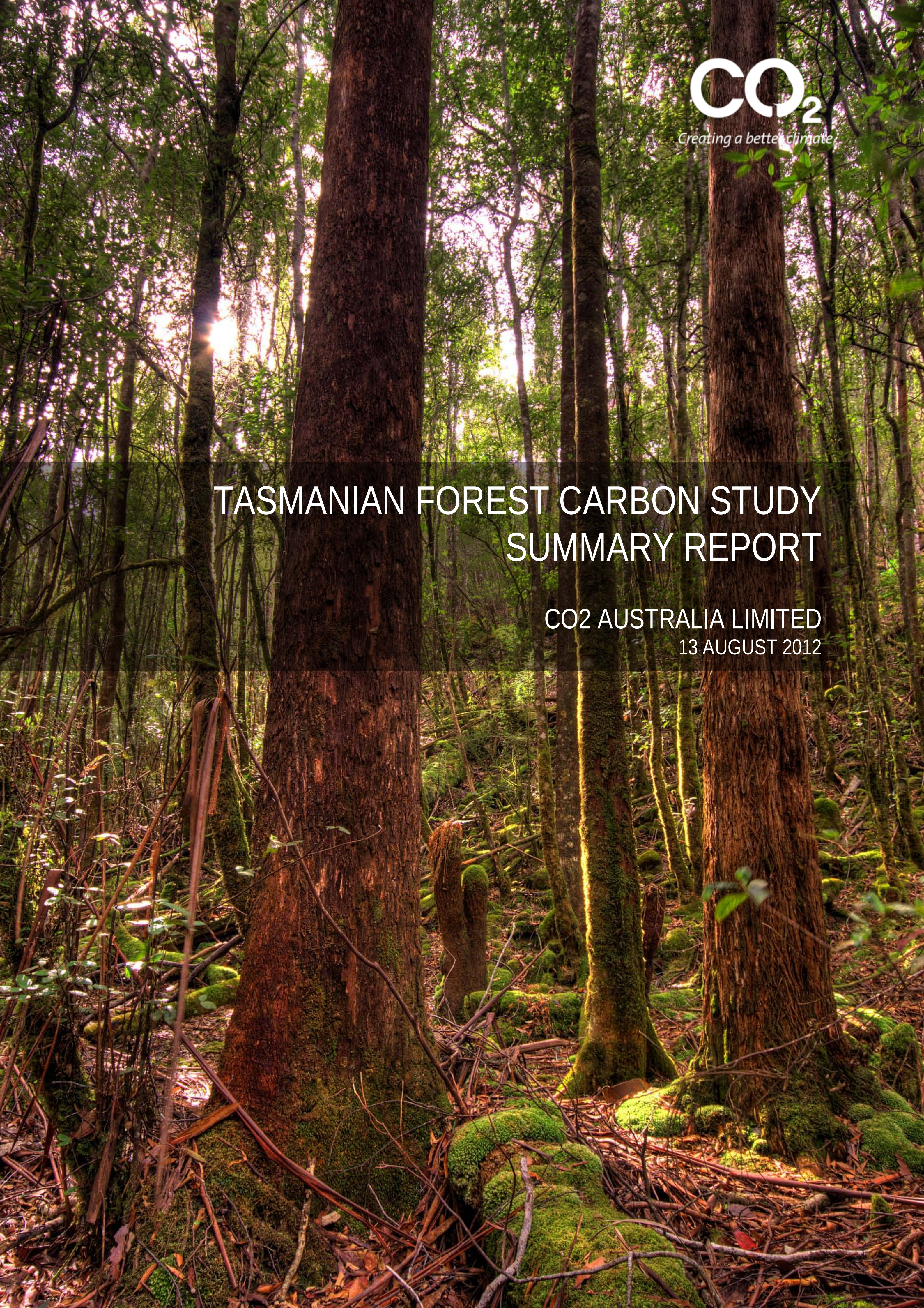

TASMANIAN FOREST CARBON STUDY SUMMARY REPORT

CO2 AUSTRALIA LIMITED

13 AUGUST 2012

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SUMMARY REPORT

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CO2 Australia Limited

13 August 2012

This report was commissioned by the State Government through the Tasmanian Climate Change Office.

Steering Committee: Jim Reid, Brendan Mackey & Cris Brack

Creating a better climate

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TASMANIAN FOREST CARBON STUDY SUMMARY REPORT

This document provides a brief summary of objectives and key results. It is strongly recommended that this be read in conjunction with the full report, which provides a much more detailed treatment of the results, methodology, assumptions and uncertainties as well as the background information upon which the carbon modelling framework is based.

Scope and objectives

The Tasmanian Government engaged CO2 Australia Limited to undertake a Forest Carbon Study (Carbon Study) from November 2011 - July 2012. The over-arching aim of the Carbon Study has been to develop a comprehensive picture of carbon stocks in Tasmania's forests, including all significant carbon stored in living and dead biomass, soils and harvested wood products, as accurately as possible and across all forest types, land tenures and management regimes.

The Carbon Study references historic carbon stocks (to 1990) and provides estimates of future carbon stocks and emissions under a wide range of forest management and land use scenarios, allowing for a comparison of the emissions, or carbon storage profile associated with differing patterns of use. Additionally, the Carbon Study provides an assessment of the potential to monetise carbon sequestration and avoided emissions under various domestic and international carbon trading programs, including possible pathways to the realisation of verified and tradable carbon credits.

The scope and objectives of this Carbon Study have been to:

- Estimate current carbon stocks across all of Tasmania's forest estate, taking into account forest type, age-class and disturbance, land use histories and management regimes.
- Provide an assessment of the stocks and emissions in decadal time periods for the previous two decades (1990-2010).
- Provide an assessment of likely future stocks and emissions (in decadal periods to 2050) under a range of scenarios determined in consultation with the Steering Committee.
- Develop a clear accounting framework for carbon stocks and flows in Tasmania's forests.
- Identify areas of significant uncertainty with respect to estimates of carbon stocks and assess the magnitude of uncertainty and error in estimates.
- Provide an analysis of opportunities to monetise avoided emissions, emission reductions and increased carbon sequestration, with specific reference to the assessment of current and baseline carbon stocks established as part of the Carbon Study.

Scenarios

To examine the possible impacts of changes in forest and land-use practices on Tasmania's forest carbons stocks, and estimate the potential Carbon Carrying Capacity, a series of test scenarios was developed in consultation with the Steering Committee. These included a Study Baseline which sought to represent contemporary forest and land management patterns, a range of altered forest management and land-use scenarios, referred to as the Study Scenarios, and a series of fire and climate change scenarios, referred to as the Baseline Sensitivity Scenarios. In addition, the long term Carbon Carrying Capacity of Tasmania's forests in the absence of harvesting were modelled over a period of 240 years using a range of assumed fire frequencies.

Study Baseline: Business as usual

- Harvest rates and intensities based on current silvicultural regimes and log type recovery rates with an assumed sawlog quota of 300,000 m^3/y for public native forests and hardwood plantations and 55,000 m^3/y for private native forests.
- Fire regimes based on historic fire frequencies and intensities for different forest types.
- Areas of forests and plantations based on those in 2010 assuming no future reforestation, deforestation or conversion of native forest to plantations, or expansion or contraction in areas available for harvesting.

Study Scenarios: Altering management regimes in native forests

N1. Reserve 572,000 hectares (ha) of public forest; reduce the annual sawlog cut from public native forests to 155,000 cubic metres per year (m^3/y) and the annual peeler log cut from public native forests to 265,000 m^3/y.

N2. Phase out harvesting in old growth forest by 2020 on both public and private land, but increase harvesting intensity in regrowth forests so as to maintain annual sawlog production from public forest at or near to 300,000 m^3/y.

