and establishment of environmental plantings, apparently favouring biodiversity outcomes.

This current situation is relatively insignificant for non-Kyoto forestry offset projects that cannot be used to satisfy Australian obligations under the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (KP). However, recent decisions[4] of the UNFCCC/KP mean that from 2013, Australia will be in a position to elect forest management under Article 3.4 of the Kyoto Protocol. As a result, harvested wood products will no longer be automatically counted as emissions when harvest occurs.

Australia has reforestation activities that are consistent with Article 3.3 and from 2013 there may be forest management activities that will be consistent with Article 3.4. From 2013 Australia will be able to count towards its Kyoto target, sequestration of carbon in both the harvested forest estate and in the wood products pool from harvested native forest. However, because such offset projects will not be permitted under the CFI, this significant domestic abatement potential is likely to be unrealised, leading to perverse outcomes. Perverse outcomes include the sourcing of abatement credits internationally at a cost to the domestic economy; a reduction in the harvesting of domestic wood products; substitution of those products with GHG intensive imports; and potential carbon leakage through off-shore unsustainable harvesting methods. In this respect, these regulations fail to serve the objectives of the Act which are to drive the adoption of low cost GHG abatement and sequestration options and practices.

2.4 Renewable Energy Target (RET) scheme

2.4.1 Overview of RET

The *Renewable Energy (Electricity) Act 2000* and the accompanying *Renewable Energy (Electricity) Regulations 2001* define the requirements of the Large-scale Renewable Energy Target and Small-scale Renewable Energy Scheme. The Large-scale Renewable Energy Target is relevant as it creates a financial incentive for the establishment and growth of renewable energy power stations. It does this by legislating demand for Large-scale Generation Certificates (LGCs). These LGCs are created based on the amount of eligible renewable electricity produced by the power stations. LGCs can be sold or traded to liable entities, in addition to the power station's sale of electricity to the grid. Liable entities have a legal obligation to buy LGCs and surrender them to the Office of the Renewable Energy Regulator on an annual basis.

Power stations must generate their electricity from approved sources such as solar energy, wind, ocean waves and the tide, geothermal aquifers, forestry and agricultural residues (eg bagasse - sugar cane trash), black liquor (a by-product of the paper-making process), or landfill gas. A full list of eligible renewable energy sources is included in Section 17 of the *Renewable Energy (Electricity) Act 2000* (Renewable Energy (Electricity) Regulations 2001 (Appendix A)[5].

[4] Decision 1/CMP.7, Decision 2/CMP.7 http://unfccc.int/2860.php

[5] Renewable Energy (Electricity) Regulations 2001. Statutory Rules 2001 No. 2 as amended made under the Renewable Energy (Electricity) Act 2001. 13 December 2011

2.4.2 Native forests and the RET

Biomass from native forests was an eligible source for renewable electricity generation in the *Renewable Energy (Electricity) Regulations 2001*, under limited conditions specified in the Regulations (see Appendix A). However, native forest biomass was removed from the approved sources under the amendments to the Renewable Energy Act in December 2011 (Appendix A). The current exclusion covers manufactured wood products, by-products and sawmill residues derived from native forest biomass. On 8 February 2012 Mr Rob Oakeshott MP (Federal Member for Lyne) moved in the federal parliament to disallow the amendment to the regulations under the *Renewable Energy (Electricity) Amendment Regulations 2011 (No.5)*. If supported, this disallowance would have allowed for the utilisation of native forest residues for bioenergy (with controls and limitations as previously established in preceding regulations). However, the disallowance motion was defeated in the Legislative Assembly on 19th March 2012.

Complicating the potential use of native forest residues in NSW is the limitation under the *Protection of the Environment Operations (General) Regulation 2009* which prohibits use of native forest biomass (other than sawmill and wood processing residues) for electricity generation.

2.4.3 Plantations and the RET

Biomass from plantations is eligible as a feedstock for renewable energy. The only limitations are that the plantation should not be established on land cleared since 1989, and that it is managed in accordance with ecologically sustainable forest management principles (see Appendix A).

3 The role of multiple use production forests in climate change mitigation

3.1 The forest carbon cycle

Forests sequester carbon from the atmosphere, converting CO_2 into carbon stored in biomass (foliage, branches, trunk and roots), which is a non-greenhouse active form of carbon. This forest biomass accumulates rapidly in young growing forests, and continues to build, at increasingly slower rate, up to a maximum Carbon Carrying Capacity (CCC). As leaves and branches fall, and roots senesce, carbon is transferred to the litter and soil carbon pools. The CCC is influenced by the tree species, environment (rainfall, temperature and nutrition) and frequency of disturbance (fire, wind-throw and pests).

Establishing new forests, either through reforestation or afforestation, increases the carbon stored in the landscape. This is a once off carbon sequestration opportunity recognised under the Kyoto protocol and to a lesser extent, the CFI. Changing the management of native forests to reduce disturbance and allow the forest to reach the maximum CCC will also produce a once-off carbon sequestration opportunity. However this sequestration may not improve the GHG outcome as this landscape storage of carbon reduces the offsite carbon storage and potentially increases emission elsewhere.

The harvesting of trees from multiple use production forests extends the opportunities for carbon sequestration and introduces significant substitution opportunities. Harvesting of forests create new carbon stocks outside the forest. These new carbon stocks include solid wood products, composite wood products (e.g. plywood, particleboard and medium-density fibreboard) and paper. Wood products can also substitute for more GHG-intensive building products. Wood products require comparatively low fossil-fuel based energy for their extraction and manufacture, compared to GHG-intensive materials such as steel, aluminium and concrete.

Harvest and sawmill residues can be used for renewable energy, substituting for fossil fuels. The biofuels can be used for heating, electricity generation and also for liquid fuel production.

Forests producing a full range of products that are harvested on a sustainable yield basis deliver ongoing greenhouse benefits from a combination of the carbon sequestered during growth, the carbon stored in wood and fibre products and the substitution of biomass for emissions-intensive products and fossil fuels. The forest carbon cycle is shown in Figure 3.1 where the carbon stocks (boxes) and flows (arrows) in a harvested native forest system are schematically represented. Management options (white tags) will impact on the flows and stocks of carbon. Fossil fuel substitution and product substitution can significantly contribute to a net reduction in GHG emissions.

The case studies in Section 4 outline the relative importance to GHG outcomes of these ongoing carbon stocks and substitution effects.

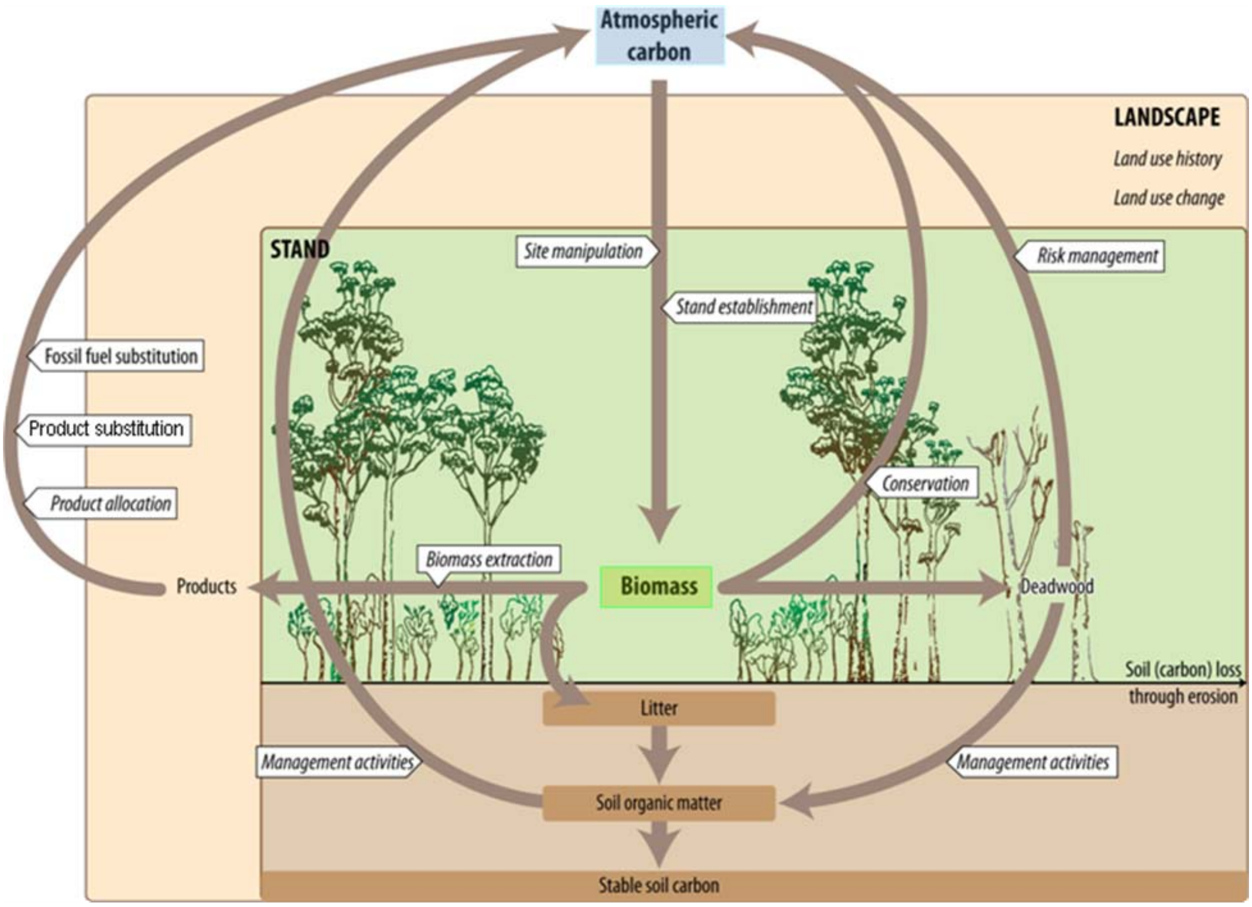

Figure 3.1 Stocks and flows of carbon in a harvested native forest system (after George & Cowie 2011).

3.2 Native forest carbon stocks

Native forests store significant amounts of carbon. Table 3.1 summarises published values of carbon stocks in a range of native forest types. The majority of these estimates were determined for mature, relatively undisturbed forests, thereby approximating the CCC at these sites. There is a wide range of published figures, from 18 to 318 t C ha^{-1}, with the mean values dominantly in the range 150- 250 t C ha^{-1}. The mean values of Mackey et al (2008) stand out from all other mean estimates. They have estimated the average across all south eastern Australian forests to be 289 t C ha^{-1} - well in excess of other published means (Table 3.1). Moroni et al (2010) cast doubt over the Mackey figures, stating that only 2.5% (by area) of Tasmanian State Forests have capacity to reach a total live biomass of 289 t C ha^{-1}, the average figure quoted by Mackey et al (2008) and Keith et al (2009; 2010). Adams & Attiwill (2011) also comment that the CCC claimed by Keith et al (2009) is “extraordinary”.

Table 3.1 Summary of published above ground C stock of native forests.

Forest type	Location	Above ground carbon ($t\ C\ ha^{-1}$) Mean	Range	Reference
Alpine mixed species	Vic	250		Grierson et al 1993
Mallee	Vic	18		Grierson et al 1993
Various	Eden, NSW	217		Turner & Lambert 1986
	NSW & Vic		68 - 318	Raison et al 2003
	Tas	155		Moroni et al 2010
	Kioloa, NSW	214		Roxburgh et al 2006
	South Coast, NSW	150	119 - 198	Ximenes et al 2005a
	South Eastern Australia	289(1)		Mackey et al 2008, Keith et al 2009

(1) Mackey et al (2008) and Keith et al (2009) figures include the above and below ground carbon *but exclude the coarse woody debris component. The value of* carbon *in roots was not reported.*

Using their carbon storage estimates for native forests, Mackey et al (2008) have called for changed management of harvested forests (including the cessation of logging) to allow these stands to reach their CCC as mature forests. Over an area of some 14.5 million ha of eucalypt forests in south-eastern Australia, Mackey et al (2008) estimated a total CCC of 9 Gt C (33 Gt CO_2-e). Mackey et al (2008) consider this change will significantly contribute to climate change mitigation. Assuming that harvesting reduces the forest carbon stocks by 40% below that of the modelled CCC (including soil carbon), the authors concluded that if logging in native eucalypt forests was halted, the forests would regrow to their natural CCC, sequestering 2 Gt C (equivalent to 7.5 Gt CO_2-e) (Mackey et al 2008). In reality, the frequent incidence of wildfire in this region would limit the proportion of the forest area that reaches CCC at any particular time (Adams & Attiwill 2011). Though Mackey et al (2008) state that fire impacts are included in their estimate of sequestration potential, it is not clear how this was calculated.

Utilising their estimate of sequestration potential of 7.5 Gt CO_2-e in the South Eastern forests and multiplying by an “atmospheric equivalence factor”, Mackey et al (2008) estimated the value of sequestration to be equivalent to abatement of 136 Mt CO_2-e per year for the next 100 years. The Garnaut review included this figure (136 Mt CO_2-e per year) in its assessment of the potential for emission reduction by Australia’s rural sectors (Garnaut 2008). Roxburgh (in CSIRO 2009) reassessed the carbon sequestration potential of those same forests. Using historical log removal data and excluding the "atmospheric equivalence factor" applied by Mackey et al (2008), Roxburgh (2009) estimated sequestration at 18.7 – 74.2 Mt CO_2-e per year for the next 40 years (CSIRO 2009), and the average of 47 Mt CO_2-e per year was subsequently included in Garnaut’s update on the opportunities for emission reductions and sequestration from rural land use (Garnaut 2011).

To date the discussion has focused on carbon storage within the forest. However, as described below, harvesting of wood products from forests creates a new storage pool in products, and, importantly, the forest biomass can substitute for emissions-intensive products and fossil fuels. Thus considering only the carbon storage in the forest fails to take into account the wider role forests can play in GHG mitigation.

3.3 Carbon storage beyond the forest

3.3.1 Off-site carbon storage in wood products

When forests are harvested the amount of biomass removed for processing into wood products various between 45 and 65% (Figure 3.2). The proportion of biomass extracted during harvest depends on factors such as tree species, site conditions, harvesting technique and log grading (Ximenes et al 2008b).

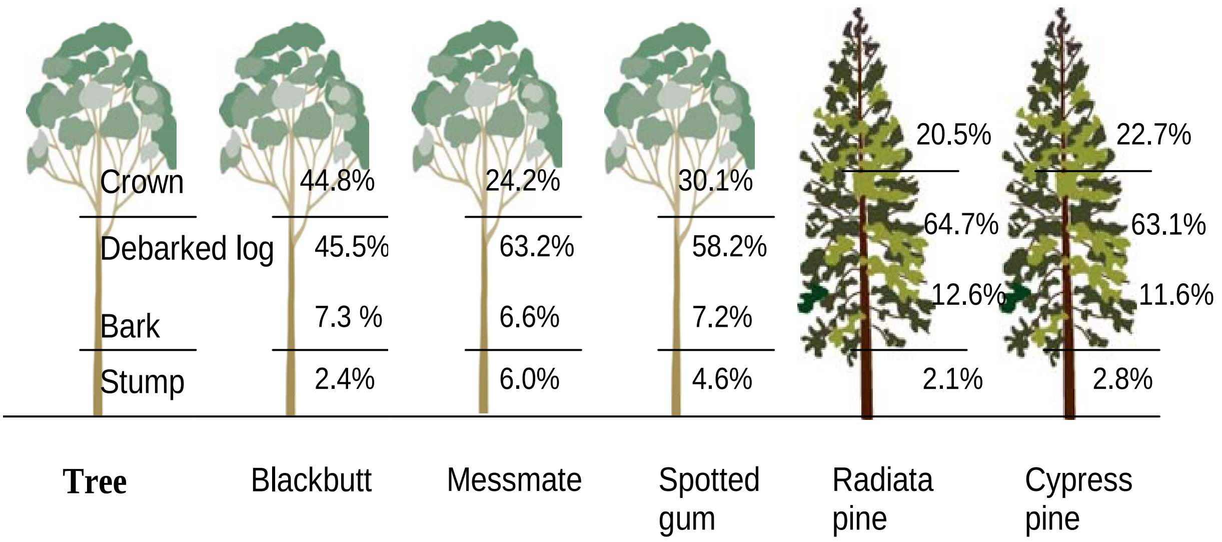

Figure 3.2 Proportion of biomass in the components of five tree species harvested for wood products in Australia. (From Ximenes et al 2008b.)

