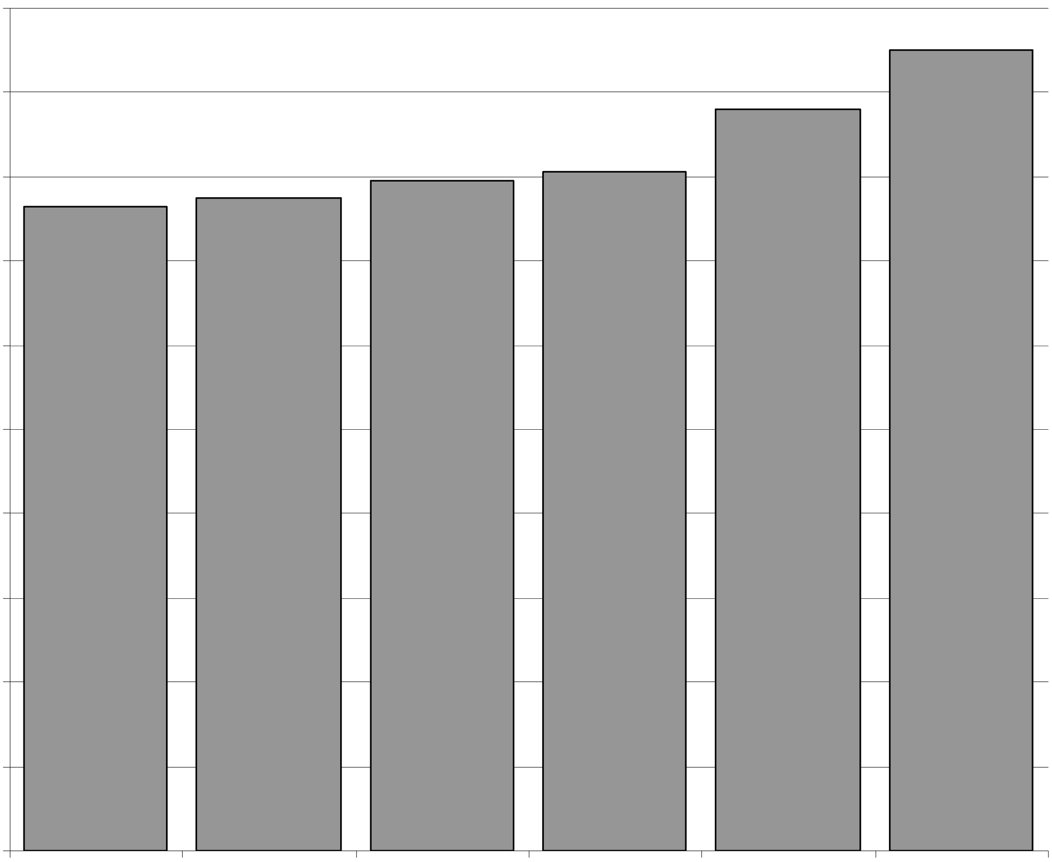
Forestry Tasmania's

Carbon Sequestration Position



Forestry Tasmania

December 2nd, 2007

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The report contains the opinion of MBAC with regards Forestry Tasmania's carbon sequestration position (an estimate) based on information supplied by Forestry Tasmania supplemented by information provided by MBAC from publicly available sources and compiled into a simple model using intellectual property contributed by FT and MBAC. Nothing in the report is, or should be relied upon as, a promise by MBAC that these estimates will occur. The variation can be significant. The IP contributed by the parties remains the property of the parties.

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7 December 2007

Acknowledgements

MBAC acknowledges the work undertaken by FT staff, in particular Mike McLarin, Matt Wood, Tom Kelley and Kevin Swanepoel and the recommendations from Dr Hans Drielsma. MBAC has simply taken this work, checked it, made some bold assumptions for any omissions (ie work yet to be tackled by FT), benchmarked the results against some very broad national figures and collated the data into a simple Microsoft Excel© model. MBAC wishes to thank the FT staff above who were able to explain their work and provide the material for MBAC to complete this and develop the model.