N2A. Phase out harvesting of old growth forests by 2020 on both public and private land, and vary harvest intensity in regrowth forests so as to maintain annual sawlog production from public forest at 155,000 m^3/y.

N3. Vary rotation length in regrowth forests from 60-120 years, with reference to the current rotation lengths of approximately 80 years (as indicated in the literature).

N4. Immediate cessation of the harvest of old growth forests on both public and private land with no increase in harvesting of regrowth forests.

N5. Immediate cessation of all native forest harvesting on both public and private land.

Study Scenarios: Altering management in plantations

P1. Increase the rotation length of all existing plantations by 10%.

P2. Convert all existing pulplog plantations to sawlog plantations by increasing the rotation length to 25 years.

P3. Increase the growth rates of existing plantations by 25% through improved management.

Study Scenarios: Altering land use

A1. Conversion of private native forest to plantation, or non-forest uses, continues at the recent rates indicated by Forest Practices Authority and as permitted under the Permanent Native Forest Estate Policy 2009 up until 2015, after which it ceases.

A2. Existing un-stocked areas in native forests are regenerated back to native forest (non-harvested).

A3. The plantation forest estate expands into cleared agricultural lands at the average annual rate of expansion that occurred from 2000-2010.

A4. The plantation forest estate expands into cleared agricultural lands at double the historic average (2000-2010) to a maximum point where 10% of existing cleared agricultural lands are converted to plantations by 2050.

A5. Twenty-five percent (25%) of existing pulpwood plantations are not replanted after their first harvest.

Baseline Sensitivity Scenarios: Altering fire frequency

F1. Fire frequency decreases by 10% (against assumed current frequency) for all native forest types.

F2. Fire frequency increases by 10% for all native forest types.

F3. Fire frequency decreases by 20% for all native forest types.

F4. Fire frequency increases by 20% for all native forest types.

Baseline Sensitivity Scenarios: Effects of climate change

C1. Based on SRES A2, using climate projections from the CSIRO Mk 3.0 climate model which predicts the Tasmanian climate in 2050 will be similar to that of 2010 with a 0.6 ^{o}C increase in average temperature and 2% decrease in annual rainfall.

C2. Based on SRES A2, using climate projections from the CSIRO Mk 3.5 climate model, which predicts the Tasmanian climate in 2050 will be hotter and drier than in 2010 with a 1.6 ^{o}C increase in average temperature and an 8% decrease in annual rainfall.

C3. Based on SRES A1b, using climate projections from the CSIRO Mk 3.5 climate model which predicts the Tasmanian climate in 2050 will be warmer and drier with a 1.4 °C increase in average temperature and a 7% decrease in annual rainfall.

Carbon Carrying Capacity Scenarios

L1. Modelled carbon stocks at 2250 in the absence of timber harvesting under Study Baseline fire regimes (Carbon Carrying Capacity Baseline)

L3. Modelled carbon stocks at 2250 in the absence of timber harvesting assuming a 20% reduction in fire frequency.

L4. Modelled carbon stocks at 2250 in the absence of timber harvesting assuming a 20% increase in fire frequency.

Modelling carbon stocks (Forestry Carbon Modelling Framework)

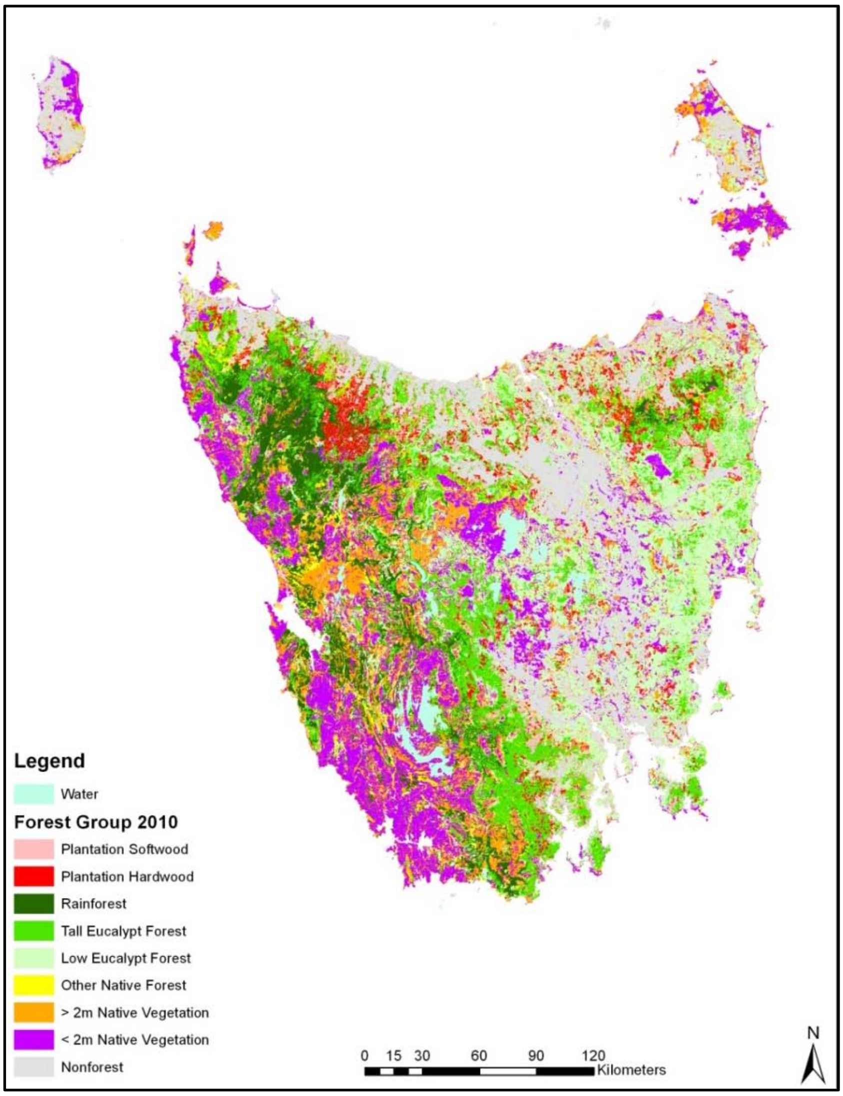
One of the major areas of activity and outcomes of the Carbon Study has been the development of a unique, built-for-purpose Forest Carbon Modelling Framework (FCMF) that models forest carbon stocks, and changes to these stocks, across all forest types within Tasmania. Given the scale of the modelling task, the FCMF has been designed in a way that allows for the rapid generation of large numbers of simulations, representing a significant efficiency improvement over alternate, publicly available approaches.

The FCMF utilises a similar approach for modelling carbon pools as that included within the Full Carbon Accounting Model (FullCAM), but extends its functionality and application by linking modelling processes to detailed input information for all forest types and carbon pools, referencing forest growth, fire and harvesting regime data and incorporating spatial data for climate, soil and forest type, productivity, management and tenure across Tasmania at a one square kilometre level. The FCMF also links forest growth to amounts of harvested wood products produced, allowing full modelling of the impact of changes in timber harvest volumes on carbon stocks, this being a key requirement of the Carbon Study.

Critically, the FCMF incorporates a significant body of actual growth data for native forest and plantations across Tasmania, access to most of which was negotiated under the Carbon Study. Key data providers have included Forestry Tasmania, DCCEE, the Wilderness Society and the University of Tasmania. These data inputs have been incredibly valuable to the outcomes of the Carbon Study and the authors express their thanks and appreciation to all contributors.

Classifying and mapping forests

The Carbon Study included all vegetation across Tasmania classified as woody vegetation, with height >2 m and >20% canopy cover (this being consistent with definitions applied under the Kyoto protocol). To do this, 10 vegetation groups were developed based on information from Forestry Tasmania (Forest Classes and Forest Groups) and the TasVeg spatial layer developed by the Department of Primary Industries, Parks, Water and Environment (DPIPWE).