Once extracted the proportion of logs in the five broad product classes varies substantially between tree species (Figure 3.3). The wood products produced from these product classes are outlined in Table B3 (Appendix B). The bulk of the plantation timber products and value-added products from native forest logs have a long service life and represent a valuable store of carbon. Different product groups have different service lives, with domestic house framing typically having a long service life (around 50 years).

At the end of their service life, the vast majority of wood products in Australia are deposited in landfill. Although some wood products may be recycled at least once, eventually a high proportion of them will also end up in landfills. The majority of the carbon in wood products deposited in landfill remains undecomposed (Ximenes et al 2008a). Carbon in wood products in landfill is quantified from estimates of waste composition and volume, and assumed decay rates (IPCC 2006).

Decomposition of organic materials in landfills results in the generation of greenhouse gases, mainly CO_2 and methane in approximately equal proportions. Emissions occur over a period of about 30 years after the waste has been deposited. The decomposition factors used are critical to the calculation of GHG emissions from landfills, as methane is a GHG 21-25 times as powerful as CO_2. In the IPCC Guidelines it is currently assumed that 50% of the carbon in wood products in landfill is released as a result of decomposition (IPCC 2006). The Department of Climate Change and Energy Efficiency (DCCEE) has recently revised that factor down to 23% for wood products, based on earlier experimental results from the USA (DCCEE 2010). However, NSW DPI research (e.g., Ximenes et al 2008a), and a recently published study in the USA (Wang et al 2011), has demonstrated that harvested wood products in landfill represent a long term carbon store, with minimal or no decomposition taking place.

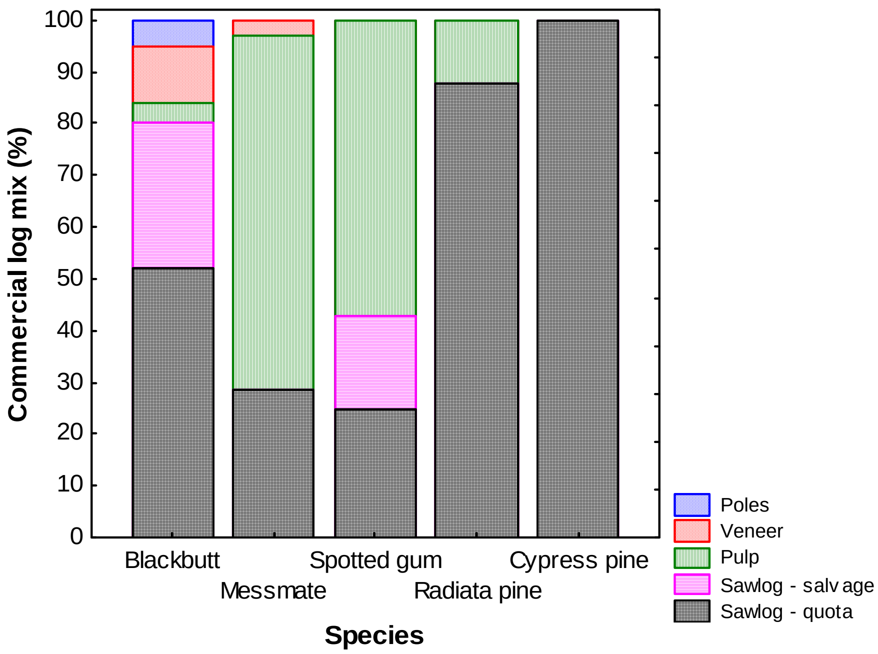

Figure 3.3 Proportion of total commercial log biomass in different product classes (Ximenes et al 2008b).

3.3.2 Product substitution effect

Besides storing carbon sequestered during forest growth, wood products can provide additional GHG benefits through the substitution for other more energy and greenhouse-intensive materials such as steel, aluminium, plastic and concrete (Ximenes 2006). Research from around the world has shown that the life-cycle greenhouse impact of wood products is significantly lower than that of competing, non-renewable products (Australia and New Zealand - McLennan Magasanik Associates 1991; Buchanan & Levine 1999; Ximenes 2006; Ximenes & Grant 2009; May et al 2011; Europe - Sathre a& O'Connor 2010; Gustavsson et al 2006; US - Perez-Garcia et al 2006; Lippke et al 2011).

A meta-analysis of twenty European and North-American studies found an average reduction of two tonnes of carbon for each tonne of carbon in wood products substituted for non-wood products (Sathre & O'Connor 2010).

3.3.3 Life cycle approach

In order to understand the full contribution that forests managed for wood products can deliver in reducing GHG emissions, the full life cycle of wood products should be considered, including all sequestration and emissions that occur through that life cycle. The net impact on GHG emissions across the life cycle is dependent on:

1. carbon removed from the atmosphere by the growing forest (expressed as the change in long term average carbon stock);
2. any change in soil or biomass carbon stock;
3. change in stock of carbon in wood products in use and in landfill; and
4. emissions from fossil fuel use in forest establishment, forest management, harvest, transport and processing.

We have used a whole of life approach to consider the net GHG impact of two contrasting native forest regions in NSW.

4 NSW native forest case studies

Two case studies, based on two contrasting NSW native forests from northern and southern coastal areas, are used to simulate the GHG balance of managing forests for:

(i) multiple use – sustainably managed for the production of wood products and fibre and maintenance of natural resource management (NRM) values;

(ii) conservation - managed as part of the nature conservation reserve system with no harvesting.

The full life cycle of carbon in forests and wood products is considered. The simulation was run over a period of 200 years. The two management scenarios take into account:

- carbon sequestration in standing trees in the forest;
- carbon storage in harvest residues (above and below-ground);
- long-term carbon storage in wood products;
- GHG emissions due to the establishment and management of forests, harvesting, log transport, manufacture, transport to customer and disposal of products;
- emissions avoidance associated with of the use of wood products in place of more greenhouse-intensive alternatives. A 100% substitution for non-wood materials was assumed;
- fossil-fuel substitution benefits of using a proportion of harvest residues for bioenergy generation;
- GHG emissions due to the forest management, harvesting, log transport, manufacture, transport to customer and disposal of products.

Forest soil carbon was assumed to be at steady state over the 200 years. Native forestry harvesting operations typically produce only a slight change, if any, to total soil carbon levels (May et al 2011; Raison et al 2003). Removal of native forest residues for bioenergy may have some impact on soil carbon levels, particularly if bark, foliage and branches are removed (Johnson and Curtis 2001).

GHG emissions due to wildfire and prescribed burning (non-CO_2) were not directly included in the analyses, due to the lack of site-specific parameters. Instead the potential impact of including those emissions on the net GHG balance of the case study forests, using best available published references, were discussed (details in Appendix C). We also discuss but do not explicitly include the effect of incorporating carbon in coarse woody debris (CWD) in the analysis, and the effect that a decrease in harvest within the systems could have, through market forces, on harvest and forest carbon in other domestic or foreign forests.

The main characteristics of the areas included as case studies are described in the following section and more details are provided in Appendix C.

4.1 Prediction of the above ground biomass carbon of NSW north coast and south coast forests

The above-ground biomass carbon predictions were derived using the empirical model FRAMES developed by FNSW for harvest scheduling (Appendix C). The predictions up to year 80 were based on inventory data from 179 plots (0.1 ha) across the native forest estate. Extrapolation beyond year 80 was based on a constrained growth model set by an imposed basal area limit for the relevant forest types, as inventory data was not available beyond age 80. The forest yields (volume ha^{-1}) were converted to carbon by firstly converting the volumes to dry biomass (using the mean basic density for blackbutt of 700 kg m^{-3}(Ximenes et al 2005a), which was the dominant species in the North Coast plots, and the basic density of dominant species for the

South Coast forests – detailed in Appendix C), and then used a carbon concentration of 50% to derive above-ground carbon.

For the North Coast and South Coast forests the above-ground biomass carbon stock was 160 and 130 t C ha^{-1}, respectively, for the '*conservation*' forests at year 200. This is considerably lower than the mean value predicted by Mackey et al (2008) for south eastern Australian forests not disturbed by harvesting, but within the range of values in Table 3.1. The estimated carbon carrying capacity will have little impact on the relative difference between the '*conservation*' and '*harvest*' options. A higher carbon stock in the '*conservation*' forest at year 200 implies greater forest productivity which would equally apply to the harvested forest scenario. As a result both the forest carbon stocks and off-site GHG benefits, such as wood products, would also increase.

4.2 Simulation results

This section describes the net GHG implications of '*conservation*' and *'harvest'* management approaches for the selected forest areas over 200 years. The start point (Year 0) for the simulation was a randomly chosen point in the forest lifecycle where the forest was mature and a harvest event followed soon after.

The GHG mitigation outcomes for the '*conservation*' and '*harvest*' management approaches are shown in Table 4.1. Table 4.1shows the GHG balance and **the change** in carbon stocks in forest and products. An increase in carbon stock indicates a removal of CO_2 from the atmosphere while a decrease indicates an emission. The net mitigation is the balance between emissions and removals. The positive values for product substitution and bioenergy indicate the fossil fuel emissions avoided through use of wood products and bioenergy. At year 200 the 'forest carbon' value (*Changes in forest carbon stock)* for the '*harvest*' scenario is negative (-14.7 i.e., a net emission) for the North Coast forests due to fluctuation in the forest carbon stock caused by a scheduled harvest. As no harvest takes place in the '*conservation*' scenario, there is a net increase in carbon sequestered in the North Coast and South Coast forests (Table 4.1). For the North Coast forests the GHG mitigation effect of long-term carbon storage in wood products (78.4 t C ha^{-1}) was slightly greater than the GHG mitigation benefit of the '*conservation*' scenario over 200 years

Emissions associated with forest-based operations (establishment, maintenance, harvest and transport of logs), manufacture and disposal of wood products are relatively small compared with the mitigation value and reduce the total mitigation benefit by approximately 12%.

Table 4.1 Greenhouse gas mitigation (t C ha^{-1}) for significant components of the forest and product life cycle.

	Life cycle component	North Coast		South Coast	
		Harvested forest	Conservation forest	Harvested forest	Conservation forest
Changes in forest carbon stock	Above-ground carbon	-14.6	77.4	1.2	44.0
Off-site changes in carbon: HWPs and Bioenergy	Storage in HWPs	78.4	0	18.3	0
	Product substitution	195.5	0	49.7	0
	Bioenergy (30% residue removal)	48.9	0	33.7	0
	Forest transport, processing	-16.9	0	-6.3	0
	Landfill disposal	-19.0	0	-5.9	0
	Net GHG balance off-site	286.9	0	89.5	0
	Overall GHG balance	272.3	77.4	90.7	44.0

Values are derived from the difference between the carbon stock at year 200 and the starting carbon stock at year 0. A negative number indicates an emission.

The long-term carbon storage in wood products from the North Coast was much greater than that of the South Coast. The main reason for the difference was the fact that the South Coast forests yielded a much higher proportion of short-lived products (pulp and paper), which were not assumed to provide long-term carbon storage. This also explains the differences in the product substitution effect between the North Coast and South Coast (195.5 and 49.7 t C ha^{-1} respectively).

Accounting for the product substitution impact makes a large difference to the overall GHG assessment of the multiple use production forest scenario. For the North Coast forests, after 200 years the cumulative benefit associated with the product substitution effect is 2.5 times greater than the net carbon sequestered in the '*conservation*' scenario. For the South Coast forests the use of medium and high proportions (50 and 70%) of harvest residues for bioenergy applications results in larger benefits than the product substitution effect for those forests. This is primarily explained by the comparatively small proportion of the harvested biomass from the South Coast that was assumed to become products with long service life.

Although not directly included in the overall GHG assessment of the case study forests, indicative figures suggest the cummulative GHG emissions (non-CO_2 only) due to fire are large under the assumptions used (110 and 164 t C ha^{-1} at year 200 for '*production*' and '*conservation*' forests, respectively). Although emissions due to fire also significantly reduce the overall GHG mitigation benefits of '*production*' forests, at year 200 the GHG mitigation benefit is between 100-250 t C ha^{-1} greater for SC and NC forests respectively than for '*conservation*' forests.

In Figure 4.1 and Figure 4.2 the net life cycle implications of the '*conservation*' (conservation forest areas) and *'harvest'* (multiple use production forest areas) scenarios are represented over the simulation period as t C ha^{-1}. 'Carbon storage in products' does not include carbon in paper products; 'Forest carbon (remaining in harvested forest)' includes temporary carbon storage in the slash from harvest events. Net product substitution is calculated as the GHG benefit of using wood products calculated using a product displacement factor of 2 t C t^{-1} of C in wood products (Sathre & O'Connor 2010), minus process emissions (harvest, processing) and methane from landfill, specific to the product mix modelled in this analysis. This ensured that the results were conservative, as the figure suggested by Sathre & O'Connor (2010) already incorporates those emissions.

For the North Coast forests, apart from a short period around year 30, the '*harvest*' option represents a more beneficial GHG outcome (Figure 4.1) with greater mitigation compared to the carbon sequestration in the '*conservation*' forest areas. The benefits become more apparent over time as more harvest events are taken into account, allowing for greater long-term carbon storage and an increased product substitution effect of the solid wood products. For this simulation, a limited proportion (30%) of the estimated harvest residues was assumed to be extracted for bioenergy generation. At the 200^{th} year, the greenhouse benefit of the '*harvest*' scenario is 2.5 times greater than that of the '*conservation*' scenario, an increase in the GHG mitigation benefit in the order of 235 t C ha^{-1}(Figure 4.1).

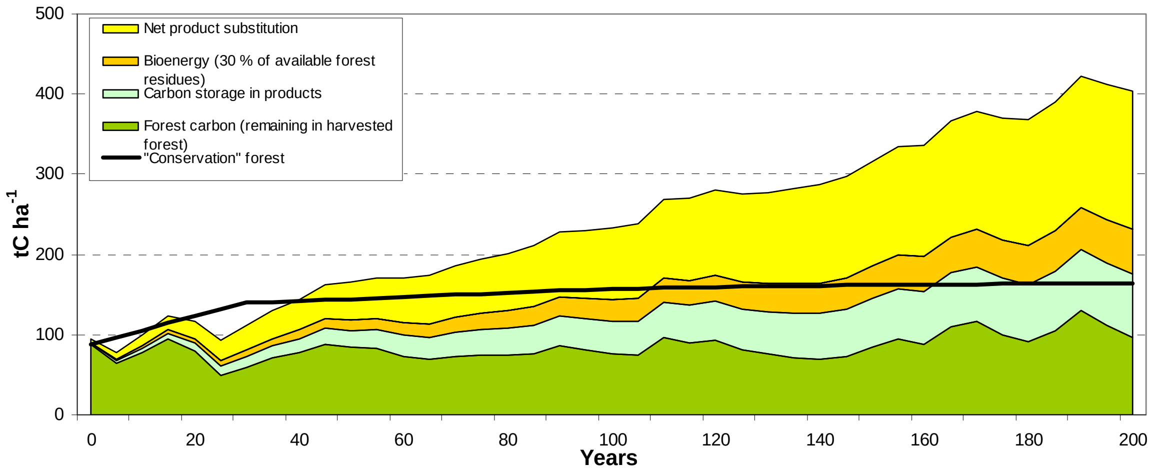

Figure 4.1 GHG implications of the 'conservation' and 'harvest' scenarios (t C ha-1 sequestered or displaced) for North Coast forests modelled over a 200 year period.

In the South Coast forests scenario a similar pattern emerges. Apart from an initial short period of time (until around year 30), where the '*conservation*' scenario results in slightly higher carbon benefits, the '*harvest*' option yields a more positive GHG outcome over the simulation period. This becomes increasingly evident over time as more harvest events are taken into account, illustrating the cumulative effect of long-term carbon storage in wood products and increased product substitution (Figure 4.2). After 200 years, the GHG total mitigation of the '*harvest*' scenario is 1.5 times greater than that of the '*conservation*' scenario (Figure 4.2). This is an increase in the GHG mitigation benefit in the order of 67 t C ha^{-1}. A higher utilisation, (for example 70 % of harvest slash for bioenergy applications), would increase the benefit to about 112 t C ha^{-1}. However, any increase in residue utilisation needs to account for sustainability issues such as potential impacts on biodiversity and soil health (Stupak et al 2011).