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GLOSSARY

A/R	Afforestation/Reforestation
AG	Above ground
AGO	Australian Greenhouse Office
BG	Below ground
Cat	Category
CRCGA	Cooperative Research Centre for Greenhouse Accounting
Euc	Eucalypt
FT	Forestry Tasmania
FWPRDC	Forest and Wood Products Research Development Corporation
FullCAM	Carbon Accounting Model
GGAS	NSW Greenhouse Gas Abatement Scheme
HWD	Hardwood
HWP	Harvested wood products
IPCC	Intergovernmental Panel on Climate Change
N	No
NCAS	National Carbon Accounting System
NCAT	National Carbon Accounting Toolbox
NF	Native forest
SWD	Softwood
TimberCAM	Timber Carbon Accounting Model
Y	Yes
YT	Yield table

EXECUTIVE SUMMARY

This report builds on substantial work undertaken by Forestry Tasmania (FT) staff in identifying the major components of carbon pools in FT's commercial and non-commercial estate as well as forest product production and life cycle assessments. This project checks this work, makes minor modifications, identifies any gaps, fills these gaps and benchmarks the results with broader global, national and state estimates of forest related carbon pools.

The main focus was to compile the information into a simple carbon model that FT can use on a periodic basis to report their carbon balance. The MBAC work supports FT's initial assessments based on their Woodstock (estate model) and shows a close correlation between FT's and MBAC's approach to estimating the forest carbon pool. There is also a reasonable correlation between the FullCAM Approach and Woodstock, after completing and refining this work.

The Woodstock derived forest based carbon estimate was 151 million tonnes in 2007, consisting of 61 million tonnes (40%) from the commercial estate and 90 million tonnes (60%) from the non-commercial estate. Note, all figures are quoted as pure carbon, and may be converted to CO_2-e (the standard trading unit of carbon) by multiplying by 44/12.

Million tonnes carbon					
Year	Commercial native forest	Eucalypt plantations	Softwood plantations	Non-commercial native forest	Total
2007	56.7	1.3	3.1	90.3	151.3

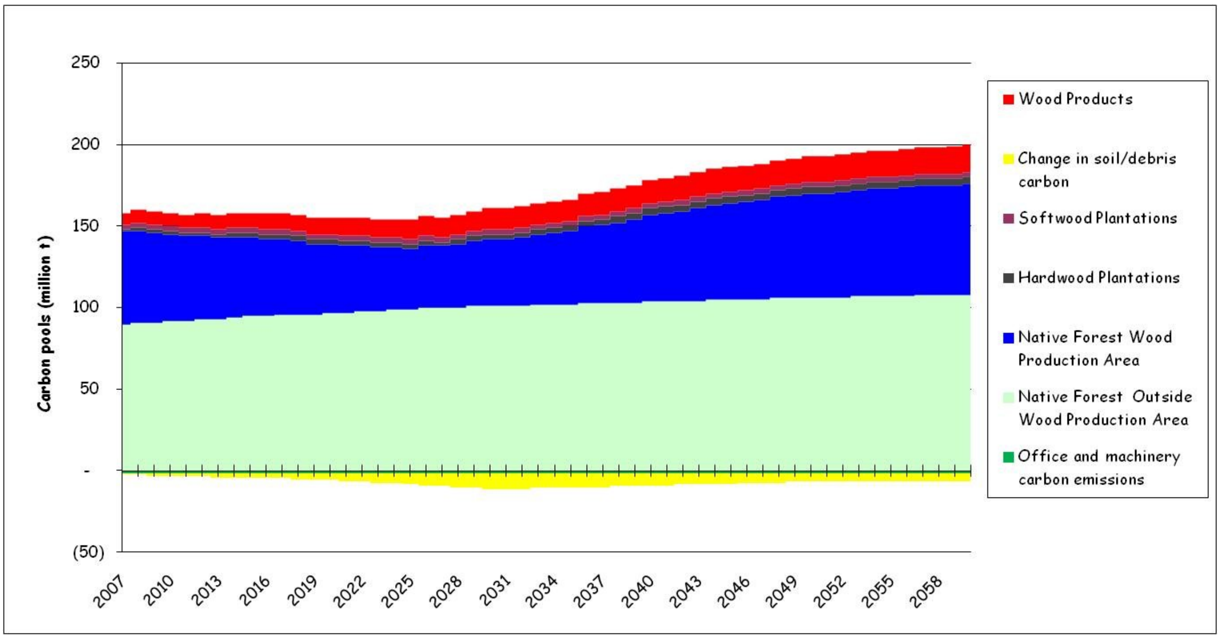
The FT forest estate modelling approach, with some additional values added and subtracted after modelling, is recommended by MBAC. This approach projects standing volume in the forest and, external to the estate model, converts this to carbon equivalent using simple but acceptable ratios and formulae to account for above and below ground biomass. The estate model estimates volume over time providing an acceptable means to also estimate carbon balance.