Distribution of forest and native vegetation types across Tasmania in 2010 (Derived from Forest Group and TasVeg maps). Tasmania is covered by 3.4 million ha of native forests and plantations, making it Australia's most forested state. 2.3 million ha are on public land with 1.1 million ha on private land. In addition, around 1.0 million ha of native vegetation is classed as non-forest, but is accountable in terms of changes in carbon stocks (i.e. > 2 m tall). Of the total forested area, 1.7 million ha is located in formal or informal reserves and a further 0.2 million ha is classified as non-harvestable for economic or other reasons. The total area of native forest available for wood production is around 1.2 million ha.

Filling in data gaps

Two of the key data gaps identified during the course of the Carbon Study are: the lack of data for carbon stocks in pure temperate Rainforest in Australia and the lack of information on the change in carbon stocks across the succession from Tall Eucalypt Forest to Rainforest. For this reason, a series of field measurements were undertaken as part of the Carbon Study.

Sixteen paired measurement plots were selected at locations ranging from the Styx River valley to near Lake Gordon, in adjacent areas of Rainforest and mature (> 110 year old) Tall Eucalypt Forest. Measurements were collected from trees within the plots and allometric functions were used to convert these to estimates of biomass. Analyses of these data indicated that total live and dead biomass was significantly ($P<0.01$) lower on the Rainforest plots than eucalypt plots. On eucalypt plots, average biomass was 1170 tonnes per hectare (t/ha), equivalent to 2,145 tonnes carbon dioxide equivalent per hectare (t CO_2e/ha) and on Rainforest plots average biomass was 590 t/ha (1,080 t CO_2e/ha).

The Tasmanian Wilderness Society also provided relevant data from the Tarkine Wilderness area (four measurement plots in Rainforest) and the Styx Valley (five plots in mature Tall Eucalypt Forest), which were analysed as part of the Carbon Study together with published data from a third Tall Eucalypt Forest site in the Florentine Valley (Dean *et al.,* 2012). Total biomass in live trees was found to vary from 1360 t/ha (3,180 t CO_2e/ha) at Styx, to 422 t/ha (1,040 t CO_2e/ha) at Tarkine (the Rainforest only site) and, as with the measurement data collected under the Carbon Study, indicated that biomass at the Rainforest site was lower than at the two Tall Eucalypt Forest sites. These results were supported by additional data collected as part of a PhD project by Ian Riley from University of Tasmania from paired eucalypt and Rainforest plots.

These results suggest that, following senescence of the eucalypt stand during the transition from Tall Eucalypt Forest to Rainforest, total biomass and carbon stocks decrease and that the carbon content of live vegetation in Rainforest may be less than 50% of the preceding eucalypt forest. Both this relative difference and estimates of Rainforest biomass need to be confirmed with further measurements. However, for the purpose of modelling growth and decline of Tall Eucalypt Forest, the Carbon Study assumed the average biomass of Rainforest (as mapped by Forestry Tasmania and the Department of Primary Industries, Parks, Water and Environment) was around 50% that of mature Tall Eucalypt Forest.

Interpreting the results – Key assumptions & data gaps

The following results provide an indication of the potential effects of changes in management, land use, fire, and climate on carbon stocks in Tasmania's forests. While these represent the first detailed assessment of carbon stocks and dynamics across all forest types in Tasmania, they should not be considered definitive. Despite an extensive review of relevant literature and rigorous design and testing of the modelling framework, there are important uncertainties and assumptions in the underlying data that could have substantial impacts on the results. These are covered in detail within the main body of the report, and it is strongly recommended that these are read in conjunction with this summary. For quick reference, some of the key issues identified during data gap and sensitivity analyses are as follows:

- Growth rates for native forests - based on plot data from Forestry Tasmania and field measurements (current average standing volumes of existing mature forest with >40% eucalypt cover, assumed to represent the 95% maximum stand volume).
- Growth rates of plantations – based on a relationship between DCCEE's Forest Productivity Index (FPI) and plantation site index using data from Forestry Tasmania.
- Native forest harvesting rates - based on forward estimates from Forestry Tasmania and historic harvesting volumes and set to deliver sawlog quotas of 300,000 m^3/y from public native forests and hardwood plantations and 55,000 m^3/y from privately owned native forests, assuming an average rotation length of 80 years for regrowth native forests.
- Plantation harvest rates – based on data on age class distributions and assumed average rotation lengths of 13 years for pulpwood plantations, 25 years for hardwood sawlog plantation and 30 years for softwood plantations.
- Proportion of sawlogs produced from logs harvested and removed from site - based on data from Forestry Tasmania and ABARES and assumed to be:
  - 12-13% for public native forests,
  - 5-6% for private native forests,
  - 38% for hardwood sawlog plantations, and
  - 47% for softwood plantations.
- Frequency of wildfire - based on published estimates for different forest types, and modelled as likelihood of fire in any year as follows:
  - Tall Eucalypt Forest: 0.4% – 0.7%/y (assumed to be greater for regrowth than mature stands) with an average 50% of 80 year old trees killed;
  - Low Eucalypt Forest: 3.0 – 3.8%/y (assumed to be greater for regrowth than mature stands) with an average 20% of 40 year old trees killed;
  - Rainforest: 0.05%/y, with an average 75% of 80 year old trees killed;
  - Other Non-Forest: 4.0%/y, with an average 20% of 80 year old trees killed; and
  - Plantations: 1.0%/y, with all trees killed.
- Carbon losses from debris and soil due to wildfire and regeneration burns - based on limited published data and assumed to vary with fire intensity,
- Stem mortality rates - based on a new stem mortality model developed specifically for the Carbon Study from modelled height, diameter and volume growth for different forest types and published and unpublished studies of changes in stocking over time.
- Debris production and decomposition rates – based on plot data from Forestry Tasmania and default figures from DCCEE.

- Soil carbon – based on the RothC model from FullCAM used for soil carbon cycling which has not yet been validated for Australian native forests.
- Effect of temperature and rainfall on carbon in debris and soil – modifiers for FullCAM used (based on one study by CSIRO in plantations only).

Accounting for uncertainty

'Natural' variation in harvesting and fire events and uncertainty in parameter values were taken into account using a probabilistic approach. The likelihood of an individual stand (*i.e.* grid point) being harvested or burnt in any year was determined using input probability distributions.