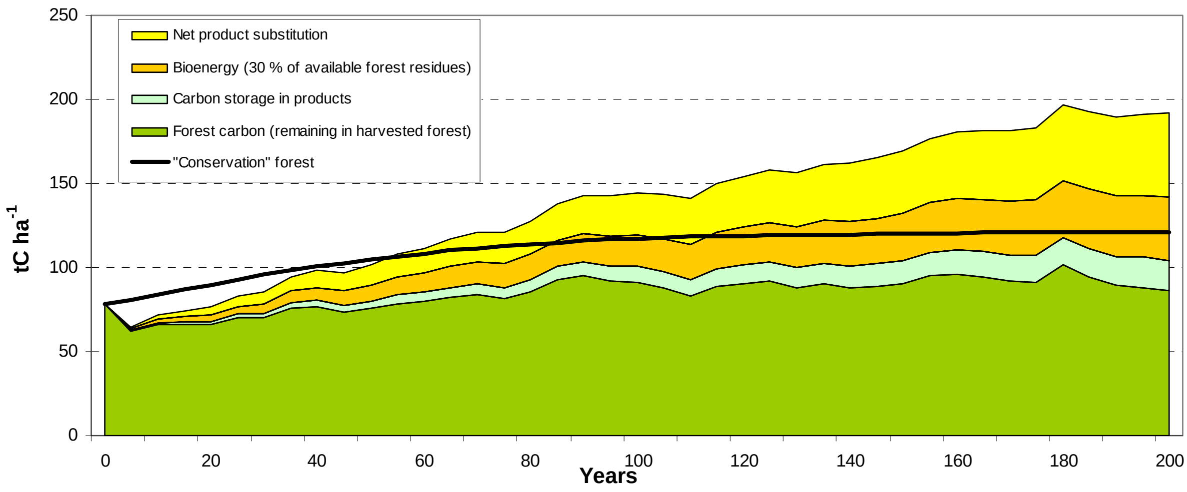

Figure 4.2 GHG implications (t C ha^{-1} sequestered or displaced) of the 'conservation' and 'harvest' scenarios for South Coast forests.

4.2.1 End of life utilisation of wood products and impact on GHG outcomes

In Figure 4.3 and Figure 4.4 the net GHG impact for the *'harvest'* scenario with two disposal options for wood products (*viz.*, (*i*) landfill or (*ii*) incineration with energy recovery[6]) are shown. The two disposal options are compared to the '*conservation*' scenario for the total areas from the North Coast and South Coast forests. The mitigation effect of harvest slash utilisation for bioenergy is not included in these figures. The landfill decay factor assumed was 4.5 %, being the average of average values from Ximenes et al (2008a) (9%) and Wang et al (2011) (0%).

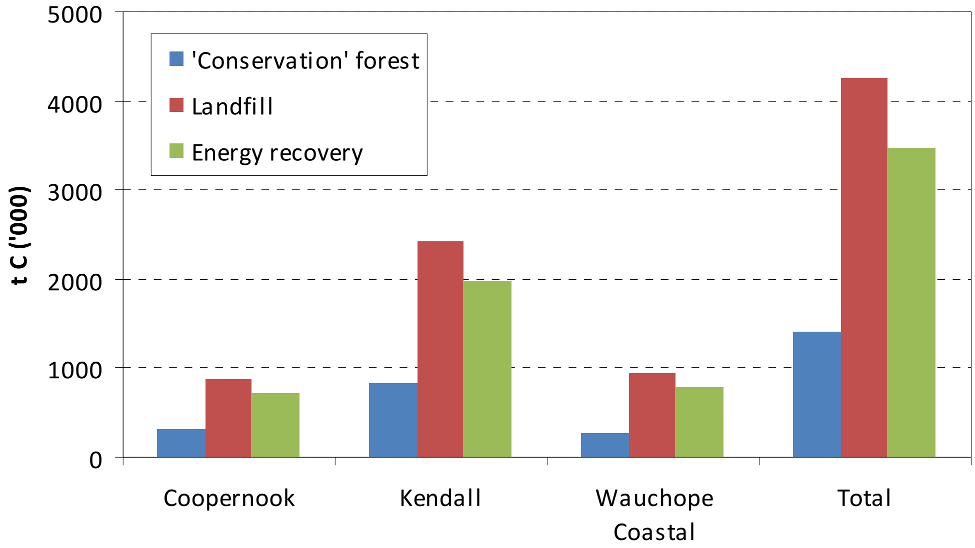

Figure 4.3 Total carbon mitigation benefits (t C) from the 'Landfill' and 'Energy recovery' options for wood products compared to the 'Conservation' scenario in the North Coast forest simulation.

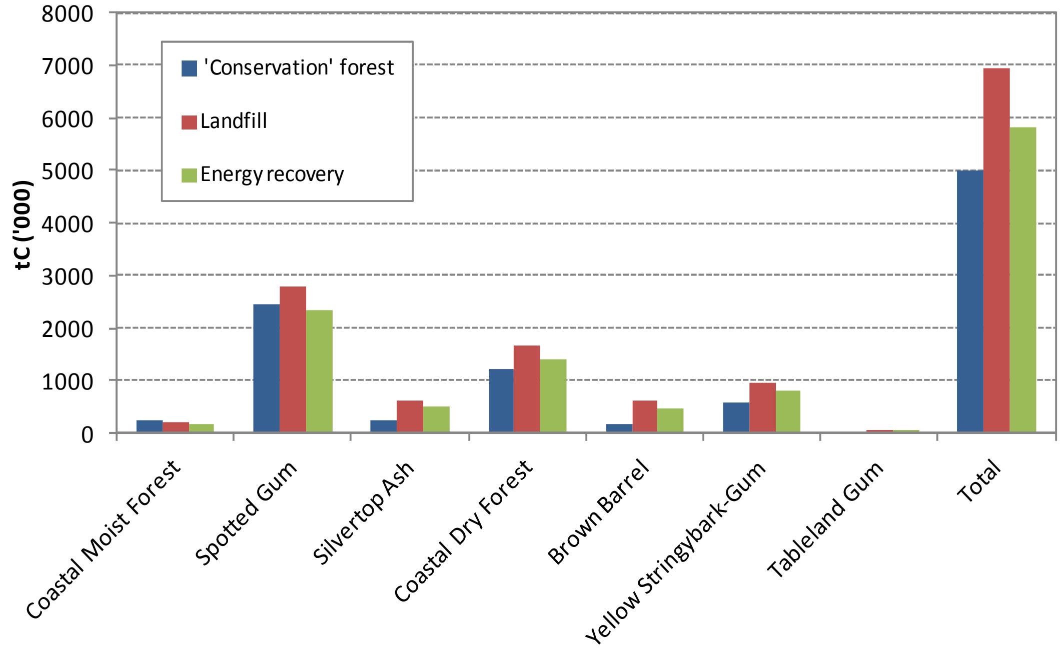

Figure 4.4 Total carbon mitigation benefits (t C) from the 'Landfill' and 'Energy recovery' options for wood products compared to the 'Conservation' scenario in the South Coast forest simulation.

[6] This is recovery of the wood products and not to be confused with utilisation of residues for bioenergy.

In Figure 4.3 the 'Landfill' option of the wood products offers the greatest GHG benefit. Landfill and Energy Recovery are end-of-life options and are not related to bioenergy.

The difference in the total carbon for each North Coast forest zone is largely a reflection of the different areas of forest modelled (Appendix C Tables C2 and C3). For each forest zone, the '*harvest*' option results in significantly greater GHG benefits, and the total GHG benefit for the combined North Coast areas is in the order of 2 – 2.8 Mt C after 200 years (Figure 4.3).

There is greater variability in the results for the South Coast forest areas, partly due to the greater number of forest zones included with a wider range of dominant species types across a larger forest area. Typically the *'harvest'* option results in greater greenhouse benefits, with the combined GHG benefit for the combined areas is in the order of 1.0 – 2.0 Mt C after 200 years (Figure 4.4). Although the order of magnitude of the greenhouse benefit is similar to that found for the North Coast forests, it is diluted over a much larger area (five times larger). The high proportion of biomass from South Coast forests utilised for pulp and paper manufacture significantly reduces the long-term carbon storage and product substitution benefits of those forests.

The 'landfill' option gives slightly greater mitigation benefit for both the North Coast and South Coast forests than the 'waste to energy' option under the assumptions adopted here (Denison 1996). These assumptions were based on overseas industry-average incinerator technology producing electricity alone, as no waste to energy plants are currently operating in Australia, on which to base this estimate. Modern plants using gasification or combined heat and power could have an even greater efficiency and therefore increased net GHG benefits.

4.2.2 Utilisation of residues for bioenergy

Currently, native forest wood waste is not an accredited Renewable Energy Target source in Australia. However, the greenhouse mitigation benefits of extracting a proportion of the harvest slash currently left in the forest and utilising it for electricity generation are very large (Figure 4.5 and Figure 4.6). This takes into account a reduction in the temporary C storage in harvest slash residues as a result of extraction of that biomass.

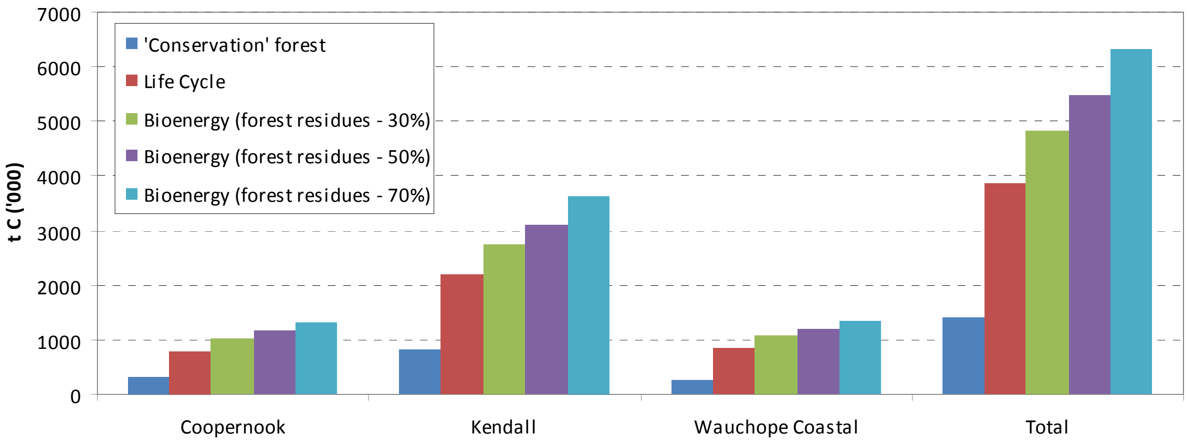

Figure 4.5 Net greenhouse impact (t C) of the extraction of varying proportions of biomass compared with 'Conservation' and 'Life Cycle' emissions in the North Coast simulation.

Figure 4.5 shows the net greenhouse impact (t C) of the extraction of varying proportions of biomass (30, 50 & 70%) from the North Coast forest zones for bioenergy generation. These values are compared to the '*conservation*', and '*Life Cycle*' emissions (i.e., the net effect of long-term storage in wood products and product substitution, minus product-specific process emissions (harvest, processing, transport and disposal)).

For the combined North Coast forest zones modelled, extraction of an increased proportion of harvest slash would result in an extra mitigation benefit in the order of 2.4 – 3.7 Mt C; whilst still retaining a significant proportion of residues to maintain nutritional and ecological values

(Lattimore et al 2009; Farine et al 2011). For the South Coast forests, the impact of residue extraction for bioenergy is even higher, resulting in an extra mitigation benefit ranging from 3.8 – 8.9 Mt C, depending on the proportion of harvest slash removed.

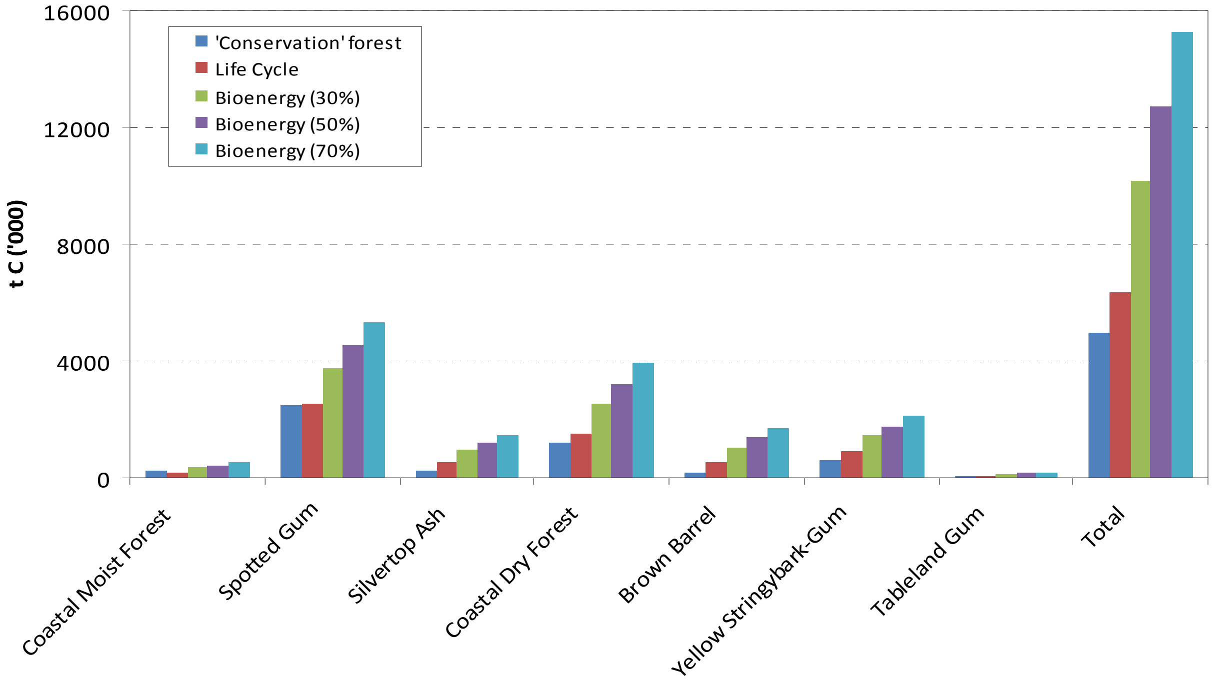

Figure 4.6 Net greenhouse impact (t C) of the extraction of varying proportions of biomass from the South Coast forest zones for bioenergy generation.

Figure 4.5 and Figure 4.6 show that when assessing the relative greenhouse benefits of different forest management approaches, it is important to take all the relevant stages of the life cycle of sustainably managed native forests into consideration. The long-term carbon storage and product substitution benefits of harvested wood products are critical. Although the nature of the overall impact of the inclusion of the effect of regular fire events and management of residues on carbon stocks is clear (i.e., they will favour the *'harvest'* scenario), insufficient data are currently available to underpin more refined assessments. This knowledge gap will be addressed in proposed research programs.

5 General discussion

The case studies show that management of forests for production has the potential to generate greater greenhouse mitigation benefits than managing for conservation alone. Similar conclusions have been drawn by others (e.g., Schlamadinger et al 1997; Eriksson et al 2007; Lippke et al 2011). Similar to a conservation forest, a production forest takes CO_2 from the atmosphere and fixes the carbon within the tree biomass. However, when biomass is removed at harvest the carbon is stored in wood products while the forest grows more biomass, generating more wood products. After several harvest cycles more carbon is stored in the forest plus through the use of products than if the forest had not been harvested. Furthermore the case studies show that substitution, through the use of wood products in place of alternative GHG-intensive materials (such as cement, steel, aluminium etc), provides greater GHG benefits than the value of carbon storage in products, as also reported by Kauppi & Sedjo (2001).

Thus, the current forest management regime applied in these NSW forests gives greater GHG benefits than would be delivered by forest conservation. Cessation of logging in some native forests will give no additional mitigation benefits over BAU. However, the CFI does not provide encouragement of production forests; rather, it foreshadows credit for converting production forest to conservation forest, which, as demonstrated in this study, may deliver no additional GHG benefit in the long term.