FT has also estimated the mass of carbon in timber and wood products in the marketplace. This work, based on TimberCam, suggested values for years in service, CO_2-e loss to the atmosphere while in service, proportions recycled, proportions sent to land fill, and decay rate (CO_2-e generation) in landfill. Only three products were recognised – housing material (long life cycle), fibre (short lifecycle) and waste (immediate loss). Considerable work is required here, as the model assumes 1989 to 2006 annual production and 2007 to 2050 annual production is the same as FT's 2006 forest product production. Notwithstanding, wood products modelling estimated 7 million tonnes of carbon stored in finished products such as timber, panels and paper in 2007, rising to 16 million tonnes by 2050. The FullCAM work identified 4-5 million tonnes associated with carbon in products. The basis for this calculation has not been assessed by MBAC.

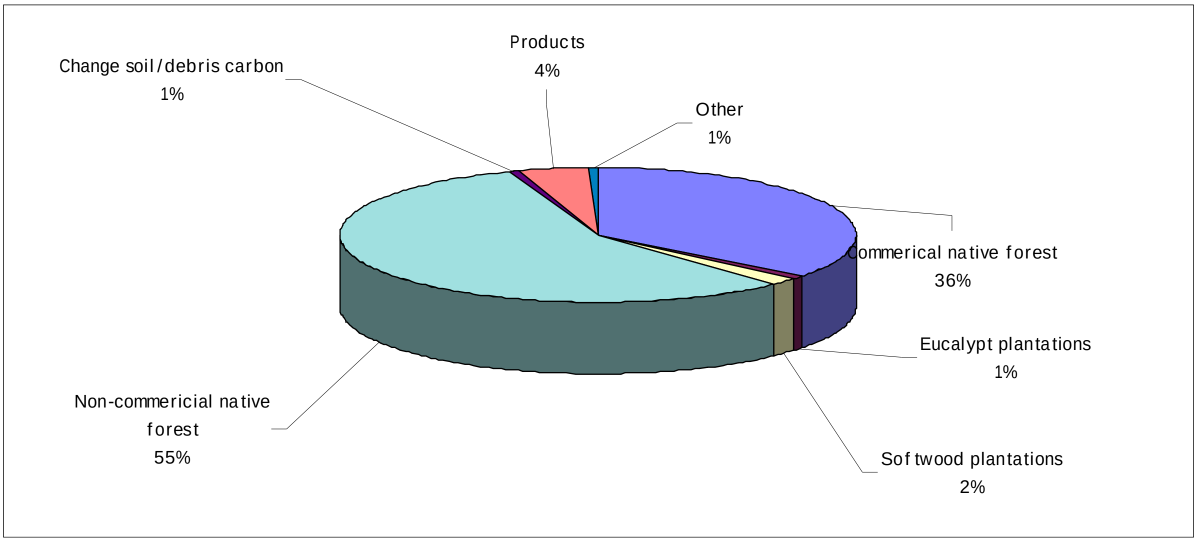
Using the MBAC life cycle assumptions, FT's combined forest and wood product carbon store, less emissions (ie head office, harvesting, energy consumption etc) was estimated at 156 million tonnes in 2007, rising to 187 million tonnes in 2050, with a wide confidence interval.