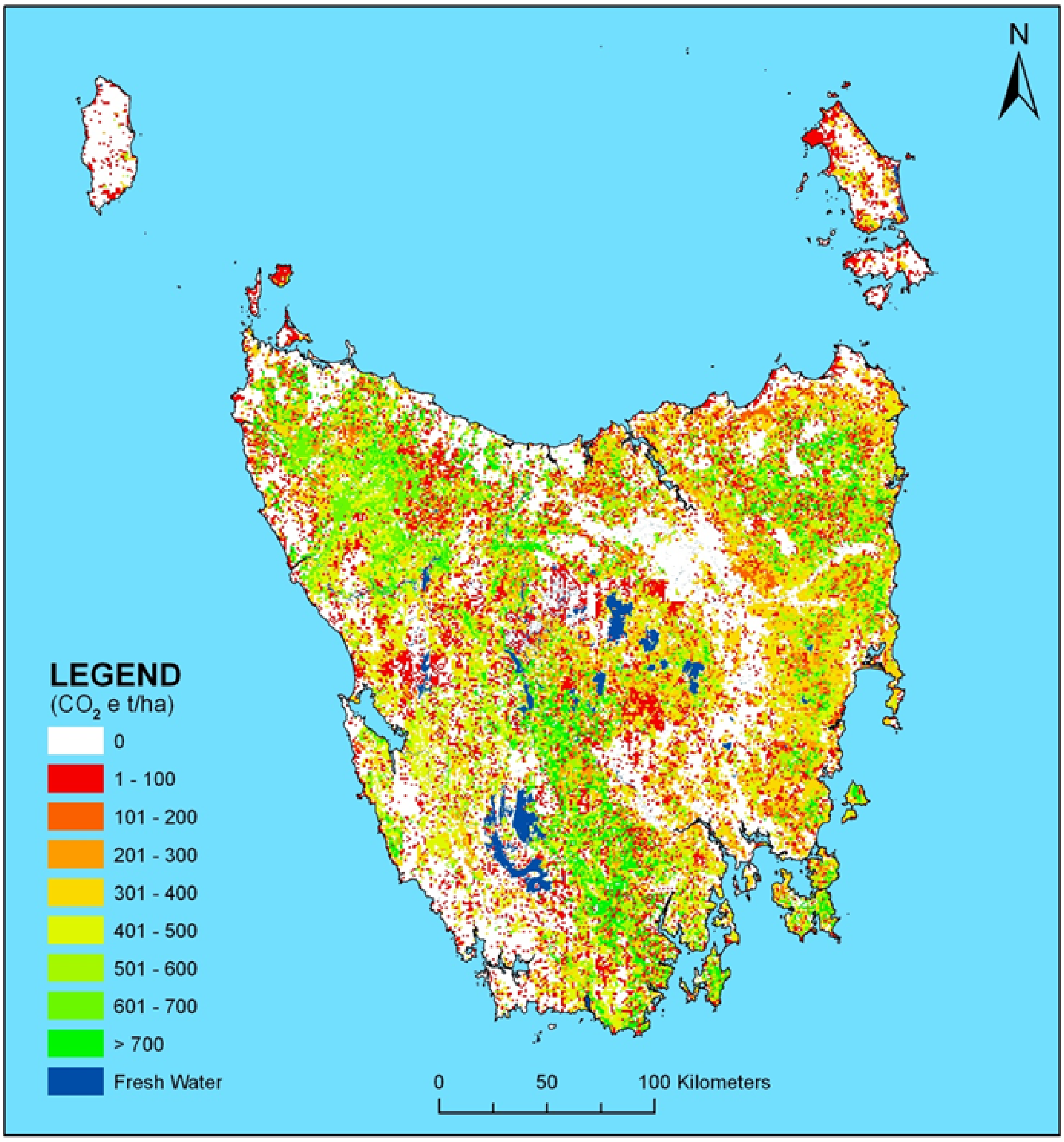
A set of primary (or central) estimates of carbon stocks and emissions was first generated. To do this, all parameters were set at values considered to be most likely to represent their true average. To enable valid comparison between the Study Baseline and Study Scenarios, the same set of simulation conditions were applied between the two, so as to remove potential effects of the randomisation process. As an example, if an individual stand was burnt or harvested under the Study Baseline, the same stand was assumed to be burnt or harvested under the Study Scenario, unless the latter was specifically modelling a change in fire or harvest parameters.

The effect of uncertainty in model parameters on the primary estimates of carbon stocks and emissions was estimated by allowing parameter values to vary within a predefined range and examining the effect of this on the results. To do this, each input parameter for the model was assigned a mean and an uncertainty value (coefficient of variation) based on the degree of confidence in its estimated value and reported variation. The Study Baseline and each Study Scenario were then run over a series of iterations with each parameter allowed to deviate randomly within an assumed normal distribution. Coefficients of variation were calculated for each model output and these were used as the basis for estimating variation in primary outputs.

The effects of these uncertainty analyses are reflected in the presentation of results through this report, which present carbon stock and emissions estimates as ranges, rather than absolute values. These ranges represent one standard deviation from the primary estimate, as calculated from the outputs of the iterative simulation process described above.

Study Baseline: Current carbon stocks

The current total carbon stock in live vegetation in Tasmania's forests is estimated to be 1,400 – 1,900 million tonnes (Mt) of carbon dioxide equivalent (CO_2e). A further 1,000-1,500 Mt CO_2e is contained in forest debris and dead trees, with 600-900 Mt CO_2e contained in soil (< 30cm). The total amount of carbon stored in vegetation, debris and soil of native forests and plantations is estimated to be 3,000 – 4,400 Mt CO_2e. An estimated 97% of the total carbon is contained in native forests, with hardwood and softwood plantations containing 3%.



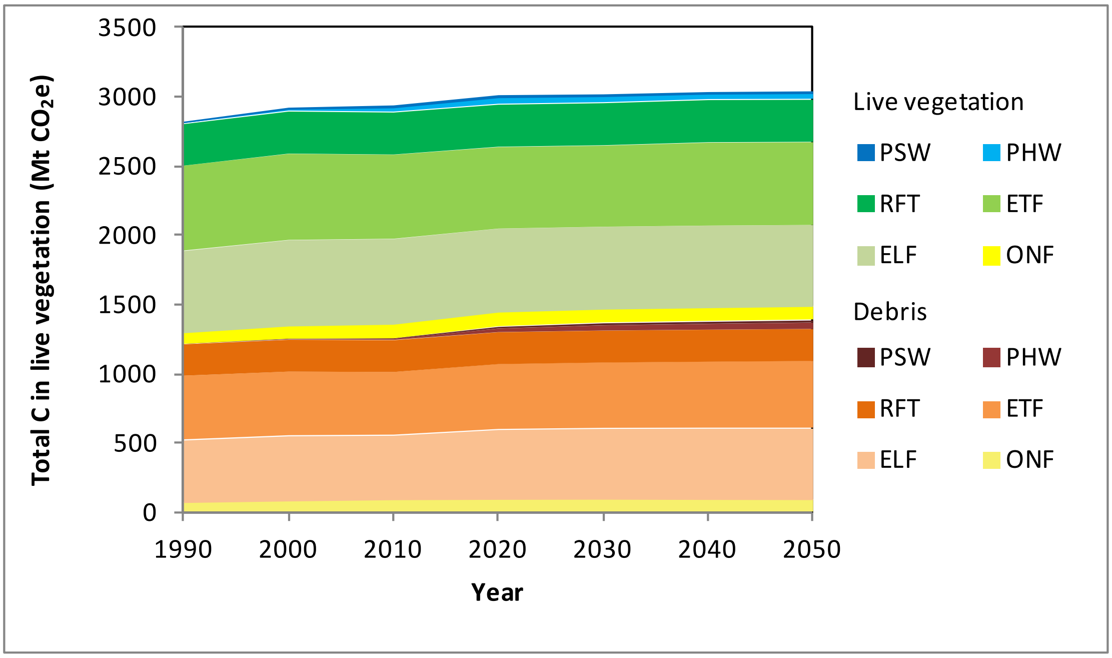
Modelled distribution of carbon stocks in live vegetation (>2m and >20% cover) across Tasmania in 2010. The highest density carbon stocks are located in highly productive forests in the north-west, southern and the north eastern regions.

Average modelled carbon density in vegetation (amount per ha) is greatest for Tall Eucalypt Forests (averaging 560-730 t CO_2e /ha) and least for Other Native Forests (90-120 t CO_2e/ha). Estimated current carbon density in plantations averaged 130-150 t CO_2e/ha CO_2e. Across Tasmania, carbon densities were highest in the more productive forests in the southern, central, north west and north east regions of the state (> 600 t CO_2e/ha) with lower carbon densities in the drier forests of the south east and alpine vegetation covering much of the south west.

Study Baseline: Changes in stocks and emissions over time

Carbon stocks have tended to remain relatively stable over time, with the total amount of carbon in vegetation and debris of native forest varying from 2,500-3,100 Mt CO_2e in 1990 to 2,500-3,300 Mt CO_2e in 2010. Over the same time period, carbon stocks in plantations are estimated to have increased from 14-17 Mt CO_2e to 53-65 Mt CO_2e.