The GHG implications of not producing paper products from the '*harvest'* forests were not taken into account. It is possible that a proportion of the displaced paper products, that would need to be sourced elsewhere if harvest of native forests decreased significantly, would be sourced from areas where unsustainable forestry practices are adopted. This would lead to increased GHG emissions associated with the '*conservation*' scenario.

Inclusion of carbon in coarse woody debris (CWD), dead standing wood and fine litter would increase the carbon stocks for the "*conservation*' forest scenario by approximately 25 $tCha^{-1}$, assuming that published figures for forest types similar to those included the South Coast study areas (Roxburgh et al 2006) can be applied here (similar published data was not found for forests comparable to those included in the North Coast case study area). Although this would reduce the combined forest and offset GHG balance for the South Coast forests by approximately 25% (Table 8), the overall GHG outcome of the South Coast '*harvest*' forest is still significantly better (75 $tCha^{-1}$) than that of the South Coast '*conservation*' forests. The magnitude of the difference in the GHG balance between North Coast '*harvest*' and '*conservation* forests' was such (249.5 $tCha^{-1}$) that inclusion of carbon in CWD would result in, proportionally, even less significant changes to the overall GHG outcome.

Although the GHG impact of fires is large over time (even discounting biogenic CO_2 emissions), their effect is more pronounced for '*conservation*' forests, as the proportion of fire events represented by wildfires was greater for those forests. This resulted in higher estimates of GHG emissions. The impact of including non-CO_2 GHG emissions is significant - the net GHG outcome for North Coast '*conservation'* forests at year 200 is nullified, and it becomes negative for South Coast '*conservation*' forests. A more accurate calculation of the impact of fire on carbon balance requires better field data as well as modelling - using average fuel consumption rates will reduce the reliability of estimates of GHG emissions from fire (Gould and Cheney 2007)

The case studies illustrate that the abatement benefit would be enhanced by using a portion of the harvest residues for energy, as previously also demonstrated by Schlamadinger et al (1997). However, the recent revision of the RET regulations has disallowed native forest biomass as an eligible feedstock for generation of renewable energy.

The findings of the case studies will apply equally to plantations: management of plantations for production of wood products and bioenergy will deliver greater GHG benefits than unharvested plantings. However, the CFI presents major hurdles for plantations that are not applied to environmental plantings. Reforestation under the current policy is likely to be limited, without opportunity for financial returns from wood products or biomass.

Thus it appears that current policy fails to recognise the greater mitigation benefits of production forests over conservation forests, favouring instead the conversion of native forests from production to conservation management, and encouraging reforestation with not-for-harvest environmental plantings. This will limit the potential mitigation that *could* have been achieved by policy that acknowledged and supported production of wood products, and use of forest biomass for renewable energy. Abatement provided by forest sequestration, wood products and bioenergy has low cost compared with the costs of abatement through many other measures (McKinsey & Company 2008); therefore, current policy is likely to increase the cost of meeting abatement targets.

It has been suggested (Ajani 2008) that wood products from native forests could be replaced with products from the existing plantation estate, which would avoid the use of GHG-intensive non-wood products. However, the existing NSW plantation estate has not expanded at the anticipated rate, and the species grown are not suitable for replacing the products such as flooring and external decking, for which native forest timbers are used (See Appendix B; Table

B2). Therefore, if wood products are to replace native forest timbers these are likely to be imported. Much of Australia's hardwood imports are derived from south east Asia, predominantly Indonesia (Jaakko Poyry Consulting 2005). The rate of deforestation in Indonesia is about 1.1 Mha per year, and this is anticipated to increase (Ministry of Environment 2010). Indonesia's emissions due to deforestation, excluding emissions from peatland fire and oxidation, averaged about 850 Mt per year in the period 2000-2004 (Ministry of Environment 2010). Logging is a leading cause of deforestation and forest degradation in Indonesia (Ministry of Environment 2010; Blaser et al 2011). While the Indonesian Government is taking action to promote sustainable forest management (Ministry of Environment 2011) increased imports of tropical hardwood timber by Australia are likely to be supplied at least partially from deforestation.

Thus, the current policy direction, in which the CFI provides incentives for cessation of logging in native forests and environmental plantings, but raises barriers for participation by harvested plantations, is likely to result in increased net global emissions, due to the need for GHG-intensive alternative products and/or the import of wood products from unsustainably managed forests.

The case study findings demonstrate the importance of considering the whole system, from a life cycle perspective. Upstream, downstream and indirect effects need to be accounted for when assessing the GHG impacts of forest management decisions.

While it may be efficient to address environmental multiple objectives such as water management, biodiversity conservation and GHG management simultaneously, striving for synergistic outcomes, there are inevitably tradeoffs (Cowie et al 2007), and these should be made transparent and explicit. In devising policy measures to meet environmental and production objectives, government should be mindful of the need to provide clear and consistent policy, to encourage industry to develop low GHG products and energy systems including bioenergy (George 2012).

This paper quantifies the GHG outcomes of alternative forest management options, and concludes that significant tradeoffs and suboptimal outcomes may result from the implementation of the current and emerging Clean Energy policy. A manuscript which expands on the discussion on this paper has been submitted to the "Forests" journal (Special issue: The Role of Forests for Carbon Capture and Storage). It has been through the review process and when published will be available at http://www.mdpi.com/journal/forests.

6 Conclusion

The following key points are supported by the NSW DPI data, modelling and case studies:

- Young forests grow faster than old forests, so regular harvesting and regrowing can sequester more carbon in the long-term than not harvesting.
- Whilst for a specific site and point in time, the carbon stored in a forest reserved for conservation may be greater than in a harvested forest, when the full GHG balance is considered, multiple use production forests have significantly higher GHG abatement potential than conservation forests.
- Forest products store carbon and have lower process emissions than alternative products such as concrete and steel, so using wood products from multiple use production forests lowers emissions.
- Most native forest sawlogs are manufactured locally into high-value, long-term products such as flooring, decking and structural timber. Existing or near future plantations are unable to meet timber supply and quality needs.
- Irrespective of the end of life path for hardwood products (e.g., recycling, landfill or energy recovery systems) the GHG outcome from harvested forests will be positive compared with conservation forests.

- Managing the forests so that they grow productively is important for sustained mitigation benefit, as is ensuring that they are utilised in long-life products and can be utilised to reduce fossil-fuel emissions at the end of their service life.
- There is a need to explore opportunities associated with limited extraction of harvest slash (residues) for bioenergy (taking into account biodiversity and forest soil and nutrition needs). This limited extraction has potentially large GHG mitigation benefits associated with the abatement of emissions from coal-based electricity generation.
- Current policy directions in Australia towards returning more '*production*' forest estate into 'conservation' areas on the basis of perceived GHG benefits will have perverse outcomes in the long-term, resulting in increased GHG emissions.

When quantifying the climate change impacts of alternative forest management options it is critical to consider the whole forest system, including indirect impacts of management decisions in order to reduce the risk of perverse environmental outcomes.

Multiple-use, native forests could play a significant part in climate change mitigation when managed for production of wood and non-wood products including biomass for bioenergy.

The lack of incentive for expansion of plantation forests will limit the mitigation delivered through reforestation. It fails to provide incentive to develop the hardwood plantation industry, and for establishment of renewable energy and biochar industries.

Given the 'missed opportunity' from under-deployment of forestry-based options it is likely that the cost of mitigating GHG emissions will increase and targets may not be achieved.

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Appendix A

Positive list from the *Carbon Credits (Carbon Farming Initiative) Regulations 2011*

[This section is copied from the Explanatory Statement - Select Legislative Instrument 2011 No. 268; Page 19-]

<u>3.28 Specified offsets projects</u>

66. The positive list consists of the following kinds of projects:

(a) The establishment of permanent plantings since 1 July 2007

67. For these purposes, permanent plantings are plantings that are not harvested other than

(i) for thinning for ecological purposes; or

(ii) to remove debris for fire management; or

(iii) to remove firewood, fruits, nuts, seeds, or material that is to be used for fencing or as craft materials, if those things are not removed for sale; or

(iv) in accordance with traditional indigenous practices or native title rights.

68. This activity includes the establishment of native and non-native plant species, so long as they are not for harvest other than in the circumstances described.

- Ecological thinning is the removal of some plants to improve the health and condition of the vegetation or vegetation community. For environmental benefit, all ecological thinning should include the retention of all large standing trees (including dead trees), trees containing hollows and trees with signs of current or recent wildlife occupation.
- Removal of debris for fire management should only be undertaken to protect life, property and community assets from the adverse impacts of fire or to protect Aboriginal sites, historic places and culturally significant features known to exist within the project area or to improve the condition of the vegetation on site. Removal of debris for fire management should be undertaken in accordance with a fire management plan which has been developed for the project.
- Removal of firewood, fencing and craft materials, fruit, nuts and seeds can take place where they are for household use and not for sale.
- Removal of items for traditional Indigenous uses can also take place as part of this activity, and the resulting products can be sold. This is because it is not common to establish plantings for the purpose of growing materials for Indigenous crafts and products, such as the use of plants for food, medicine, tools, utensils, weapons and ceremonial purposes. Traditionally, these products are harvested from naturally occurring bushland rather than planted.

69. The establishment of most types of 'not for harvest' permanent plantings has been determined to be not common practice and eligible for inclusion in the CFI. This is

because there are significant establishment costs with no commercial benefit and it is therefore likely that the uptake is very low in most circumstances.

70. ‘Permanent plantings’ do not include ‘landscape plantings’. Landscape plantings are plantings in an urban centre or locality as follows:

(a) in a residential place (for example, in a backyard, park or on a nature strip);

(b) on the grounds of a sporting facility, factory or other commercial facility;

(c) on the grounds of a hospital, school or other institution;

(d) in a car park or cemetery.

71. ‘Urban centres’ are defined by the Australian Bureau of Statistics as population clusters of 1,000 or more people with a density of at least 200/km^2. A ‘locality’ is described as containing a non-farm population of 200 - 999 people, with a minimum of 40 occupied non-farm dwellings with a discernible urban street pattern and a discernible nucleus of population. Establishing landscape plantings in urban centres and localities is considered to be common practice.

72. Most commercial plantation activities and certain other types of plantings, such as orchards and plantings for livestock fodder are also common and are not included in the positive list.

(b) The following transitioning carbon offset projects:

(a) a forestry project accredited under the Commonwealth Government’s Greenhouse Friendly™ initiative;

(b) until 1 July 2012, a waste diversion project accredited under the Commonwealth Government’s Greenhouse Friendly™ initiative;

(c) permanent plantings accredited under:

(i) the New South Wales Government’s Greenhouse Gas Reduction Scheme; or

(ii) the Australian Capital Territory Government’s Greenhouse Gas Abatement Scheme; and

(d) permanent plantings established before 1 July 2007 for which there is documentary evidence, to the satisfaction of the Administrator, that the primary purpose of the plantings was generation of carbon offsets.

73. Certain activities covered by non-CFI carbon offset schemes can transition to the CFI.

74. The Australian Government’s Greenhouse Friendly™ initiative accredited a number of projects between 2001 and 2010. More information about the Greenhouse Friendly™ initiative can be found on the Department’s website at www.climatechange.gov.au/greenhousefriendly

75. The NSW Greenhouse Gas Reduction Scheme and the ACT Greenhouse Gas Abatement Scheme (GGAS) have been operating since 2003. More information on these two schemes can be found at http://greenhousegas.nsw.gov.au/.

76. Only land sector and legacy landfill waste Greenhouse Friendly and GGAS projects can transition to the CFI; energy efficiency and other types of projects are not within the scope of the CFI.

77. Greenhouse Friendly waste diversion projects will only be eligible until 1 July 2012 as emissions from waste generated after this date will be covered by the carbon pricing mechanism. Greenhouse Friendly landfill gas flaring projects are dealt with separately under the activity listed as '*the capture and combustion of methane from waste deposited in a landfill facility before 1 July 2012*'.

78. Other plantings have been established specifically for carbon sequestration outcomes, typically in anticipation of participating in Greenhouse Friendly, but were not accredited before the scheme ceased operating. Where there is concurrent documentary evidence that demonstrates that these projects were established primarily for generation of carbon offsets, these projects are also able to transition to the CFI. The evidence must include the registration of carbon rights, show that the plantings were entirely privately funded and may also include contracts for the sale of offsets.

(c) The human-induced regeneration, on or after 1 July 2007, of native vegetation, on land that is not conservation land, by:

(i) the exclusion of livestock; or

(ii) the management of the timing and the extent of grazing; or

(iii) the management, in a humane manner, of feral animals; or

(iv) the management of plants that are not native to the project area; or

(v) the cessation of mechanical or chemical destruction, or suppression, of regrowth;

79. 'Conservation land', for these purposes means an area that is both owned and managed by the Commonwealth, a State or a Territory government for biodiversity conservation, such as a national park (regulation 3.27).

80. Assisted regeneration is an alternative to adding seed or seedlings to a site. Instead, seed stores in the soil or from remnant plants (e.g. trees, shrubs, grasses), and/or rootstock and lignotubers already present at the site, are encouraged to sprout or germinate, usually in areas where regrowth has been routinely suppressed or on cleared areas around existing remnant vegetation. The activity is the management or removal of external pressures that prevent regrowth from occurring.

81. Undertaking these measures in areas that are both owned and managed for biodiversity conservation purposes by the Commonwealth or a state or territory government is excluded from this activity because taking action to encourage regeneration is considered to be common practice in these areas. This exclusion does not apply to areas that are privately or Indigenous owned or managed, as these areas are not commonly managed to promote regrowth.

(d) The restoration on land that is not conservation land, of natural wetlands that had been drained

82. 'Wetlands', for these purposes, are areas of marsh, fen, peatland or water, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

83. Wetlands, especially peatlands, are a significant store of carbon on land. Carbon accumulates in wetland soils because of high rates of plant productivity and low rates of decomposition in these ecosystems. The draining and degradation of wetlands turns them into a net source of greenhouse gas emissions. The restoration of damaged wetlands can halt emissions of carbon dioxide and even reverse them, causing carbon removal from the atmosphere. Emissions of nitrous oxide and methane can also be

reduced or halted by restoration. However, some wetlands also produce methane - a potent greenhouse gas.

(e) The application of biochar to soil

84. Biochar is charcoal created by pyrolysis of biomass. The key chemical and physical properties of a biochar are greatly affected by the type of material being used and the conditions of the pyrolysis process (i.e. temperature and time).

85. When converted to biochar, organic materials that would otherwise emit carbon dioxide as they decompose naturally are oxidised and converted into a stable solid form of carbon – most of which will remain in the soil for at least hundreds of years, resulting in a net decrease of atmospheric carbon.

86. This activity credits the application of biochar to soil. The production of biochar alone is not currently an eligible CFI activity.

(f) The capture and combustion of methane from livestock manure

87. The collection and storage of manure waste in uncovered lagoons leads to the production of methane. This is caused by the anaerobic decomposition of the organic matter in the waste which, in the absence of any abatement activity, is emitted to the atmosphere. This abatement activity is the capture and combustion of methane from the decomposition of livestock manure which would otherwise be released into the atmosphere.

88. Lagoons containing livestock manure waste are covered to prevent release of biogas (containing methane) into the atmosphere; the emitted gas is collected and the methane component of the gas is combusted to convert it to carbon dioxide which is a less potent greenhouse gas. This carbon dioxide is released to the atmosphere.

89. The activity does not cover the capture and combustion of methane from abattoir waste, meat processing waste, or other processing activities.

(g) Early dry season burning of savanna areas greater than 1 km^2

90. Early dry season fires are characterised by low intensity, a high degree of patchiness, a greater propensity to extinguish spontaneously, and reduced total fuel consumption. Late dry season fires are characterised by high intensity, low levels of patchiness, a greater propensity to spread, and high total fuel consumption.

91. The result of a shift from predominantly late to predominantly early dry season fires is a net reduction in fuel consumed per unit area and area burnt. This generates a corresponding reduction in methane and nitrous oxide emissions released by fire per unit area.

92. Burning of patches of savanna of less than one square kilometre is commonly undertaken as asset protection and is not covered by the activity description.

(h) The reduction of methane emissions through the humane management of feral goats, feral deer, feral pigs or feral camels

93. Animals produce methane as a by-product of digesting plant material. Reducing the numbers of feral goats, deer, pigs and camels would result in a reduction of emitted methane.