Year	Commercial Native Forest	Euc pltns	SWD pltns	Non-commercial Native Forest	Change in soil/debris carbon	Timber and Wood Products	Emissions	Total Carbon Balance
2007	57	1	3	90	-1	7	-1	156
2010	53	2	3	92	-2	8	-1	155
2020	42	3	3	97	-4	10	-1	150
2030	41	3	3	101	-10	13	-1	150
2040	53	4	3	104	-8	14	-1	169
2050	64	4	3	106	-5	16	-1	187

The change in carbon pools over time is illustrated in the figure below.



The contribution of each component to the carbon balance, in 2007, is shown below.



1 INTRODUCTION

1.1 OBJECTIVE

To provide an estimate of Forestry Tasmania's (FT's) carbon pool in the forest, forest soils, and carbon storage in wood products. Undertake this by developing a basic model to accommodate these data to allow FT to update these estimates based on changing forest and market conditions.

1.2 DELIVERABLES

1. Check the logic and frameworks for each approach (Woodstock, FULLCAM, TimberCAM), focusing on area, merchantable to gross volume, stem volume increment, basic density, stem to canopy biomass, stem to root biomass, carbon proportion, commercial and non-commercial forests.
2. Undertake a gap-analysis – what has been completed and what needs to be completed. Fill in the gaps using best available knowledge, recognising some of this may be within FT and some elsewhere (ie MBAC, AGO, FWPRDC, NCAS etc). Bring the FT and MBAC work together (or complete the FT work to a preliminary stage) acknowledging and recognising the work already undertaken by FT staff.
3. Benchmark the outputs against other independent data (ie MBAC data, AGO data etc) where available and relevant (ie comparable) - at a forest type level and against broader Australian figures (AGO, FWPRDC etc) i.e. the FT estate as a proportion of reported national or state values.
4. Identify the major FT carbon components by mass (million tonnes) and forest area (ha) - i.e. what strata and products account for most of FT's sequestered carbon? This will allow MBAC to focus attention on the major components.
5. Prepare a basic model covering the FT estate for commercial and non-commercial forests, combining in-forest and in-service carbon values, making sure the individual components remain identifiable.
6. Prepare a brief internal report including limitations, recommended steps for any further carbon accounting refinement i.e. verification, imprecision, concerns, acknowledgements.

1.3 INFORMATION PROVIDED TO MBAC

- FT Carbon Management Policy.
- FT draft Carbon Management Strategy.
- FT draft Technical Report: The carbon cycle in Tasmanian State forest.
- Estate model approach – Excel workbook containing calculations providing residual standing volume input from Woodstock.
- FULLCAM approach – summary graph, model, plot files and estate files.
- Forest product life cycle analysis inputs.

- Area by broad forest class.

1.4 LOGIC AND FRAMEWORK ASSESSMENT

There are innumerable methods used in Australia and overseas to estimate the mass of carbon stored in forests. It is not the purpose of this report to document or comment on these.

FT has developed three approaches for carbon accounting purposes. The first is to use their Woodstock estate model to determine total standing merchantable volume and convert this to carbon mass. The second approach is to use FullCAM, a dedicated carbon accounting model developed by the Australian Greenhouse Office (AGO). The third is to develop a product life cycle model based on TimberCam, also developed by the Cooperative Research Centre for Greenhouse Accounting (CRCGA).

The approach MBAC has taken is to:

- Check the calculations used by FT.
- Fill in any gaps.
- Compare the outputs (i.e. mass of carbon) with alternative calculations provided by MBAC.
- Benchmark all calculations against some industry standard values (i.e. national and state estimates).
- Further develop the TimberCam model (called TimberCam proxy).
- Compile a simple Microsoft Excel model which belongs to FT, is for FTs use and contains intellectual property from FT and MBAC.