Under current harvesting patterns, fire regimes and environmental conditions, the total amount of carbon in vegetation and debris in native forests is expected to increase by around 1.0-1.7% (21-61 Mt CO_2e) to 2050. Over the same period, carbon stocks in vegetation and debris in plantations are expected to increase by about 56-65 Mt CO_2e, reaching 109-131 Mt CO_2e in 2050. Carbon stocks in soil are expected to increase by 42 to 73 Mt CO_2e in native forests, but could decrease slightly in plantations by 5-8 Mt CO_2e.



Modelled carbon stocks in live vegetation and debris in different forest types from 1990 to 2050 under the Study Baseline. Currently 2,500 - 3,400 Mt CO_2e are estimated to be stored in live vegetation and debris. This amount is expected to increase slightly over time to 2,600-3,500 by 2050. PSW: Plantation Softwood, PHW: Plantation Hardwood, RFT: Rainforest, ETF: Tall Eucalypt Forest, ELF: Low Eucalypt Forest, and ONF: Other Native Forest.

Based on the modelled increases in carbon stocks in native forests and plantations over time for the Study Baseline, Tasmania's forests are expected to sequester an average 3-4 Mt CO_2e/y between 2010 and 2050. Emissions from fossil fuel use and non-greenhouse gas emissions from regeneration burns in native forests and plantations are expected to average 0.2-0.3 Mt CO_2e/y and thus have a relatively small impact on total carbon fluxes as compared with the total amount of carbon sequestered. CO_2 emissions from regeneration burns are included in the net change in carbon stocks for harvested native forests and plantations.

Wood products harvested between 2010 and 2050 and processed and used domestically are estimated to contribute a total of 10-12 Mt CO_2e to carbon stocks (including losses through decomposition). The reason for the relatively low contribution from wood products is that a large proportion of forest products are exported, either in the form of woodchips, or as finished products such as veneer. Under current accounting rules used by the Department of Climate Change and Energy Efficiency, carbon in these exported products is assumed to be emitted as CO_2. However, in reality, a proportion of this carbon is stored in wood products processed and used overseas (or imported back into Australia).

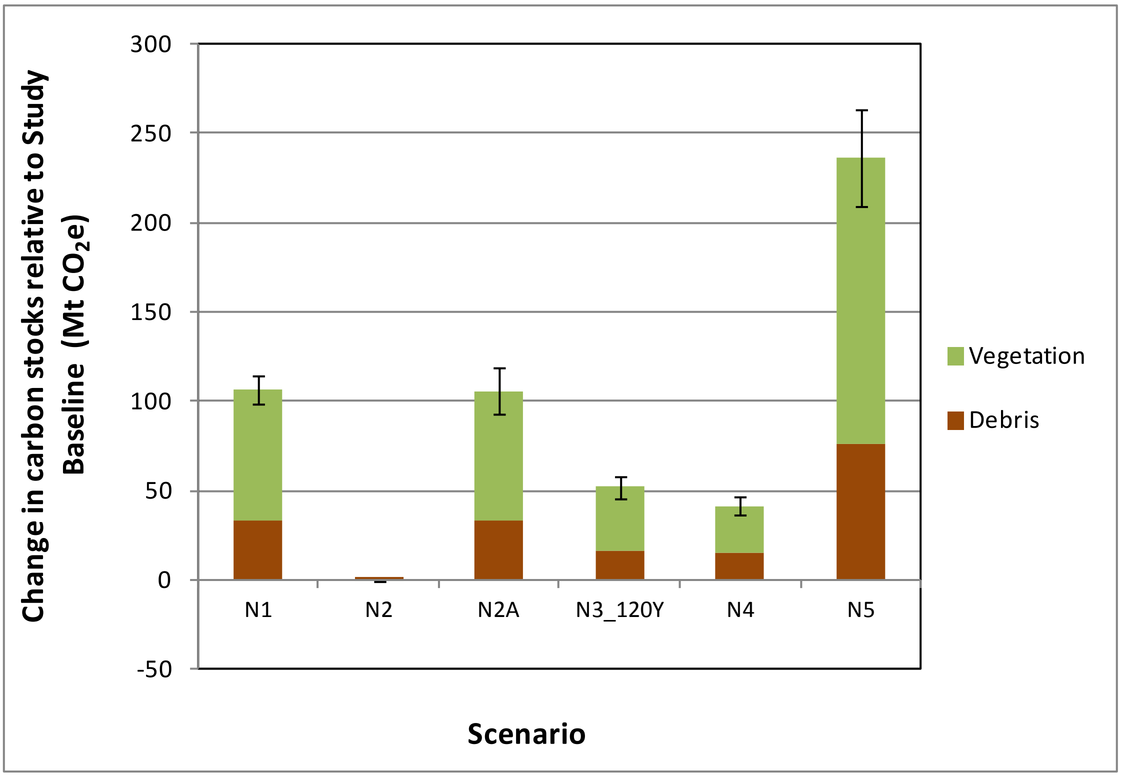
Study Scenarios: Effect of varying management of native forests

Results from the native forest management Study Scenarios indicate there is potential to increase carbon stocks by reducing harvesting rates, or increasing rotation length. Results for Study Scenario N1, under which 572,000 hectares (ha) of publicly owned forest are reserved and the rate of sawlog harvest is reduced from 300,000 m^3/y to 155,000 m^3/y, suggest that between 98 and 114 Mt CO_2e may be sequestered in live vegetation and debris (here termed forest carbon stocks) by 2050 relative to the Study Baseline. Reducing the rate of harvesting in this way could reduce the total pool of carbon in wood products by an estimated 2 Mt CO_2e.

Results for Study Scenarios N2 and N2A differed markedly. Under the Study Scenario N2, (which includes phasing out old growth harvesting while maintaining sawlog production at 300,000 m^3/y) carbon stocks in public forest decreased by around 3 Mt CO_2e despite the reservation of old growth forest in 2020. This effect resulted from the increase in harvest intensity required in unreserved forest in order to meet the 300,000 m^3 sawlog quota. In contrast, when the sawlog quota was reduced to 155,000 m^3/y (N2A) for public land, forest carbon stocks increased by 88-113 Mt CO_2e due to the reduction in harvesting intensity across the forest estate. Similarly, in private forests, where harvesting was assumed to decrease in line with the reduction in harvestable area, modelled forest carbon stocks also increased slightly (4-6 Mt CO_2e).

Results for Study Scenario N3 suggest that carbon stocks are also sensitive to changes in forest rotation lengths. Extending the average rotation length of regrowth forests from 80 years to 120 years increased forest carbon stocks by 46-59 Mt CO_2e. In contrast, reducing rotation lengths to 60 years decreased carbon stocks by 37-46 Mt CO_2e.

Results for Study Scenarios N4 and N5 indicate the potential effect of cessation of timber harvest in old growth forest (N4) and across all native forest (N5). Under N4, where old-growth forest was reserved while harvesting rates in unreserved forest were maintained at the same rates as the Study Baseline, forest carbon stocks increased by 36-46 Mt CO_2e by 2050. Where all native forest harvesting ceased across public and privately owned forests (N5), forest carbon stocks increased by between 210 and 270 Mt CO_2e.