94. Although hunting of some of these species is common in certain circumstances, for example in hunting reserves, it is not common practice to undertake hunting activities or other management of these species in a manner that will effectively reduce the population. To receive credits, the activity would need to reduce emissions below the baseline determined in accordance with the relevant methodology.

95. The management of feral goats, feral deer, feral pigs or feral camels must be undertaken in a humane manner. In most instances this will be in accordance with a relevant State or Commonwealth code of practice for the humane management of pest species.

(i) The reduction of emissions from ruminants by manipulation of their digestive processes

96. Enteric methane produced during rumen fermentation in ruminants such as sheep and cows accounts for two thirds of Australia's agricultural emissions, and 12% of national emissions. Methane and nitrous oxide are significant greenhouse gases as they are many times more potent than carbon dioxide over a 100 year period.

97. There are a number of new technologies currently under development to reduce methane emitted by ruminants. Depending on research outcomes, this may occur through the use of vaccinations, feed additives and the manipulation of an animal's diet.

(j) The application of urease or nitrification inhibitors to, or with, livestock manure or fertiliser

98. Nitrous oxide emissions can occur from animal manure and urine as well as nitrogenous fertilisers when some of the urea that they contain is lost to the atmosphere. Inhibitors in the form of chemical additives are available to slow the chemical processes driving these emissions and in so doing improve plant uptake and reduce atmospheric loss.

99. Urease inhibitors reduce the initial atmospheric loss of surface applied urea by reducing the conversion of urea to ammonium. Nitrification inhibitors slow the subsequent process of converting ammonium to nitrate, and hence to nitrous oxide in soil which is then released into the atmosphere. Both of these inhibitors can be applied directly to solids, pastures or incorporated into nitrogenous fertilisers to reduce emissions of nitrous oxide from soils.

(k) The capture and combustion of methane from waste deposited in a landfill facility before 1 July 2012

100. Only emissions from waste deposited in a landfill before the commencement of Australia's carbon pricing mechanism on 1 July 2012 (legacy waste) are covered by the CFI. The carbon price will not apply to emissions from waste deposited prior to 1 July 2012 because landfill operators cannot recover the cost of emissions from waste deposited in the past.

101. Landfill gas is passively emitted due to the anaerobic decomposition of the organic components of waste within a landfill. Landfill gas combustion converts the methane component of landfill gas to carbon dioxide, a less potent greenhouse gas.

102. Waste continues to decompose and emit greenhouse gas for many years after being deposited in landfill. Landfill operators can continue to earn CFI credits after 2012 for reducing emissions that are attributable to legacy landfill waste.

Division 3.12—Types of projects

<u>3.35 Kyoto offsets projects</u>

103. This regulation specifies kinds of offsets projects that are Kyoto offsets projects for the purposes of the CFI Act.

104. If a project is a Kyoto offsets project, and the reporting period ends before the Kyoto abatement deadline, then any ACCUs issued in relation to the project will be Kyoto ACCUs. Kyoto ACCUs can be exchanged for Kyoto units (section 157). They will also be eligible for surrender under the carbon pricing mechanism.

105. Only certain anthropogenic emissions sources and carbon storage is counted towards Australia's emissions reduction commitment under the Kyoto Protocol. Eligible activities are identified in the Annex to Decision 16/CMP.1 of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol. This regulation, together with the activities recognised in paragraphs 55(1)(a) and (b), reflects this decision.

106. This regulation provides that the following types of projects are Kyoto offsets projects:

- the direct human-induced conversion of non-forested land to a forest through planting or seeding if the land was not forest on 31 December 1989. This does not extend to cyclical natural regrowth on the land;
- avoiding deforestation; and
- establishing a planting on land that was subject to deforestation through seeding, planting or assisted regeneration.

107. Other types of Kyoto offsets projects are referred to in paragraphs 55(1)(a) and (b) of the CFI Act.

Negative list: excluded offsets specified in the *Carbon Credits (Carbon Farming Initiative) Regulations 2011*

[This section is copied from the Explanatory Statement - Select Legislative Instrument 2011 No. 268; Page 25-]

<u>3.36 and 3.37 Excluded offsets projects</u>

108. Offsets projects are not eligible to generate ACCUs if they are 'excluded offsets projects' (paragraph 27(4)(m) of the CFI Act). A project is an excluded offsets project if it is of a kind specified in regulations made under subsection 56(1) of the CFI Act. These regulations are known as the 'negative list'.

109. The negative list identifies activities that are ineligible in circumstances where there is a material risk that the activity will have a material adverse impact on one or more of the following: the availability of water; the conservation of biodiversity; employment; the local community; and land access for agricultural production.

110. The potential for adverse impacts from projects is mitigated under the CFI through several mechanisms, including the negative list. The negative list is designed to address residual risks that are not addressed through existing regulations and planning regimes.

111. Projects must also comply with environmental, water and planning regulations at all levels of government and have all necessary approvals before they can receive credits under the CFI. Furthermore, project proponents must take account of regional natural resource management (NRM) plans. The Government's Clean Energy Future Plan will provide $44 million over 5 years to help regional NRM organisations to develop plans to a consistently high standard. Regional NRM plans will be used to provide guidance to landholders about the type and location of carbon farming projects that could deliver environmental and social benefits.

112. Like the positive list, the negative list will grow over time as new methodologies are developed and risks are identified. Some activities will not pose risks when undertaken by only a few landholders, but would have impacts when undertaken on a broad scale. Activities such as these may not be included on the list when first approved, but would be added before they reached that threshold where adverse impacts could occur.

113. Anyone can propose the addition of an activity to the negative list, the removal of an activity from the negative list or the modification of an activity on the negative list. Further information on the proposal process is available on the Department of Climate Change and Energy Efficiency website.

114. The negative list consists of the following activities:

(a) Projects that were mandatory at 24 March 2011

115. Activities that are specifically mandated by government regulations are not additional (paragraph 41(1)(b)). Projects that were required by law at 24 March 2011, when the CFI Bill was introduced to the Parliament, are on the negative list to remove the incentive to repeal legal requirements in order to circumvent this part of the additionality test.

116. The CFI can credit abatement from activities that go beyond what is required by law, for example flaring more landfill gas than is required to meet license conditions and comply with local government regulations. If legal requirements are eased or repealed after 24

March 2011, the CFI will still only credit abatement beyond what was required before that date. This is to remove any perverse incentive to weaken regulation of landfill facilities.

(b) Planting a species in an area where it is a known weed species

117. Planting weed species will have adverse environmental impacts and will be excluded from participation in the CFI. The regulations define known weed species with reference to existing weed lists (regulation 3.34).

(c) Establishment of a forest as part of a forestry managed investment scheme

118. This provision excludes from the CFI the establishment of new forests as part of a forestry managed investment scheme.

119. Division 394 of the *Income Tax Assessment Act 1997* sets out the rules about tax deductions for contributions to forestry managed investment schemes. The aim of this Division is to encourage the expansion of commercial plantation forestry in Australia through the establishment and tending of new plantations for felling.

120. These types of projects are excluded to ensure the additive effect of the forestry managed investment scheme incentives and the CFI does not have adverse impacts on access to agricultural land, communities and employment.

(d) Cessation or avoidance of harvest of a plantation forest

121. Plantation forests are established for the purpose of harvest and are not designed to be permanent plantings. Retention of these forests will not be eligible to earn credits under the CFI.

(e) and (f) Establishment of vegetation on land subject to clearing of native forest or draining of a wetland:

- *within 7 years of application as an eligible offsets project; or*
- *within 5 years of the application as an eligible offsets project where there is a change in land ownership since the event; or*
- *under any circumstances, where the clearing of native forest or draining of a wetland was illegal.*

122. This exclusion is to remove the incentive to clear existing forest to make way for new carbon planting projects. The 7-year period is intended to provide a disincentive to clear land for carbon projects, but also to recognise that landholders may clear land for other purposes but then wish to convert back to forested land. The shorter 5-year period is to ensure new land owners who wish to undertake a project on land that was cleared or drained by the previous land owner are not penalised. The provision also excludes projects on land that was illegally cleared or drained, regardless of the time since that event to ensure that the CFI provides no incentive for illegal land clearing.

123. The continued suppression of regrowth by grazing, after the original clearing event, is generally not considered to be clearing of native forest.

124. 'Native forest' is defined in the CFI Act. This means that projects established on land that has been cleared of weeds or of a harvest plantation are not excluded from the scheme. Methodologies will contain rules for calculating project baselines, including the

circumstances in which pre-existing vegetation must be deducted from abatement estimates.

125. The clearing of other types of vegetation may be included on the negative list in the future as detailed information about location and condition of those vegetation types becomes available.

Planting trees in an area that receives more than 600mm long-term average annual rainfall, except when:

- *the project is a permanent planting that is also an environmental planting; or*
- *the project contributes to the management of dryland salinity; or*
- *the project occurs in an area where the relevant jurisdiction has been determined by the National Water Commission as meeting its National Water Initiative commitment to manage interception by plantations; or*
- *the project holds a suitable water access entitlement for the life of the project; or*
- *where it is not possible to obtain a water access entitlement, and the CFI Administrator is satisfied that the project causes no material impact on water availability.*

126. Forests established in high rainfall areas can have adverse impacts for other water users and environmental flows due to the amount of water they intercept.

127. Long-term average annual rainfall is determined by using the CFI rainfall map. This map shows long-term average annual rainfall using data collected by the Bureau of Meteorology for the period from at least 1921 to 1995 as processed by the Department, and is available at http://ncat.climatechange.gov.au/cfirefor/.

128. Projects that establish environmental plantings or contribute to the mitigation of dryland salinity are not excluded by this provision. Salinity Guidelines, setting out the requirements for demonstrating that a project will help to mitigate dryland salinity, are available on the Department's website at www.climatechange.gov.au. Information provided in accordance with the Guidelines must be verified by either the Chief Executive Officer of the relevant regional NRM organisation or an appropriately qualified, registered Greenhouse and Energy Auditor.

129. Projects that are in an area where the National Water Commission is satisfied that the relevant State or Territory government has adequately implemented its National Water Initiative commitment to manage water interception by plantations are not excluded. The project would need to meet all other scheme eligibility requirements, including being compliant with the State or Territory provisions to manage water interception by plantations. If the National Water Commission does not continue beyond June 2012, then this provision will be amended or a new provision will be put in place.

130. If a project is in an area where the National Water Commission is not satisfied with how the relevant State or Territory is managing water interception by plantations, then the project proponent will need to hold a water access entitlement to offset the water intercepted by the forest. This water access entitlement will need to be held from two years after the trees were planted for the life of the project. This is because for the first two years after a plantation is established, the trees do not intercept as much water as they do after this time.

131. The regulations specify that the volume of water required to offset the water intercepted by the forest is to be calculated using a formula in the regulations. This formula is based on the Table A1. The regulations also specify the characteristics that the water access entitlement must have. The water access entitlement must be for water in the project area, and the water to which the water access entitlement relates cannot be used for any other purpose other than to offset the water intercepted by the forest. This means it cannot be used to irrigate the forest or be stored by the project proponent.

Table A1 Volume of water required per hectare per year for the life of the project

Long-term average annual rainfall	**Volume of water required as an offset per hectare per year for the life of the project**
600-700mm	0.9 ML
700-800mm	1.2 ML
800-900mm	1.5 ML
900-1000mm	1.8 ML
greater than 1000mm	2.1 ML

132. In some areas of Australia it is not possible to obtain a water access entitlement because the relevant State or Territory has no framework in place to issue one. If a project is established in one of these areas, then the project will not be excluded by the negative list if the CFI Administrator is satisfied that there is no material impact on water availability for existing users.

Definition of native forests under the *Carbon Credits (Carbon Farming Initiative) Act 2011*

[This section is copied from the Act, 8 December 2011; Part 1 Section 5 Page 14]

native forest means an area of land that:

(a) is dominated by trees that:

- (i) are located within their natural range; and
- (ii) have attained, or have the potential to attain, a crown cover of at least 20% of the area of land; and
- (iii) have reached, or have the potential to reach, a height of at least 2 metres; and

(b) is not a plantation.

It is immaterial whether any of the trees have been established with human assistance following any of the following events:

(c) flood;

(b) bushfire;

(d) drought;

(e) pest attack;

(f) disease;

(g) an event specified in the regulations.

The regulations may provide that, for the purposes of this definition, ***trees*** and ***crown cover*** have the respective meanings given by the regulations.

Meaning of wood waste and energy crops under the *Renewable Energy (Electricity) Regulations 2001* (13 December 2011).

[This section is copied from the Part 2, Division 2.2. Regulation 8; Page 18]

8 Meaning of *wood waste*

For section 17 of the Act, ***wood waste*** means:

(a) biomass:

(i) produced from non-native environmental weed species; and

(ii) harvested for the control or eradication of the species, from a harvesting operation that is approved under relevant Commonwealth, State or Territory planning and approval processes; and

(b) a manufactured wood product or a by-product from a manufacturing process, other than a product or a by-product that is derived from biomass from a native forest; and

(c) waste products from the construction of buildings or furniture, including timber off-cuts and timber from demolished buildings; and

(d) sawmill residue, other than sawmill residue derived from biomass from a native forest.

Examples for paragraph (b)

Packing case, pallet, recycled timber, engineered wood product (including one manufactured by binding wood strands, wood particles, wood fibres or wood veneers with adhesives to form a composite).

9 Energy crops (Act s 17)

(1) For section 17 of the Act, biomass from a plantation is not an energy crop unless all of the following apply to it:

(a) it must be a product of a harvesting operation (including thinnings and coppicing) approved under relevant Commonwealth, State or Territory planning and approval processes;

(b) it must be biomass from a plantation that is managed in accordance with:

(i) a code of practice approved for a State under regulation 4B of the Export Control (Unprocessed Wood) Regulations; or

(ii) if a code of practice has not been approved for a State as required under subparagraph (i), Australian Standard *AS 4708—2007 — The Australian Forestry Standard*;

(c) it must be taken from land that was not cleared of native vegetation after 31 December 1989 to establish the plantation.

(2) For section 17 of the Act, biomass from a native forest is not an energy crop.

Meaning of wood waste under previous *Renewable Energy (Electricity) Regulations* 2001

[This section is copied from the Part 2, Division 2.2. Regulation 8; Pages 18-19; 1 January 2011 SLI 2010 No. 321]

8 Meaning of *wood waste*

(1) For section 17 of the Act, ***wood waste*** means:

(a) biomass:

(i) produced from non-native environmental weed species; and

(ii) harvested for the control or eradication of the species, from a harvesting operation that is approved under relevant Commonwealth, State or Territory planning and approval processes; and

(b) a manufactured wood product or a by-product from a manufacturing process; and

(c) waste products from the construction of buildings or furniture, including timber off-cuts and timber from demolished buildings; and

(d) sawmill residue; and

(e) biomass from a native forest that meets all of the requirements in subregulation (2).

Examples for paragraph (b)

Packing case, pallet, recycled timber, engineered wood product (including one manufactured by binding wood strands, wood particles, wood fibres or wood veneers with adhesives to form a composite).

(2) Biomass from a native forest must be:

(a) harvested primarily for a purpose other than biomass for energy production; and

(b) either:

(i) a by-product or waste product of a harvesting operation, approved under relevant Commonwealth, State or Territory planning and approval processes, for which a high-value process is the primary purpose of the harvesting; or

(ii) a by-product (including thinnings and coppicing) of a harvesting operation that is carried out in accordance with ecologically sustainable forest management principles; and

(c) either:

(i) if it is from an area where a regional forest agreement is in force — produced in accordance with any ecologically sustainable forest management principles required by the agreement; or

(ii) if it is from an area where no regional forest agreement is in force — produced from harvesting that is carried out in accordance with ecologically sustainable forest management principles that the Minister is satisfied are consistent with those required by a regional forest agreement.

(3) For subparagraph (2) (b) (i), the primary purpose of a harvesting operation is taken to be a high-value process only if the total financial value of the products of the high value process is higher than the financial value of other products of the harvesting operation.

(4) In this regulation:

ecologically sustainable forest management principles means the following principles that meet the requirements of ecologically sustainable development for forests:

(a) maintenance of the ecological processes within forests, including the formation of soil, energy flows, and the carbon, nutrient and water cycles;

(b) maintenance of the biological diversity of forests;

(c) optimisation of the benefits to the community from all uses of forests within ecological constraints.

high-value process means the production of sawlogs, veneer, poles, piles, girders, wood for carpentry or craft uses, or oil products.