2 FT APPROACH 1 - ESTATE MODEL APPROACH

2.1 COMMERCIAL ESTATE

Native forest wood production estate

For the commercial estate - FT's Woodstock model identifies potential wood production by coupe (based on underlying forest class yield tables). Woodstock also identifies residual volume comprising the un-logged area in a coupe. Combined, an estimate of total standing merchantable volume per gross hectare is available. For carbon accounting, FT has:

- Converted the Woodstock estimate of merchantable standing volume to total under-bark bole volume using internal ratios (on average 20% is non-merchantable) by multiplying by 20/80 plus 1 or 1.25.
- Given not all a coupe is harvested (ie on average 22.5% of a coupe is retained), the net gross bole volume is converted to a gross commercial area equivalent by multiplying by 22.5/77.5 plus 1 = 1.29.
- This then is converted to biomass by multiplying by basic density (in units of tonnes/m^3 = kg/m^3/100) to derive above ground stemwood dry tonnes.
- This is converted to total above ground biomass by multiplying by an industry sourced (NCAS Technical Report No 17) conversion factor for native eucalypt forest (1.46).
- To derive below ground biomass, a industry sourced (NCAS Technical Report No 17) shoot to root ratio is used (1:0.25). A minor change was made by MBAC for the ratio to apply to above ground biomass rather than shoot volume.
- By adding the above ground biomass to the root biomass, an above and below ground (i.e. total) biomass figure is derived.
- This is converted to carbon mass by multiplying by an accepted (Source: NCAS Technical Report No 17) carbon fraction (0.5) see Table 1.

Table 1: FT's approach to convert merchantable volume of native forest to carbon mass

Component	Factor	Description/reference
Convert merchantable to total under-bark stemwood volume	1.25	Assume 20% of total stemwood volume is non-merchantable
Area discount adjustment[1]	1.29	Assume average statewide area discount is 22.5%
Basic Density kg/m^3 (HWD)	500	Source: NCAS Technical Report No 18
Expansion factor	1.46	Source: NCAS Technical Report No 17 pg. 21
Root to Shoot ratio	0.25	Source: NCAS Technical Report No 17 pg. 63
Convert total biomass to carbon mass	0.5	Source: NCAS Technical Report No 17 pg. 15

[1] The forest estate model yields are per net ha, to account for the area within a provisional coupe that is not actually harvested come operation time. Therefore a statewide average is used to boost standing volume of entire coupe area.

The mathematics for the commercial native estate is provided in Table 2. This shows that 77.1 million m^3 merchantable volume equates to 124.3 million m^3 of total stemwood after area adjustment. This in turn equates to 56.7 million tonnes carbon for the commercial estate. The Table also shows the MBAC approach, which determines green volume of the various components (stem, bark/branches/leaves, roots) and converts these to dry mass and then carbon. In this case, MBAC estimates there is 55.9 million tonnes carbon in the commercial native forest estate. There is an excellent correlation between the two approaches.

Table 2: Mathematics for determining carbon mass in the commercial native forest estate as at 30 June 2007

FT - Component	Factor	Calculation	Units
Merchantable volume		77.1	million m^3
Convert merchantable to total stemwood volume	1.25	96.4	million m^3
Area discount adjustment	1.29	124.3	million m^3
Basic Density (kg/m^3)	500	62.2	million t
Expansion factor (to AG biomass)	1.46	90.8	million t
Root to Shoot conversion (BG biomass)	0.25	22.7	million t
Total biomass		113.4	million t
Convert total biomass to carbon stocks	0.5	56.7	million t

MBAC - Component	Factor	Calculation	Units
Merchantable volume		77.1	million m^3
Convert merchantable to total stemwood volume	1.25	96.4	million m^3
Area discount adjustment	1.29	124.3	million m^3
Stem:branch/bark/leaves multiplier	0.4	49.7	million m^3
Stem:roots	0.4	49.7	million m^3
Total		223.8	million m^3
Basic Density (kg/m^3)	500	111.9	million t
Carbon fraction	0.5	55.9	million t

As a 'first-cut' approach, either method is satisfactory for the circumstances before considering changes in soil carbon.