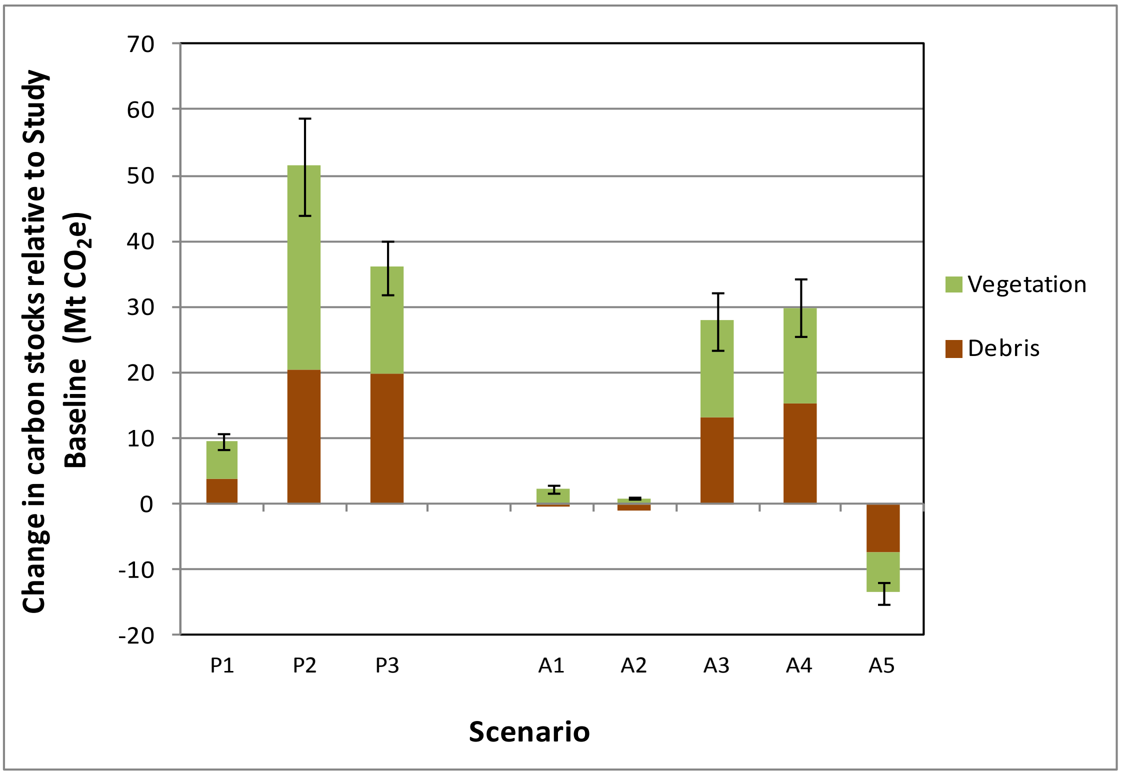


Modelled changes in carbon stocks live vegetation and debris by 2050 for the native forest management Study Scenarios relative to the Study Baseline. Carbon stocks increased for most Study Scenarios with the greatest increases associated with reductions in harvested volumes. Error bars are standard deviations of means.

Under both Study Scenarios N4 and N5, the increase in carbon stocks was greatest in the first 20 years. After 2030, the change in stocks plateaued for the Study Scenario N4 and slowed for Study Scenario N5.

Study Scenarios: Effect of altering plantation management

The plantation management related Study Scenarios include two that increase rotation length (P1 & P2) and one that increases growth rates (P3). A 10% increase in rotation length of all plantations (P1) resulted in an 8-11 Mt CO_2e increase in forest carbon stocks by 2050, while conversion of hardwood pulpwood plantations to longer rotation sawlog plantations (P2) increased forest carbon stocks by 44-59 Mt CO_2e. Increasing growth rates of all plantations (P3) resulted in a 32-40 Mt CO_2e increase in forest carbon stocks.



Modelled changes in carbon stocks in live vegetation and debris by 2050 for the plantation management (P1-P3) and landuse change (A1-A5) Study Scenarios relative to the Study Baseline. Large increases in carbon stocks were associated with conversion of pulpwood plantations to sawlog production, increasing plantation growth rates, or establishment of new plantations on cleared grassland. However, conversion of existing plantations to grassland resulted in a large decrease in carbon stocks. Error bars are standard deviations of means.

Study Scenarios: Effect of altering land use patterns

Five Study Scenarios investigated the effects of altered land use patterns, including native forest conversion (A1), replanting unstocked areas of native forests (A2) and either increasing (A3 & A4), or reducing, the total area of hardwood plantations (A5).

Under A1, continued conversion of native forest, up to the current limit of around 10,000 ha by 2015, initially decreased forest carbon stocks by 1-2 Mt CO_2e. However, carbon stocks gradually recovered to be 1-3 Mt CO_2e above the Study Baseline by 2050. This recovery was a result of reduced harvesting of remaining native forest combined with faster growth and increased sawlog yield from newly established plantations (assumed to be planted on 82% of the area cleared) compared with the relatively low productivity of the original eucalypt forest. Reforestation of cleared land with plantations boosted carbon stocks by reducing the need to harvest the remaining native forest. In contrast, permanent removal of trees across 18% of the total area resulted in a total loss of 1 Mt CO_2e over the 40 years.

Under A2, replanting land areas currently classified as ‘unstocked native forest’ (41,000 ha) with native eucalypt forest resulted in no net carbon benefit over the 40 years. This was due to an initial reduction in carbon stocks through removal of existing vegetation and debris in the ‘unstocked’ areas and the relatively slow growth of the newly established forest. Over a longer time frame, it is expected that carbon stocks would increase to exceed current carbon stocks.

Establishment of plantations across 10% of existing cleared land (A3 and A4) resulted in a substantial increase in forest carbon stocks (24-33 Mt CO_2e at current planting rates, or 25-33 Mt CO_2e for double the current rate). In contrast, removal of 25% of existing hardwood plantations after harvest (A5) resulted in a reduction in forest carbon stocks of 12-15 Mt CO_2e.

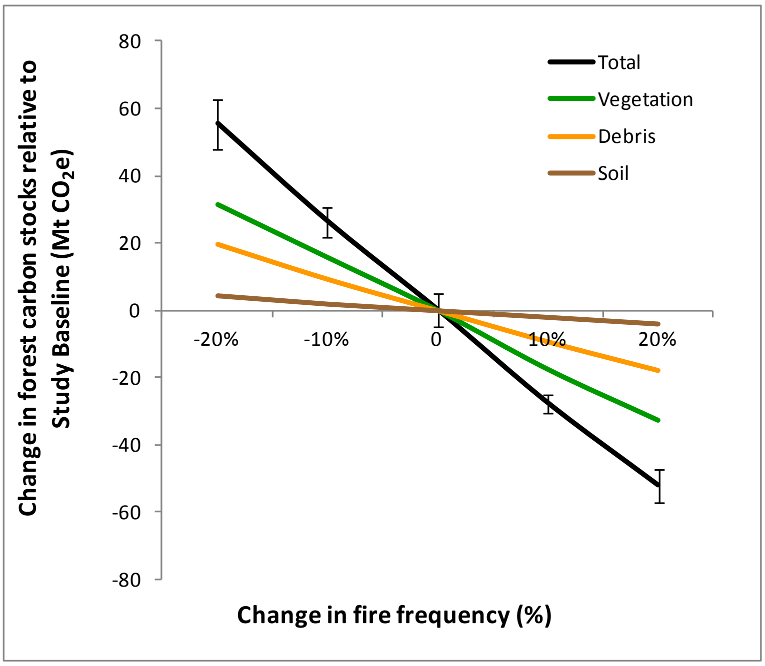
Baseline Sensitivity Scenarios

Given how critical assumptions around the Study Baseline are to estimating net abatement or emissions amounts, a series of Baseline Sensitivity Scenarios were used to test the influence of varying rotation length (tested in the native forest management Study Scenarios), varying fire frequency and varying climate.