Appendix References

Carbon Credits (Carbon Farming Initiative) Act 2011, Australian Parliament (8 December 2011), http://www.comlaw.gov.au/Details/C2011A00101

Carbon Credits (Carbon Farming Initiative) Regulations 2011, Explanatory Statement. Select Legislative Instrument 2011 no. 268, http://www.comlaw.gov.au/Details/F2011L02583/Download

Renewable Energy (Electricity) Regulations 2001, Australian Parliament (13 December 2011), http://www.comlaw.gov.au/Series/F2001B00053

Appendix B

Forests in Australia and New South Wales

Australia has about 4 % of the world's forests, comprising 147.4 million hectares (Mha) of native forest and 2.0 Mha of forestry plantations, covering about 19 % of the continent (Figure B1, ABARES 2011). Agricultural development has resulted in the removal of approximately 13 % of Australia's native vegetation (woodlands and forests) over the last 200 years, with clearing concentrated in the woodlands (Australian Greenhouse Office 2000).

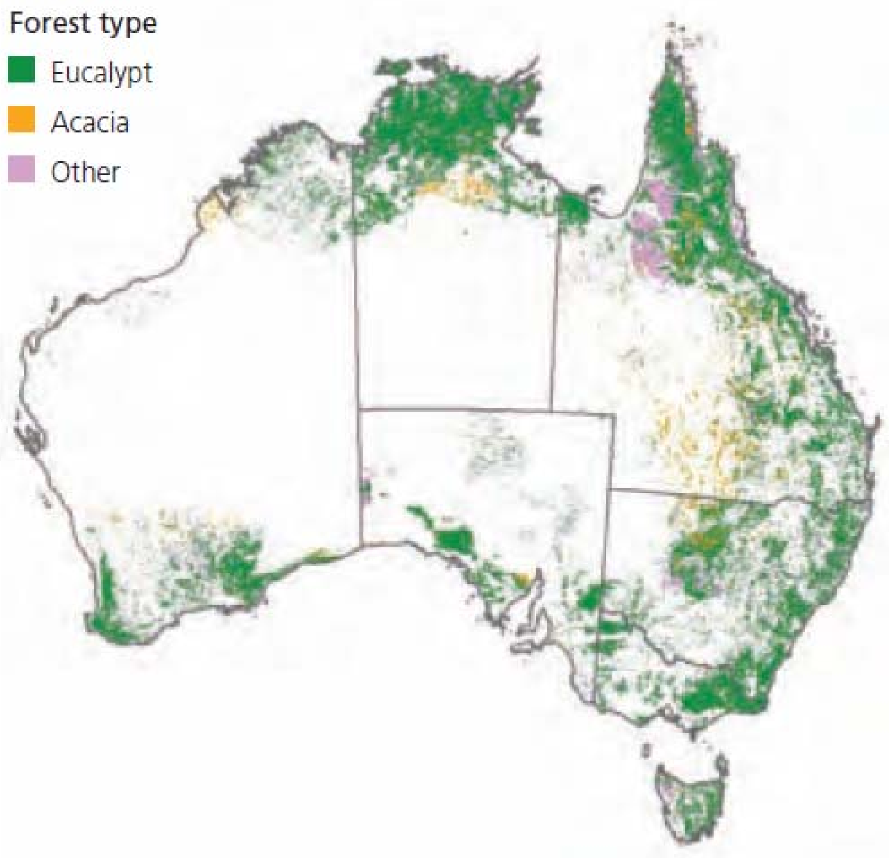

Figure B1 Distribution of Australia's forest types (ABARES, 2011).

Native Forests

Concern over the clearing of eucalypt tall forests and open forests in the early twentieth century saw the development of crown reserves to protect these forest types, either as national parks or as production forests, and the establishment of state-based forestry departments. During the twentieth century the estates transferred to forestry departments were harvested for a range of wood products.

By the end of the twentieth century the management of Australia's forests was guided by the 1992 National Forest Policy Statement (NFPS). Under the NFPS, ecologically sustainable forest management is implemented through management plans that incorporate sustainable yield harvest practices. There are 10 twenty-year management plans, called Regional Forest Agreements (RFAs) for the conservation and sustainable management of Australia's native forests covering Western Australia, Victoria, Tasmania and New South Wales. The RFAs were negotiated and commenced from 1996 – 2001 and specify agreements for wood harvesting and other commercial and non commercial uses of forest areas, including conservation reserves and leased Crown land. Public and private native forests in Australia that are managed for wood production must meet standards established in the RFAs.

Over the last 20 years various state and federal initiatives have converted multiple use production forests (managed for production and other benefits) into conservation areas (Table B1). Since the RFAs were agreed, State Governments in New South Wales, Victoria and Western Australia have made additions to their formal nature conservation reserve systems. For example, in New South Wales, the *Brigalow and Nandewar Community Conservation Area Act 2005* added 352,000 ha of multiple use production forest to nature conservation reserves. In Tasmania recent increases in reserved forest areas include the transfer of some 430,000 ha of multiple use production forests in 2012[7].

Table B1 Land use change in Australia from 1992 – 2006 (Leslie et al 2011). The area of conservation of forests has increased and the area for production forestry decreased.

Land use (km^2)	1992–93	1996–97	2000–01	2005–06
Conservation and natural environments	2 609 700	2 619 500	2 674 900	2 821 300
Multiple use production forestry	161 500	160 500	151 800	138 200
Grazing	4 551 100	4 510 700	4 437 200	4 287 600
Cropping	193 300	225 300	250 300	268 200
Horticulture	4 000	4 100	4 700	5 000
Intensive uses (incl. some ag land)	22 900	22 700	24 100	30 800
Water	133 200	133 200	133 200	125 000
No data	2 200	1 900	1 600	1 700
Total area				*7 677 800*

The area available for wood production within the defined RFA regions has therefore declined. In NSW and Victoria the multiple-use forest area (available for wood production), declined by 67 and 25% respectively, by 2002[8]. By 2006, areas managed as multiple-use forests in Tasmania and Western Australia declined by 32 and 24%, respectively.

Across Australia approximately 13.6 Mha have been transferred from multiple-use to the conservation reserve network under the RFA process, bringing the total area of forests in nature conservation reserves to 23 Mha (ABARES 2011). Just over 5 Mha of publicly owned forests remain for multiple-use in the RFA regions (Davidson et al 2008) and a total of 9.4 Mha across Australia. In New South Wales public native forests managed for multiple-use declined from 2,600,000 ha in 1990 to 1,100,000 ha by 2008. Additional forests are conserved within leasehold land, multiple-use forest and private land (through covenants or other management arrangements). The current forest areas and types managed by Forests NSW are shown in Figure B2. Codes of forest practice and other regulatory mechanisms also require conservation of forest biodiversity and protection of other values, such as water quality in forests available for wood production.

[7] http://www.environment.gov.au/minister/burke/2012/mr20120113.html ; accessed 24/01/2012

[8] data for 2006 were not available for these States at the time of writing

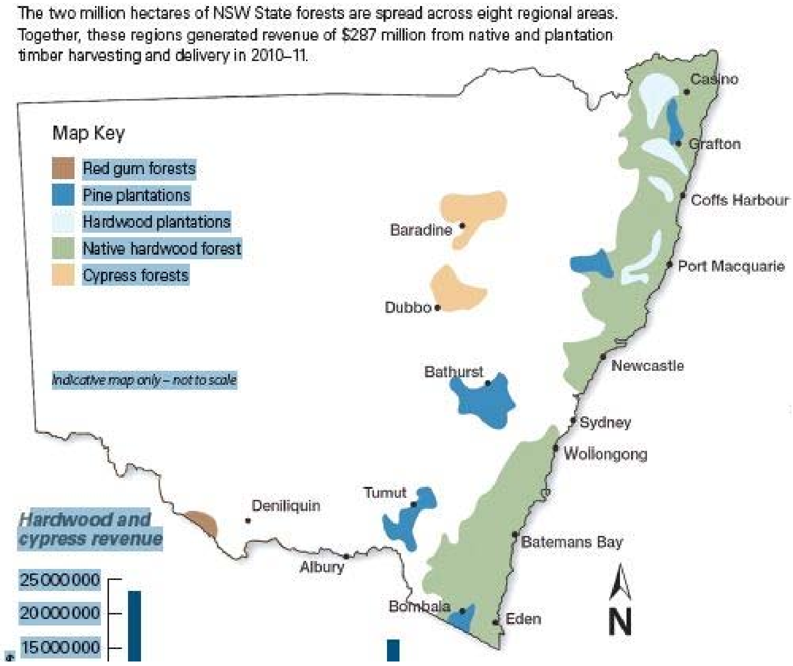

Figure B2 Forest estate of NSW.

Plantations

Plantations were identified as an important opportunity for Australia to meet wood supply needs, especially as access to native forests diminished. The ‘Plantations for Australia: The 2020 Vision’ was launched in 1997 with Federal and State Government support and significant commitment from industry, aiming to treble the plantation estate, from 1.1 Mha in 1996 to 3 Mha by 2020. The revised 2020 Vision has 16 actions broadly grouped into the following strategic elements[9]:

1. better regional planning and a comprehensive policy approach;
2. establishment of an appropriate legislative environment;
3. promotion of investor confidence, research and development and skills development;
4. improvement in stakeholder engagement and identification of environmental benefits and services;
5. understanding future developments and opportunities to maintain investment.

From 1995 – 2009 the area of plantation forests in Australia has grown by from ≈1.2 Mha to 2.0 Mha as shown in Figure B3. Following the increase in uncertainty regarding the interpretation of Federal Government legislation and more recently the impact of the failing Managed Investment Schemes (MIS) sector the area of new plantations in NSW has declined dramatically (Table B2).

[9] Adapted from http://www.daff.gov.au/forestry/plantation-farm-forestry/2020; accessed 4 Feb 2012.

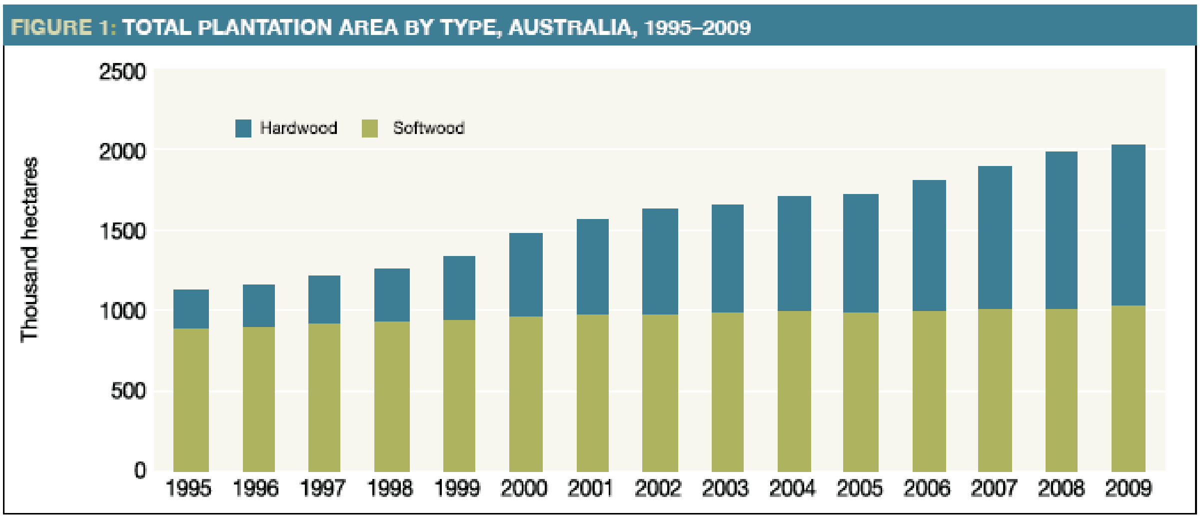

Figure B3 Area of hardwood and softwood plantation forests in Australia from 1995 – 2009 (Gavran & Parsons 2010).

Table B2 New plantation areas authorised through the NSW Plantation & Reafforestation Act from 2006-07 to 2010-11.

Year	Softwood	Hardwood	Cabinet Timbers	Environmental plantings	Total
2006-07	10 314	17 218	2 195	3 942	33 669
2007-08	10 636	19 205	581	2 050	32 472
2008-09	1 550	10 174	2 680	911	15 315
2009-10	978	2 655	641	9 402	13 676
2010-11	1 265	1 199	172	2 866	5 502

Commonwealth and State governments, while recognising the need for plantation expansion to supply wood demands, have sought to limit any negative impacts that could result from plantation expansion. Reduced water availability resulting from interception by plantations is recognised as a potential issue. Through the National Water Initiative, State and Federal governments committed to identify significant interception activities for all water systems (National Water Commission 2010). For fully allocated systems, proposals for additional significant interception activity will require a water access entitlement, whilst non-fully allocated water systems will require the calculation of a threshold level of interception above which a water access entitlement would be mandated for significant interception activity. The National Water Commission has produced a baseline assessment (National Water Commission 2010) of national unaccounted water use in order to identify key interception activities, their extent and respective jurisdiction, and prioritise their management. This first estimate of unaccounted water use quantified forestry plantations as using approximately 2000 gigalitres (GL) a year. The CFI regulations include specific reference to water use and are discussed in more detail in Section 2.3.

Forestry tends to be an unattractive investment due to the long period between investment and return. Managed Investment Schemes (MIS) have facilitated investment in plantation expansion, by providing a vehicle for individuals to share the investment. Forestry MIS is collective investment in a common forestry enterprise comprising plantation forestry projects that reach harvest in 8-25 years. MIS policy is primarily focused on financial oversight and regulation rather than environmental issues, although some environmental factors are considered, such as water licence requirements. By the mid-2000s, the MIS plantation industry had established over half a million hectares of plantations in Australia (26% of the Australian plantation estate) representing more than $3 billion in investment (Underwood 2007).

Following the collapse in 2009 of Timbercorp and Great Southern, which accounted for about half of the forestry area under MIS management, it has been argued that Forestry MIS tax incentives distorted the investment market, creating an uneven playing field for traditional agricultural enterprises (Parliamentary Joint Committee on Corporations and Financial Services 2009). Further, the Senate Select Committee on Agriculture and Related Industries considered tax concessions for Forestry MIS as undesirable due to their distorting effect on investment decisions and recommended reconsidering the tax advantages applied to investments in MIS (Australian Senate 2010)[10].

Wood production in NSW and Australia

About 2.6 m3 of sawlogs are harvested from native forests and plantations in NSW each year. While softwood plantations are almost exclusively utilised for structural purposes in domestic housing, hardwoods have a wide range of uses. Table B3 shows how the product mix has changed since the mid-1990's for hardwood sawlogs: whereas in 1995/96 only 29% of products from hardwood sawlogs were highly value-added products, such as floorboards, by 2008/2009 this had risen to 62% (Forests NSW 2010).

Table B3. Wood products produced from native forests in NSW. 'Value-added products' are highlighted (Forests NSW 2010)

Product	1995/96	2000/01	2004/05	2008/09
Dry structural	21%	21%	10%	7%
House framing	30%	26%	17%	14%
Fencing/landscape	8%	5%	7%	8%
Pallets	12%	8%	9%	9%
Non-Value Added Sub- Total	71%	60%	43%	38%
High strength structural*	2%	1%	2%	2%
Floorboards*	22%	34%	47%	48%
Joinery/furniture*	1%	2%	3%	6%
Decking & panelling*	4%	3%	5%	6%
Value Added* Sub- Total	29%	40%	57%	62%
Total	100%	100%	100%	100%

The demand for hardwood products in Australia has decreased since the mid-1990s, with consumption of sawn hardwood decreasing from 1.55 M m^3 in 1995/96 to 1 M m^3 in 2008/09 as uses have changed. At the same time, the availability of local and imported softwood timber has increased as plantations in Australia and New Zealand established in the 1960s matured. However the reduction in use of hardwoods is not a reflection of substitution from softwoods; in fact, due to inherent differences in quality (superior strength, durability and beauty of hardwoods)

[10] http://www.aph.gov.au/senate/committee/agric_ctte/food_production/report/report.pdf; 2010.

there is little competition between the sectors. This reduction is primarily due to increased substitution from engineered woods used for structural applications (e.g. LVL, I-beams) and increased use of concrete slab in sub-flooring applications.