Eucalypt plantation estate

FT has used an identical approach (to the commercial native estate) to estimate carbon sequestered in their eucalypt plantation estate, although Woodstock already reports the total standing volume and there are no area adjustments required. Also, a different expansion factor specific to eucalypt plantations (as opposed to native forest) of 1.34 is used for calculation of above ground biomass from total stem volume (NCAS Technical Report No 17 pg. 21). The calculations are shown in Table 3. From this, FT estimates there is 1.3 million tonnes carbon in their eucalypt plantations as at June 2007. Using the MBAC approach, we estimate there may be 1.4 million tonnes carbon in the eucalypt plantations. Again, this is an excellent correlation between the two approaches.

Table 3: Mathematics for determining carbon mass in the eucalypt plantation estate as at 30 June 2007

FT - Component	Factor	Calculation	Units
Merchantable volume		3.1	million m^3
Convert merchantable to total stemwood volume	1	3.1	million m^3
Area discount adjustment	1	3.1	million m^3
Basic Density (kg/m^3)	500	1.5	million t
Expansion factor (to AG biomass)	1.34	2.1	million t
Root to Shoot conversion (BG biomass)	0.25	0.5	million t
Total biomass		2.6	million t
Convert total biomass to carbon stocks	0.5	1.3	million t

MBAC - Component	Factor	Calculation	Units
Merchantable volume		3.1	million m^3
Convert merchantable to total stemwood volume	1	3.1	million m^3
Area discount adjustment	1	3.1	million m^3
Stem:branch/bark/leaves multiplier	0.4	1.2	million m^3
Stem:roots	0.4	1.2	million m^3
Total		5.6	million m^3
Basic Density (kg/m^3)	500	2.8	million t
Carbon fraction	0.5	1.4	million t

Softwood plantation estate

FT has used the same approach (to both the commercial native estate and eucalypt plantations) to estimate carbon sequestered in their softwood plantation estate. As with the eucalypt plantations, Woodstock reports the total standing volume and no area adjustments required. A species specific expansion factor of 1.37 was used for calculation of above ground biomass from total stem volume (NCAS Technical Report No 17 pg. 21). Additionally, a basic density to 400 kg/m^3 was used.

The calculations for softwood plantations are shown in Table 4. From this, FT estimates there is 3.1 million tonnes carbon in their softwood plantations as at June 2007. Using the MBAC approach, we estimate there may be 3.2 million tonnes carbon in the softwood plantations. Again, this is an excellent correlation between the two approaches.

Table 4: Mathematics for determining carbon mass in the softwood plantation estate as at 30 June 2007

FT - Component	Factor	Calculation	Units
Merchantable volume		8.9	million m^3
Convert merchantable to total stemwood volume	1	8.9	million m^3
Area discount adjustment	1	8.9	million m^3
Basic Density (kg/m^3)	400	3.6	million t
Expansion factor (to AG biomass)	1.37	4.9	million t
Root to Shoot conversion (BG biomass)	0.25	1.2	million t
Total biomass		6.1	million t
Convert total biomass to carbon stocks	0.5	3.1	million t

MBAC - Component	Factor	Calculation	Units
Merchantable volume		8.9	million m^3
Convert merchantable to total stemwood volume	1	8.9	million m^3
Area discount adjustment	1	8.9	million m^3
Stem:branch/bark/leaves multiplier	0.4	3.6	million m^3
Stem:roots	0.4	3.6	million m^3
Total		16.1	million m^3
Basic Density (kg/m^3)	400	6.4	million t
Carbon fraction	0.5	3.2	million t

2.2 NON-COMMERCIAL ESTATE

The approach to the dedicated non-commercial estate is similar to the commercial native forest estate, although standing volume is estimated by FT's Woodstock system as total stem volume and accounts for 100% of the gross area (FT's Mike McLarin, pers. comm.). The reasons for this are understood and accepted by MBAC. The results (FT vs MBAC approaches), are shown in Table 5 below. The FT approach estimates 90.3 million tonnes carbon and the MBAC approach 89.0 million tonnes. Again, both are well within the confidence intervals for the estimates.