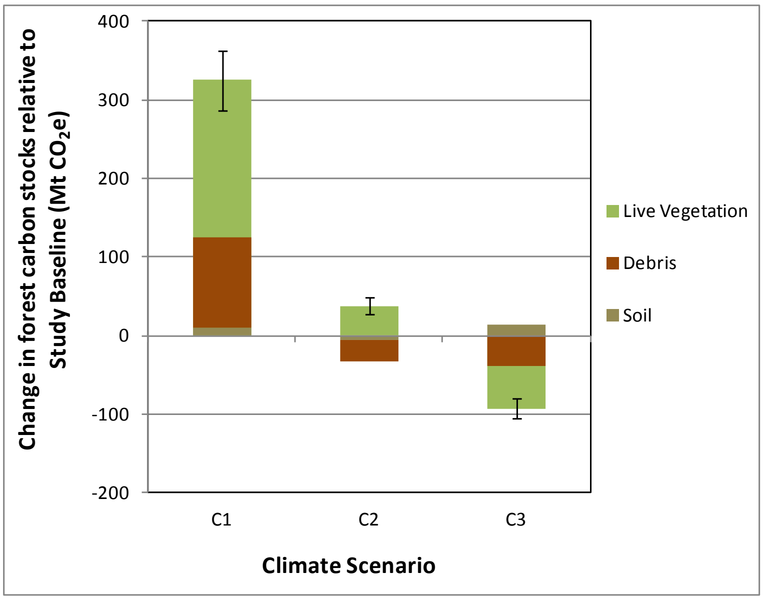
Estimates were found to be highly sensitive to fire frequency, with a 10% increase in fire frequency resulting in a 25-30 Mt CO_2e reduction in forest carbon stocks over 40 years for the Study Baseline. Similarly, decreasing fire intensity by 10% resulted in a 22-31 Mt CO_2e increase in forest carbon stocks.

The effect of climate change was tested under three alternative climate projections using published modelled changes in growth rates from ABARES and associated downscaled climate projection data from CSIRO. These analyses indicated that changes in temperature and rainfall could have major impacts on carbon stocks. Increases in growth rates of plantations and native forests under Baseline Sensitivity Scenarios C1 (warmer with similar rainfall to that currently experienced) and C2 (hotter and drier), based on results from ABARES modelling, resulted in large increases in carbon stocks in vegetation (50-240 Mt CO_2e over 40 years), while a decrease in tree growth in Baseline Sensitivity Scenario C3 (warmer and drier) reduced vegetation carbon stocks by 30-40 Mt CO_2e.

The effect of projected climate change on soil carbon differed from that for vegetation. Warmer climates which tended to increase forest growth also tended to increase decomposition rates while drier climates tended to reduce decomposition rates. As a result, soil carbon stocks decreased by 5-7 Mt CO_2e for Baseline Sensitivity Scenario C2, but increased by 12-17 Mt CO_2e for C3. The effect of climate change on debris was influenced by both growth rate and decomposition rate with an increase in debris carbon for C1, but decreases for C2 and C3.



Effect of changes in fire frequency on carbon stocks in vegetation and debris by 2050 relative to Study Baseline. There was a linear relationship between the fire frequency and change in carbon stocks relative to the Study Baseline with a 20% increase in fire frequency resulting in a 50-60 Mt CO_2e decrease in carbon stocks. Error bars are standard deviations of means.



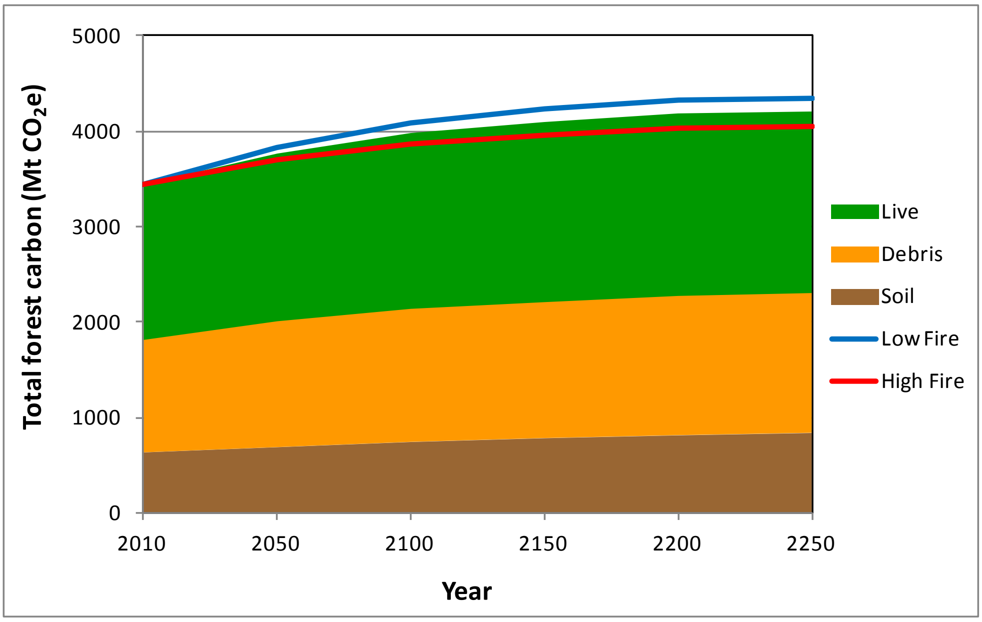
Changes in carbon stocks in live vegetation and debris by 2050 under alternative climate change Baseline Sensitivity Scenarios relative to the Study Baseline. Different Climate Change projections resulted in future carbon stocks either increasing or decreasing compared with the Study Baseline which was based on current climate. Error bars are standard deviations of means.

Carbon Carrying Capacity

Carbon Carrying Capacity is defined as the potential future carbon stock under prevailing environmental conditions in the absence of human disturbance. The potential Carbon Carrying Capacity of Tasmania's native forests was estimated by modelling forest growth over 240 years (2010 to 2200) in the absence of timber harvesting and any land clearing, or forest conversion. All native forest types across public and private land were included.

The Carbon Carrying Capacity under current fire regimes was estimated to be 1,700-2,000 Mt CO_2e for live vegetation, 1,100-1,800 Mt CO_2e for debris and 700-1,000 Mt CO_2e for soil, with the total potential carbon content of vegetation and debris estimated to be 2,900-3,900 Mt CO_2e. This figure represents an increase of 300-800 Mt CO_2e (12-26%) over current carbon stocks in vegetation and debris.

Varying fire frequency by +/- 20% resulted in only a 3% change in the estimated Carbon Carrying Capacity of vegetation and a 4-5% change in the estimated Carbon Carrying Capacity of debris and soil. This represented a 20% difference in the overall increase in carbon stocks live vegetation, debris and soil over the 240 years. However, even with a 20% increase in fire frequency, carbon stocks continued to increase over time in the absence of timber harvesting; only plateauing after 2200.



Modelled potential increase in forest carbon stocks over time in the absence of timber harvesting under current fire regimes and with a 20% increase (red line) and 20% decrease (blue line) in fire frequency. The results indicate that total carbon stocks in live vegetation, debris and soil could increase by 300-800 Mt CO_2e over 240 years. Increasing fire frequency resulted in a smaller increase in vegetation carbon stocks while decreasing fire frequency resulted in a larger increase over time.

Carbon markets

The introduction of the Australian Carbon Pricing Mechanism (ACPM) will create a major domestic mandatory market for eligible carbon abatement. The linked Carbon Farming Initiative (CFI) allows for recognition of a specific set of eligible forest management activities that generate abatement. For eligible forest management activities, it is possible to generate one of two types of credit: Kyoto-compliant ACCU's (Kyoto ACCU's), or Non-Kyoto compliant ACCU's (Non-Kyoto ACCU's). Critically, only Kyoto ACCU's can be used by emitters to offset their mandatory emissions compliance obligations under the ACPM.

This has important implications for abatement occurring in Tasmanian forests, since, by virtue of their recognition under a mandatory market (the ACPM); there will be a substantially stronger market demand for Kyoto ACCU's. In comparison, the main market for Non-Kyoto ACCU's is likely to be the much smaller, lower value, voluntary market.