The main application for sawn and panel forest products in Australia is the residential market. Approximately 75% of the sawn timber is used for residential purposes (BIS-Shrapnel 2008), with about 80% of the sawn pine used for framing applications in houses and approximately 50% of the sawn hardwood used as sub-flooring and fencing (Ximenes & Gardner 2005).

Eucalypt plantations currently contribute only 15-20% of the total volume of hardwood sawlogs produced from State forest and only 6-13% of the highest quality logs and power poles (Forests NSW 2010). The future production of sawlogs from plantations established under Managed Investment Schemes (MIS) is currently uncertain. The estimates of potential sawlog yield and timing reported by Parsons et al (2007) for the North Coast and New England tablelands regions are deemed optimistic by industry, as they comprise less-preferred species and lack ongoing management. The likely outcome is that much of this estate will be utilised for pulpwood. FNSW projections for the current wood supply agreement period, which continues until 2023, anticipate no significant increase in the proportion of plantation sawlog and power pole production from the State forest estate (Forests NSW 2010).

Whilst production of native forest hardwood logs in Australia has declined from 4M to 2.5M tonnes since 1995 as forest protection has increased through establishment of RFAs, imports of sawn tropical hardwoods have tended to increase. Tropical hardwood imports reached a peak of 146,000 m3 of sawn product in 2004/2005, before declining again to around 100,000 tonnes with the global financial crises (ABARES 2011).

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Appendix C

Explanatory information for case studies

C1 Background information for the case study sites located in northern and southern NSW coastal regions, forest growth and selective harvest

Forest types

Three forest zones (Coopernook, Kendall and Wauchope Coastal) dominated by mature regrowth blackbutt (*Eucalyptus pilularis*) established from harvest and timber stand improvement in the 1950's and 60's were selected for the North Coast forests (Figure C1). Blackbutt is the most commercially important species in NSW (Florence 1996). Seven forest yield associations (Coastal Moist Forest, Spotted Gum, Silvertop Ash, Coastal Dry Forest, Brown Barrel, Yellow Stringybark-Gum and Tableland Gum) containing a variety of dominant species were selected for South Coast forest simulations (Figure C2).

The study areas are representative of the range of 'average' site productivity forests, silviculture and product mix across native forests in eastern Australia. The selected forests have generally higher productivity than the inland mixed hardwood/cypress dominated forests of NSW, Victoria and Queensland, but lower than the productive 'ash' types in Victoria and Tasmania. The pulpwood/sawlog ratio is high for South Coast forests but low for North Coast forests – the majority of other Australian native forests fall somewhere in between. Similarly, silvicultural practices in most other Australian native forests fall somewhere in between the South Coast (moderate intensity) and the North Coast (relatively intensive) forests (clearfall 'ash' forest silviculture is more intensive).

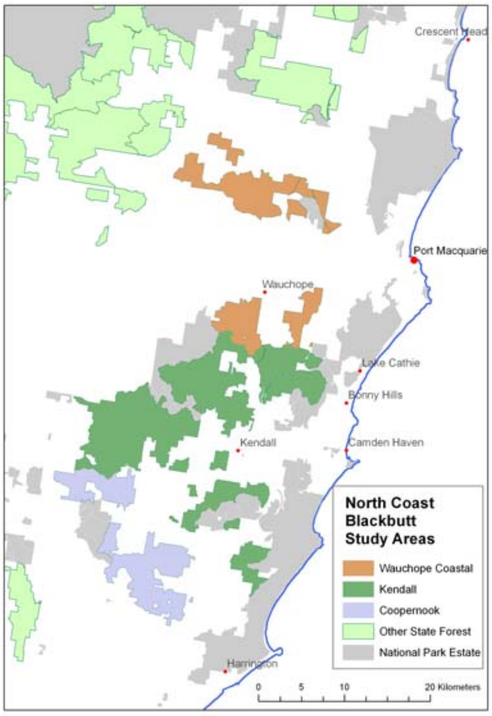

Figure C1 North Coast case study areas.

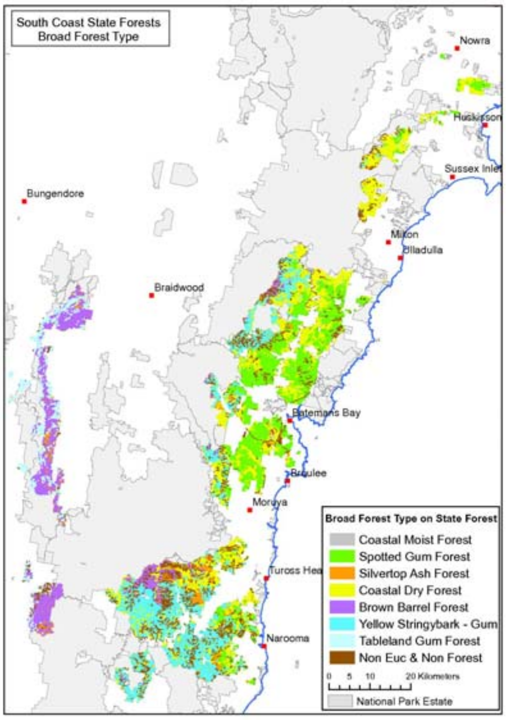

Figure C2 South Coast case study areas.

Details of the North Coast and South Coast stands are included in Table C1 below. The North Coast forest stands were similar in structure (based on average plot data for the three forest zones) and the basal area (BA) ranged from 28.2 to 29.5 m^2 ha^{-1}. The South Coast forest zones covered a broader range of forest type and stand conditions and BAs ranged from 25.3 to 44 m^2 ha^{-1} (Table C1). The total area for the North Coast and South Coast forest zones was 18,132 ha and 99,943 ha, respectively. Combined the two areas account for approximately 12% of the native forest state available for harvest in NSW and 25% of the volume of sawlogs produced in NSW (Forests NSW 2010). These forests have a long-history of harvesting (Florence 2007) The North Coast Blackbutt forests were established from intensive harvest and silvicultural treatments in the 1950s and 60s and have subsequently been subject to multiple thinning and light selective harvest operations. The south coast forests are multi-aged based on more selective harvest treatments (Florence 2007).

Forest growth and selective harvest

The above-ground biomass carbon predictions were derived using the empirical model FRAMES (Forest Resource and Management Evaluation System). FRAMES was developed by FNSW to calculate long-term wood supply volumes from native forests, to inform the Regional Forest Agreement Process in NSW (State Forests of NSW 2000). The FRAMES toolkit has been subject to a number of independent reviews (Audit Office of NSW 2009 and Vanclay 2002) and found to be suitable for modelling growth response to selective harvest in NSW.

Table C1 Stand details by study area/yield association group for North Coast and South Coast forests.

Area	Yield association	No Plots	Available area (ha)	Stocking SPH[1]	BA (m^2ha^{-1})	Live standing volume (m^3ha^{-1})
NC	Blackbutt – Coopernook	38	3,713	387	29.5	280
NC	Blackbutt – Kendall	102	10,134	467	28.2	246
NC	Blackbutt – Wauchope Coastal	39	4,285	505	29.1	231
SC	Coastal Moist Forest	13	2,837	345	25.7	214
SC	Spotted Gum	176	30,587	350	25.2	204
SC	Silvertop Ash	55	10,912	472	36.6	247
SC	Coastal Dry Forest	143	25,727	30.2	44.0	205
SC	Brown Barrel	74	13,363	315	40.0	318
SC	Yellow Stringybark-Gum	76	14,365	346	30.6	237
SC	Tableland Gum	7	2152	431	37.6	283

1 Stems per hectare

FRAMES contains a range of modules (Figure C3), and in this study key modules utilised were:

Inventory – a detailed random sample of trees currently in the forest based on strategic 0.1 ha fixed area inventory plots, where all live standing trees >10 cm DBH are measured.

Growth and Mortality Models – These models are underpinned by long-term permanent growth plots subject to repeated measurement (State Forests of NSW 2000) and individual models have been developed for each major yield association (Table C3).

Yield Simulation – integration of inventory, growth and harvest simulation.

Details of the silvicultural approaches are included in Table C2. The starting point in the simulations (Year '0') was the current stand condition of inventory plots shown in Table C1, based on inventory data collected up to the end of 2008. The plots were then grown forward for 200 years using two scenarios: current silvicultural practice (Table C2) for the area and a no disturbance, or '*conservation*' scenario. After a harvest event, the growth of a regenerating cohort of trees was simulated (Table C2).

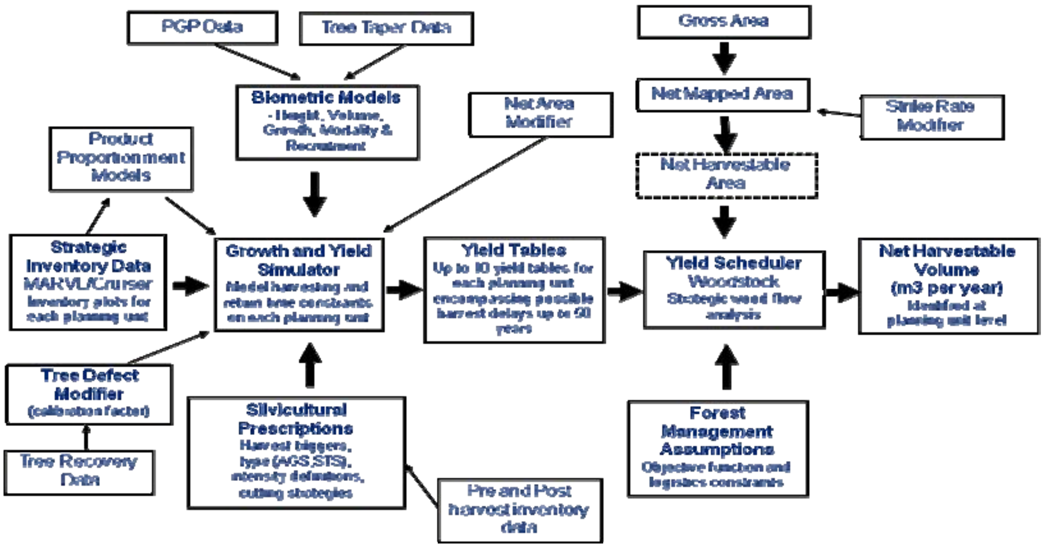

Figure C3 FramesToolkit information flow.

Table C2 Silvicultural approaches adopted in FRAMES for harvesting treatments.

Silvicultural approach	North Coast – Regeneration Single Tree Selection (STS)	South Coast – Traditional Single Tree Selection (STS)
Maximum BA removal	75%	40%
Minimum harvest volume trigger (Sawlogs)	50 m^3ha^{-1} of trees > 30 cm diameter at breast height (DBH)	20 m^3ha^{-1} of trees > 60 cm DBH
Minimum return time	Not applicable (NA)	15 years
Minimum retained BA	NA	10 m^2 ha^{-1}
Minimum tree retention	10/ha > 50 cm DBH	50/ha < 50cm DBH 10/ha > 50 cm DBH
Thinning age	Minimum 25 years age, BA >25 m^2ha^{-1}	NA
Thinning treatment	50% BA removal, from below	NA
Post STS harvest recruitment	Random between 500-1000 stems ha^{-1}	300-600 stems ha^{-1}

Carbon accumulation under the two scenarios was assessed using the outputs of the yield simulation module for harvesting treatments and from future stand tables under the '*conservation*' scenario. In the harvesting scenarios, the yield simulator reports stand level details such as stocking, BA, and volume by diameter size classes for both the residual stand and removed stems by timber product class, including waste, for 5 year periods for the 200 year simulation. For this study the yield simulator for the North Coast study area was modified to report the natural mortality volume for each 5 year period to gain an insight into the potential carbon accumulation in dead wood. The forest yields (volume ha^{-1}) were converted to carbon by firstly converting the live tree volumes to dry biomass (using the mean basic density for blackbutt of 700 kgm^{-3} (Ximenes et al 2005), and then using a carbon concentration of 50% (IPCC 2003) to derive above-ground carbon.

The same growth, mortality and recruitment models were used for both scenarios (State Forests of NSW 2000). Growth models predicted individual tree DBH increment and were a function of species, initial DBH, stand BA, overtopping stand BA and two site productivity indicators (topographic position and soil moisture). Mortality models incorporated the impact of natural mortality using tree DBH and overall stand BA as inputs. The individual tree DBH growth models were allowed to run unconstrained for 30 years, before a stand BA growth model was introduced to keep the tree level growth dynamics in check. After the 30-year switch point, the sum of individual tree BA increments was constrained to the same level as the stand BA increment prediction. Stand BA growth prediction used the dynamics of mean top height and mean top diameter to determine a site capacity, and combined these with starting BA to predict BA increment. An additional harvesting related mortality model is used in the harvesting simulations to account for trees not harvested, but destroyed, by harvesting.

Figure C4 shows the change in key stand parameters for the North Coast case study area under the '*conservation*' scenario, to demonstrate how stands develop under the growth and mortality models, under both constrained and unconstrained BA models. Initially the regrowth stands grow quickly until they reach full site occupancy at a BA of ~45 m^2ha^{-1}, after which the rate of volume growth quickly diminishes. Stocking reduces from over 400 to 150 stems ha^{-1}, whilst average tree DBH increases from 27 cm to 60 cm. The initial stand has an average of 31 trees ha^{-1}>50 cm DBH and this increases to 77 ha^{-1}after 200 years. The flatness of the volume accumulation curve after 30 years gave rise to concerns that this modelling approach was too conservative for the '*conservation*' scenario. As a result, the same model was run without plot level BA constraints. Under this modelling approach, volume accumulated until a peak at around 100-120 years into the simulation, before stands reached site capacity and mortality began to reduce volume. Under either modelling approach, the final live standing volumes are within 20% of each other, which is deemed adequate for such long-term predictions (Figure C4).

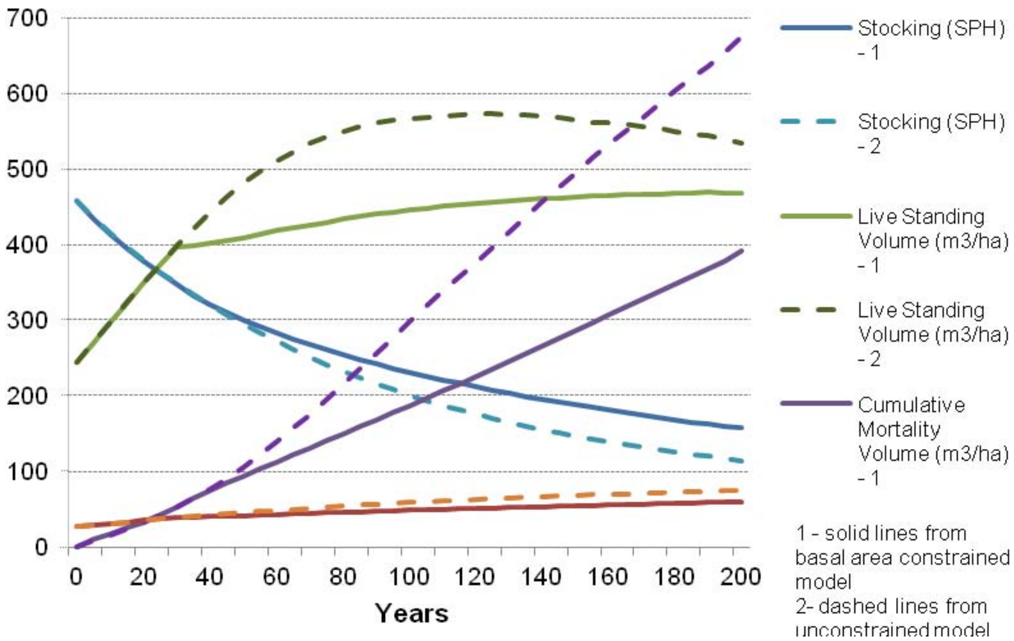

Figure C4 North Coast Blackbutt study areas – 'conservation' scenario modeled stand parameters under BA constrained and unconstrained DBH increment models.

Figure C5 shows the total volume growth and high quality sawlog volume growth trends from the growth model and yield simulator from an example plot in the Coopernook area. This plot is allowed to grow for 15 years and then subject to a regeneration harvest. After this intensive harvest a new crop of seedlings is simulated in the model and then managed on a cycle of thinning at around age 20 and a rotation length of 75 years. The average silviculture applied in the model across the North Coast study areas was thinning at age 25 and an 81 year rotation length.