Table 5: Mathematics for determining carbon mass in the non-commercial native forest estate as at 30 June 2007

FT - Component	Factor	Calculation	Units
Merchantable volume		197.8	million m^3
Convert merchantable to total stemwood volume	1	197.8	million m^3
Area discount adjustment	1	197.8	million m^3
Basic Density (kg/m^3)	500	98.9	million t
Expansion factor (to AG biomass)	1.46	144.4	million t
Root to Shoot conversion (BG biomass)	0.25	36.1	million t
Total biomass		180.5	million t
Convert total biomass to carbon stocks	0.5	90.3	million t

MBAC - Component	Factor	Calculation	Units
Merchantable volume		197.8	million m^3
Convert merchantable to total stemwood volume	1	197.8	million m^3
Area discount adjustment	1	197.8	million m^3
Stem:branch/bark/leaves multiplier	0.4	79.1	million m^3
Stem:roots	0.4	79.1	million m^3
Total		356.1	million m^3
Basic Density (kg/m^3)	500	178.0	million t
Carbon fraction	0.5	89.0	million t

2.3 COMBINED FOREST ESTATE

Given the consistent and close correlation between the FT and MBAC approaches to calculation of forest carbon, MBAC suggests the values derived by FT for the commercial native forest, eucalypt plantations, softwood plantations and non-commercial estate, before considering any omissions such as change in soil carbon, are appropriate for the purpose of estimating carbon stored in the estate with a 'fairly wide' confidence interval.

Combining carbon estimates for 2007, FT's Woodstock approach suggests there is 151.3 million tonnes of carbon which agrees closely with the MBAC approach (149.6 million tonnes) before considering omissions like changes in soil carbon (see later) for example.

Table 6: FT and MBAC estimates of carbon mass (Million tonnes) for the combined (commercial and non-commercial estate) as at 30 June 2007

Year	Commercial native forest	Eucalypt plantations	Softwood plantations	Non-commercial native forest	Total
FT	56.7	1.3	3.1	90.3	151.3
MBAC	55.9	1.4	3.2	89.0	149.6

The area of each of the components of FT's estate is shown in Table 7, along with the estimates total carbon and total carbon/ha, plus above ground biomass and above ground biomass/ha. The above ground densities can be used as a check on the magnitude of the carbon estimates.

The above ground biomass densities for the native forest appear low compared to published estimates. At 168 to 181 tonnes/ha, the above ground biomass appears more closely representative of medium woodland (150 tonnes/ha) to tall woodland (200 tonnes/ha) forest types (NCAS Technical Report No 17, p15). Notwithstanding, estimated carbon density was estimated at 105 to 113 tonnes/ha

For the eucalypt plantations, carbon density is much lower at 66 tonnes/ha. Assuming an MAI of 16 m^3/ha/yr and an average age of 6 years, then above ground biomass would be expected to be 64 tonnes/ha (16 m3/ha/yr x 6 yrs x 0.5 tonnes/m3 x 1.34 expansion factor). This is in close agreement with the estimate (Table 7).

Similarly, for Radiata pine, carbon density is 93 tonnes/ha. Assuming an MAI if 16 m^3/ha and an average age of 12.5 years, then above ground biomass would be expected to be 137 tonnes/ha (using the expansion factor of 1.37). This is slightly low compared to the estimate (Table 7).

It should be noted that these apparent under-estimates for the native forest and softwood plantation estates relate to the initial standing volume and not the conversion of volume to carbon per se.

Table 7: Above ground biomass and total carbon stocks

Factor	Commercial native forest	Eucalypt plantations	Softwood plantations	Non-commercial native forest	Total
FT land area (000 ha)	540.8	31.2	52.6	798.2	1,422.9
FT Carbon (million tonnes)	56.7	1.3	3.1	90.3	151.3
Carbon (tonnes/ha)	105	41	58	113	106
FT above ground biomass (million tonnes)	90.8	2.1	4.9	144.4	242.1
Above ground biomass (tonnes/ha)	168	66	93	181	170

2.4 FT FORWARD ESTATE MODELLING RESULTS

FT has used Woodstock to report estimated standing volumes for each component of their estate from 2007 to 2050. The above analysis assessed the 2007 calculations and showed there was a good correlation between FT's outputs and MBAC's cross check on these estimates.