Key challenges identified with participation under the CFI included:

- lack of Approved Methodologies for almost all of the activities contemplated by the Study Scenarios;
- most activities are presently not listed on the CFI Positive List;
- additionality may be challenging to demonstrate for some of the Study Scenarios that contemplate reduced log extraction rates if there is an existing business as usual trend for this reduction, or where legislative instruments are the underlying driver of changes to forest management regimes;
- there are significant barriers to entry for plantations (single-species) established in areas where average rainfall is ≥600mm per annum;
- activities contemplated under Study Scenario N3 may be excluded by virtue of Section 27(j) of the CFI Act; and
- any abatement occurring in plantations established under Managed Investment Scheme (MIS) structures is excluded from participating.

In addition to the CFI, key features of the international voluntary marketplace and the Verified Carbon Standard were reviewed. A number of Approved Methodologies exist under the VCS that have application to the Study Scenarios. Key issues associated with recognition under the VCS include:

- it is presently not possible to recognise Kyoto eligible abatement, at least for reforestation activities, by virtue of this abatement being referenced in Australia's international reporting (creates a double-counting issue);
- as for the CFI, additionality may be challenging to establish in some specific instances.

Projected abatement for 2013-2050 by tenure, with leakage factor and risk buffer netted.

Tenure/scenario	Public (x 1 million t CO_2e)	Private (x 1 million t CO_2e)	Total (x 1 million t CO_2e)
N1. Reserve 572,000 ha, reduce cut from public native forests to 155,000m³ pa sawlog, 265,000 m³ pa peeler log.	81 – 93	N/A	81 – 93
N2. Phase out old growth harvesting by 2020, increase harvest in regrowth forest to maintain 300,000m³ pa sawlog.	No net abatement	3 – 4	3 – 4
N2A. Phase out old growth harvesting by 2020, vary harvest in regrowth forest to maintain 155,000 m³ pa sawlog.	74 – 97	3 – 4	77 – 101
N3. Vary rotation length for harvest in regrowth from the Study Baseline (80 years) up to 120 years.	23 – 29	12 – 15	35 – 44
N4. Immediate cessation of old growth harvest (public & private), no increase in harvesting of regrowth.	19 – 22	9 – 11	28 – 33
N5. Immediate cessation of all native forest harvesting on public & private land.	96 – 111	77 – 88	173 – 199

Tenure/scenario	Kyoto <600mm (x1 million t CO_2e)	Kyoto ≥600mm (x1 million t CO_2e)	Non-Kyoto (x1 million t CO_2e)	Total (x1 million t CO_2e)
Public				
P1. Increase plantation rotation length by 10%.	~0	~0	2 – 3	2 – 3
P2. Convert pulplog plantations to sawlog.	~0	~0	~1	~1
P3. Increase plantation growth rate by 25%.	~0	~0	9 – 11	9 – 11
Private				
P1. Increase plantation rotation length by 10%.	~0	1 – 2	~3	4 – 5
P2. Convert pulplog plantations to sawlog.	~0	9 – 12	19 – 25	28 – 37
P3. Increase plantation growth rate by 25%.	~0	4 – 5	9 – 11	13 – 16

Tenure/scenario	Kyoto <600mm (x 1 million t CO_2e)	Kyoto ≥600mm (x1 million t CO_2e)	Non-Kyoto (x1 million t CO_2e)	Total (x1 million t CO_2e)
Public				
A2. Unstocked areas in native forests are regenerated.	Uncertain	Uncertain	Uncertain	<0
Private				
A1. Conversion of native forest to non-forest.				~1*
A2. Unstocked areas in native forests are regenerated.	Uncertain	Uncertain	Uncertain	~0
A3. Expansion of plantations at average rate.	4 – 5	18 – 24	~0	22 – 29
A4. Expansion of plantations at double rate.	4 – 6	19 – 25	~0	23 – 30

* Assumes an Avoided Deforestation project structure.

More broadly, key challenges in participating in voluntary markets include the relatively low market size, low value being realised for carbon credits ($6 per credit, global weighted average for 2011) and general oversupply of carbon credits in the market. The introduction of the Non-Kyoto Fund will establish the Australian government as a large voluntary purchaser (Non-Kyoto ACCU's created under CFI), which should substantially boost the domestic voluntary market ($250 million over six years).

Accessing the opportunity

On balance, while no option would be without substantial challenges, it was considered that there were realistic options available for most of the abatement generating Study Scenarios to participate in either mandatory or voluntary markets, or both in some instances. Exceptions to this were Study Scenarios P1 & P3, which reference a modest increase in plantation rotation length and increased growth through management (respectively). In both cases, it was considered the case for additionality was not strong and that this may limit the successful structuring of Carbon Projects around these activities.

The CFI Regulations indicate Reforestation and Avoided Deforestation are activities that are potentially eligible as Kyoto offsets projects, meaning they are potentially eligible for the creation of Kyoto ACCU's. Study Scenarios that reference plantation expansion (A3 & A4), and to a lesser extent altered management of existing plantations (P2) have potential as Reforestation projects. If avoided, the deforestation pattern contemplated by Study Scenario (A1) could be structured as an Avoided Deforestation project.

The Study Scenarios that contemplate changes to native forest management (N1 - N5) are likely to be considered a form of Improved Forest Management project. Under current policy settings and structuring of the CFI, abatement arising from this type of activity would presently not qualify for the creation of Kyoto ACCU's, so that the target market would effectively be limited to voluntary markets. In these cases, proponents effectively have the option of pursuing registration and Non-Kyoto ACCU generation under the CFI, or registration and VCU generation under the Verified Carbon Standard.

Valuing the opportunity

Abatement associated with the Study Scenarios was separated into estimates of potentially Kyoto eligible and non-eligible, split by tenure (private verse public). To consider that proportion of abatement that might be available for the creation of carbon credits, the amount of abatement occurring from 2013-2050 for each Study Scenario was estimated (with consideration of uncertainty in modelling) and allowances for risk buffer (5 - 7.5%) and market leakage (8% for native forest, 17% for plantations) factors were netted.

Net Present Value (NPV) estimates were generated in relation to abatement arising from the Study Scenarios (where a commercial Carbon Project was successfully established, and various commercial carbon project structuring options. A range of carbon pricing scenarios were referenced with relevance to mandatory and voluntary markets. It is recommended that the assumptions and approach that are fully detailed in the main body of the report be carefully reviewed. It is also recommended that further sensitivity analyses, including around assumed discount rates, be conducted in future commercial assessments.

Critically, in estimating NPV, no consideration was made of opportunity costs arising from, for example, reduced extraction of timber products, as these were beyond the scope of the Carbon Study. In effect, this means that while it is reasonable to use these NPV estimates as a comparison against 'doing nothing' following a prior decision to reduce extraction, it is not reasonable to infer the NPV represents the net value that actually arises due to making the decision. For the latter, opportunity costs associated with foregone revenue would need to be considered.

Based on the approach to estimation of NPV that was applied under the Carbon Study, positive returns are associated with establishing Carbon Projects around all of the net abatement generating native forest management Study Scenarios considered, with highest NPV's associated with N1 (Public: $80-240 million), N2A (Public: $80-250 million) and N5 (Public: $80-280 million; Private: $80-230 million).

Positive NPV estimates were associated with Kyoto eligible abatement occurring at <600mm, arising from Study Scenarios that referenced expansion of the plantation estate, being A3 & A4 ($60-170 million). For Kyoto eligible abatement occurring at ≥600mm rainfall, there are some considerable eligibility barriers to achieving the issue of Kyoto ACCU's under the CFI. However, if these could be overcome, the rewards could be substantial where these plantation expansion scenarios arise, with NPV estimates ranging from $270-760 million.

For the plantation management related Study Scenario P2, NPV's were positive where a Carbon Project was structured around privately owned, non-Kyoto eligible abatement (Private: $10-60 million). In the case of potential Avoided Deforestation (subset of Study Scenario A1) projects, which would likely be Kyoto-eligible, NPV estimates are also positive ($10-30 million).