In the '*conservation'* scenario the yield simulator reports the same details, but has no removed volumes. The '*conservation'* scenario model does not include potential major disturbances such as wildfire (dealt with separately in this study) or dieback.

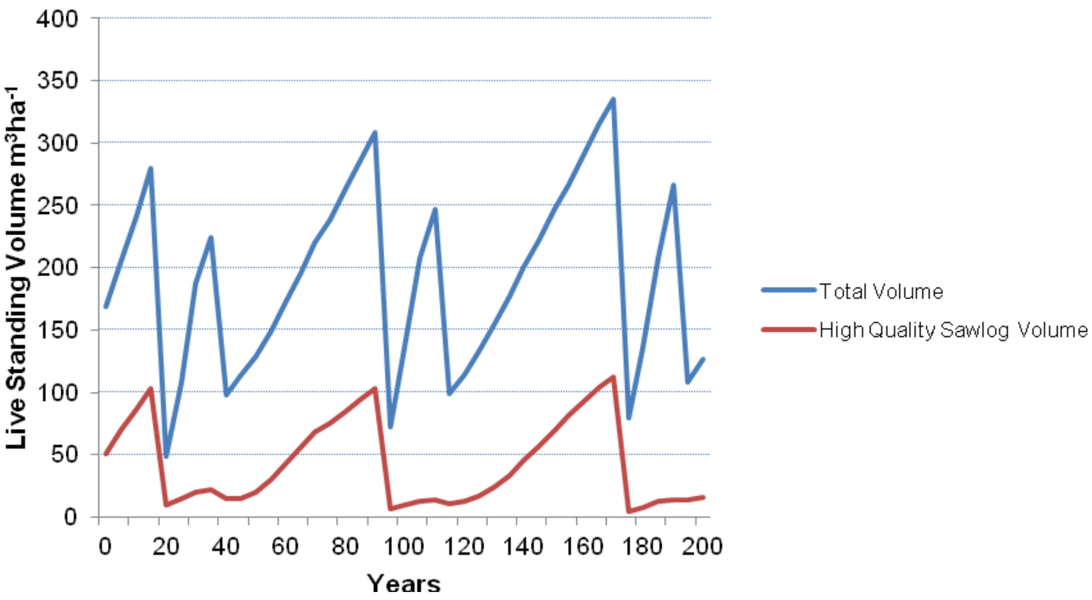

Figure C5 Total standing volume and high quality sawlog volume (m^3ha^{-1}) for forests in Coopernook (North Coast).

C2 Assumptions applied in case studies post-harvest and due to fire

Decay of residues

The rate and extent of decomposition of harvest slash (stump, bark, branches, leaves, fine and coarse roots) may have important implications for carbon stocks and greenhouse emissions and their fluctuations over time. The rate and extent of decay of the harvest slash will vary according to the type of residue, species, climate, soil conditions and level of biological hazard present (fungal or termite activity).

The forest harvest slash from the case studies described here was assumed to decay uniformly over a period of 20 years regardless of harvest slash type, in accordance with the IPCC's default decomposition factor for forest harvest residues (IPCC 2003). However, there is strong evidence that roots of harvested native hardwoods decays much more slowly following harvest. A recent study (Ximenes & Gardner 2006) suggests that between 40-70% of the biomass in the root bole of a range of native hardwood species was retained fifty years after harvest. More research is required to further refine these estimates.

Fire

Fire emissions impact climate through the direct emission of greenhouse gases, such as carbon dioxide (CO_2) and methane (CH_4), (Simpson et al 2006) and via secondary processes such as altering aerosol and ozone concentrations (Naik et al 2007). Flammable, eucalypt-dominated vegetation and dry hot summers generate a highly fire-prone environment (McCaw and Hanstrum 2003). Fire behaviour is diverse, ranging from surface fire that mainly consumes fine surface litter under low fuel loads and mild weather conditions to crown fire that completely defoliates the canopy under high fuel loads and severe weather conditions (Gould et al 2007). Fire is an intrinsic aspect of the ecology and management of SW Australian forests and woodlands (Bradstock et al 2002). Prescribed burning is the principal means of managing fuel levels in Australian forests (Ellis et al 2004).

The frequency and severity of wildfire events vary significantly according to the forest type. There is limited information available to allow accurate estimates of the effect of wildfires on biomass loss and greenhouse gas emissions for Australian native hardwood forests. There is also a limited amount of published information that would allow more refined estimates of greenhouse emissions in forests managed for timber production as opposed to forests managed purely for conservation. In this context, for the purposes of the simulations carried out here, we applied published figures on the relative areas of National Parks and State Forests subjected to wildfires and prescribed burning fires in NSW over a period of 10 years (from 1992 to 2003), (Scherl 2005) to the case study areas. We then used the fuel load, burning efficiency and emission factors recommended in the National Inventory Report (DCCEE 2010) to determine the greenhouse emissions for each of the options analysed. Factors used are detailed in Table C3.

Process emissions

The emission factors for forestry operations and wood processing are listed in Table C4. Emissions factors associated with the establishment, silviculture and management of the forest were sourced from a life cycle inventory developed for major Australian production forests by CSIRO (Tucker et al 2009). Emission factors associated with the harvest and transport of logs were derived from Tucker et al (2009) and Ximenes & Brooks (2010) – the latter report includes emission factors for the harvest and transport of major commercial forest species in NSW as well as emission factors for the manufacture and transport of a range of wood products.

Table C3 Parameters for determining non-CO_2 GHG emissions (annual averages) from wildfire and prescribed burning for native forests in NSW.

Parameters	***'Production'* forest**	***'Conservation'* forest**
Area of forest burnt $year^{-1}$ (%), Price and Bradstock 2011	4	4
Fuel load for prescribed burning (tonnes dry matter ha^{-1}), DCCEE 2011	18.2	18.2
Fuel load for wildfires (tonnes dry matter ha^{-1}) DCCEE 2011	36.4	36.4
Burning efficiency of prescribed burning DCCEE 2011	0.42	0.42
Burning efficiency of wildfires DCCEE 2011	0.72	0.72
Area of burnt forest burnt by prescribed burning (%), Scherl 2005	54	12
Area of burnt forest burnt by wildfires (%), Scherl 2005	46	88
Biomass burning load (t Cha^{-1}); derived from factors above	8.1	12
Mass of element in species mass of element in fuel $burnt^{-1}$; total emission factor for C and N trace gases from biomass burning (t Cha^{-1}) DCCEE 2011[1]	0.2506	0.2506
Emission factor (t Cha^{-1}); derived from factors above	0.55	0.82
Mass of element in CO_2 mass of element in fuel $burnt^{-1}$ (t C ha^{-1}) Hurst et al 1996	6.85	10.15

[1] – Non-CO_2 emissions only

Table C4 Process emissions assumptions.

Emissions source	**Value**	**Units**	**Reference**
Forest and transport			
Establishment and silviculture	0.2	kg CO_2 m^{-3} log	Tucker et al (2009)
Management	2.3	kg CO_2 m^{-3} log	Tucker et al (2009)
Harvest	12	kg CO_2 m^{-3} log	Tucker et al (2009)
Haulage	10.2	kg CO_2 m^{-3} log	Tucker et al (2009)
Emissions - Harvest	11.3	kg CO_2 m^{-3} log	Ximenes & Brooks (2010)
Emissions Transport	11.3	kg CO_2 m^{-3} log	Ximenes & Brooks (2010)
Sawmill emissions			
Manufacture	45	kg CO_2 m^{-3} log	Ximenes & Brooks (2010)
Transport to market	11.7	kg CO_2 m^{-3} log	Ximenes & Brooks (2010)
MDF plant emissions	610	kg CO_2 m^{-3} finished product	Ximenes & Brooks (2010)

Product Substitution effect

In their meta-analysis of twenty European and North-American studies, Sathre & O'Connor (2010) suggest that on average, for each tonne of carbon in HWPs substituted for non wood products, a greenhouse gas reduction of two tonnes of carbon is achieved. This is the factor adopted for the calculation of the product substitution benefit in these case studies. A more refined factor would require an in-depth analysis of the markets for each of the forest zones, and potential for material replacement with native regrowth hardwoods from other regions, plantation hardwood, plantation softwood, imported wood and non-wood alternatives. Such an analysis is outside the scope of this paper.

Carbon storage in paper products

Any potential long-term carbon storage in paper products is not considered in this analysis. The greenhouse implications of not producing paper products from the production forests (product substitution effect) is also not taken into account. It is possible that a proportion of the paper products that would need to be sourced elsewhere if harvest of native forests decreased significantly, would be sourced from areas where unsustainable forestry practices are adopted. This would lead to increased greenhouse emissions associated with a '*conservation*' scenario.

Product mix

The modelled product mix illustrated in Figure C6, predicted from the sawlogs, pulp logs and pole logs harvested from the North Coast forest zones, was based on the average product mix typically obtained for the forest types included in this study.

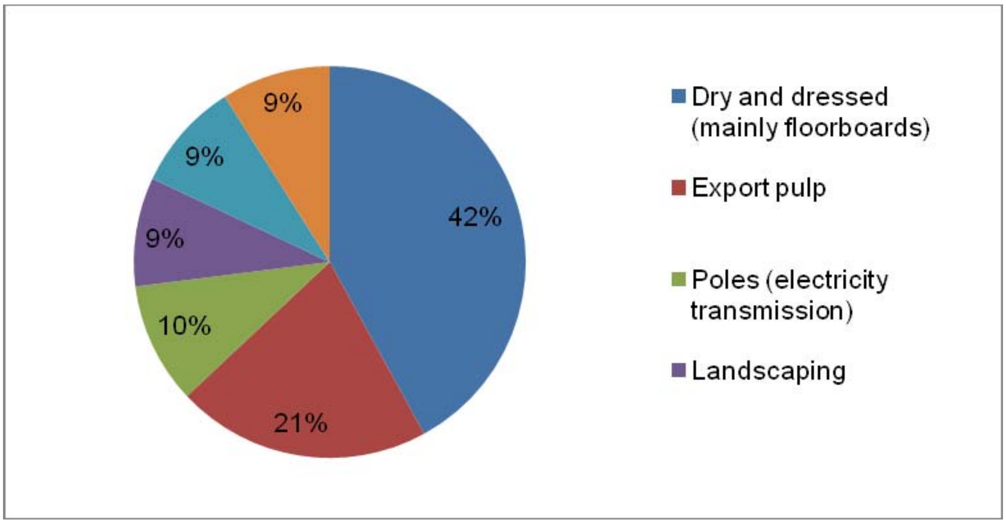

Figure C6 Product mix obtained from the North Coast forests.

Dried sawn boards (used primarily for floorboards) represented the majority of the biomass in the products from the North Coast forest zones. A smaller proportion of the biomass (21%) was used for the manufacture of products with a short service life (pulp and paper). Those products were not assigned any long-term carbon storage. The remainder of the products were assigned a level of long-term carbon storage, taking into account processing and use (decay in service) losses.

The modelled product mix from the sawlogs, pulp logs and pole logs harvested from the South Coast forest zones is illustrated in Figure C7.

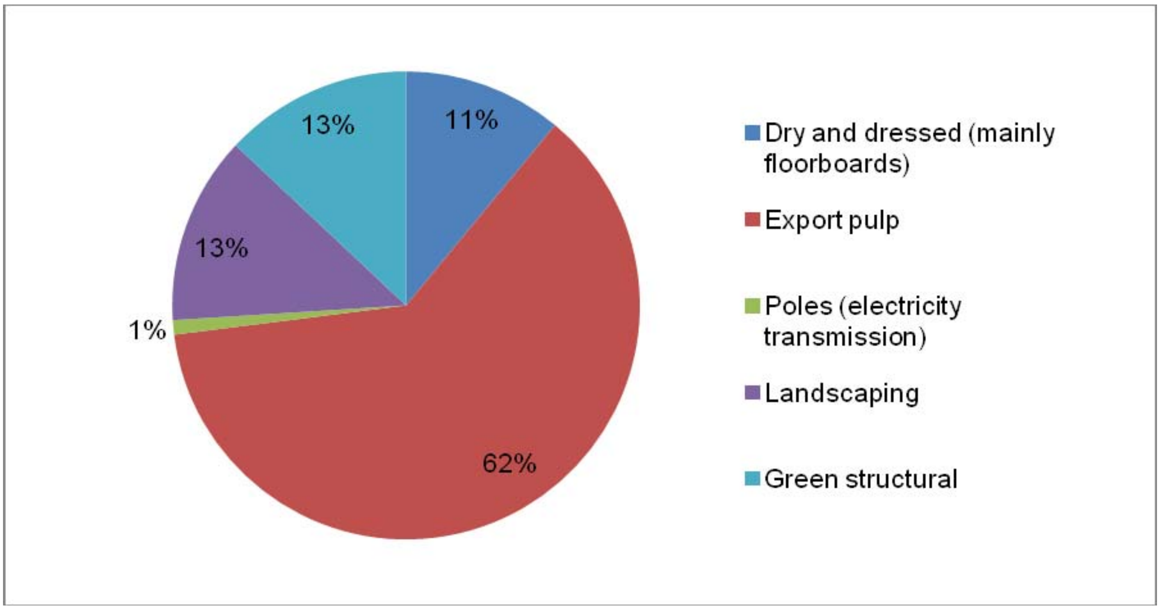

Figure C7 Product mix obtained from the South Coast forests.

For the South Coast forests a much higher proportion of the biomass (62%) was used for the production of pulp and paper. As per above, those products were not assigned any long-term carbon storage. The remainder of the products were assigned a level of long-term carbon storage, taking into account processing and use (decay in service) losses.

Fossil-fuel substitution benefits from using a proportion of harvest residues for bioenergy generation ($Substitution_{RES}$)

The fossil-fuel substitution benefits from extracting 30, 50 and 70% of the total volume of above-ground harvest residues for bioenergy generation ($Substitution_{RES}$) were modeled. Removal of native forest residues for bioenergy may have some impact on soil nutrient levels, particularly if bark, foliage and branches are removed (Johnson and Curtis 2001), and hence a conservative level of residue removal (30%) is used as a default value in this study. Emissions due to forest establishment and silviculture, management and harvest of trees were allocated to the wood products obtained from commercial logs other than pulp logs, as paper products were not included in the modelling. Emissions due to transport of harvest residues to a bioenergy plant were calculated using the factor listed in Table C5.

In our case studies we assumed that the biomass was used to generate electricity. The production of electricity is determined by the chemical and moisture characteristics of the forest biomass and the energy conversion efficiencies. Conservative values and assumptions were used to estimate the amount of electricity generated per green tonne of biomass (Table C5). Efficiency of conversion depends on the type of process, scale and operational efficiencies varying from 25% for some dedicated biomass electricity plants (Rodriguez et al 2011) to 43% for new coal-fired plants (Hansson et al 2009). A relatively conservative conversion efficiency (30%) was selected for the case studies (Table C5). For each tonne of carbon in residues used for the generation of electricity, 2.93 t CO_2 was displaced (assuming full fuel cycle for electricity generated in NSW of 1.07 t CO_2-eMWh^{-1} (DCCEE 2010), (Table C5). This factor includes emissions due to mining and transport of coal.

Table C5. Use of harvest residues for energy generation - key assumptions.

Parameters	Value
Carbon content of biomass (%)	50
Gross calorific value (GJt^{-1}, dry weight); May et al 2011	19.6
Moisture content of biomass (%); Ximenes et al 2008	40.0
Net calorific value (GJt^{-1}, dry weight); (ECN Biomass database 2012)	10.0
Assumed efficiency of conversion (%)	30.0
Electricity generated by the use of one tonne of green biomass (MWh); Peck et al 2011	0.833
GHG emissions for a coal-fired power station in NSW (t CO_2-eMWh^{-1}); Lenzen 2008	0.911
Full fuel cycle for electricity generated in NSW (t CO_2-eMWh^{-1}); DCCEE 2010	1.07
Fossil-fuel displacement factor associated with the use of one tonne of carbon in residues for the generation of electricity (t CO_2-e)	2.93

Simulation results

The simulations start at a pre-determined point in time in the forest growth stage for both forest areas (typically 5-10 years before a selective harvest event).

The simulation applies to the areas selected only and should not be used to derive State wide estimates.

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