Using their standing volume projections from Woodstock, FT estimated carbon stocks into the future using the same model as for the 2007 calculations. FT provided preliminary yield estimates to MBAC in March 2007. Revised yield estimates resulting from a review of FT's sustained yield calculations were provided to MBAC in November 2007.

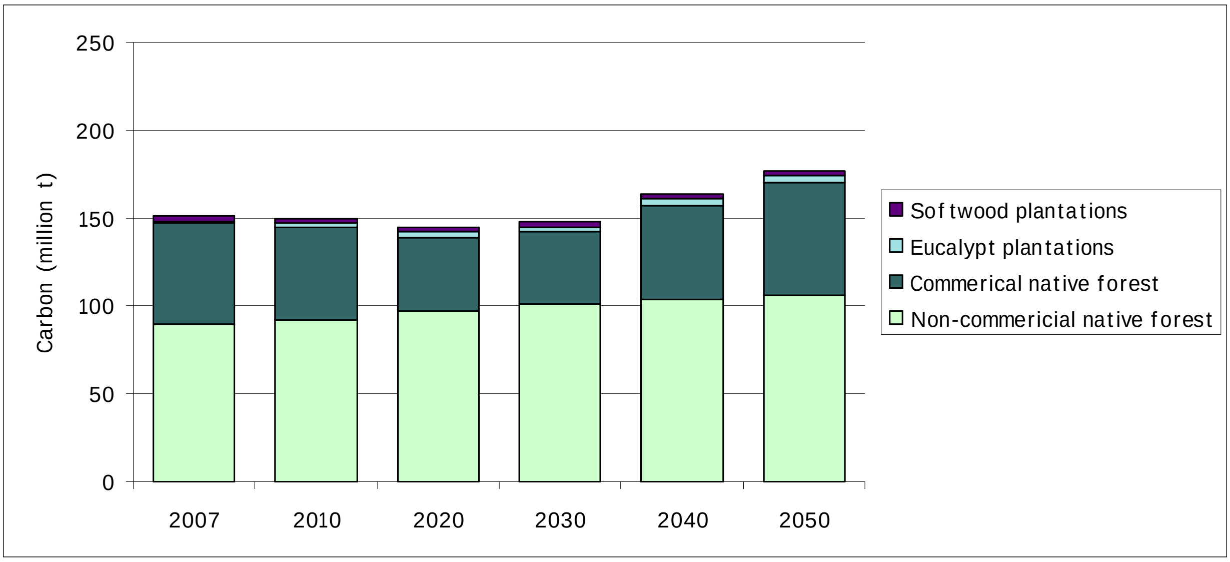
Based on these revised standing volume estimates, FT estimated carbon contained in the commercial crop ranged from a present mass of 61 million tonnes, declining to 47 million tonnes in 2030, then increasing to 71 million tonnes in 2050 (Table 8 and Figure 1). These changes are the net result of growth in the eucalypt plantation estate (from 1 million tonnes of carbon in 2007 to 4 million tonnes of carbon in 2050), and an initial decline in commercial native forest carbon from 57 million tonnes in 2007 to 41 million tonnes, followed by growth back to 64 million tonnes in 2050. Softwood carbon stores were static throughout the projection period.

In contrast to the commercial native forest, projected carbon storage in the non-commercial estate showed a steady rise from 90 million tonnes in 2007 to 106 million tonnes in 2050 (Table 8 and Figure 1).

Table 8: FT Woodstock derived forest carbon estimates – million tonnes carbon

Year	Commercial native forest	Eucalypt plantations	Softwood plantations	Non-commercial native forest	Total C
2007	57	1	3	90	151
2010	53	2	3	92	150
2020	42	3	3	97	145
2030	41	3	3	101	148
2040	53	4	3	104	164
2050	64	4	3	106	177

Figure 1: FT Woodstock derived forest carbon estimates – million tonnes carbon



The rising carbon stored in the non-commercial estate appears at odds with the commercial native forest estate. This was also identified as an issue in the previous MBAC report on this work. MBAC previously speculated that the rising carbon in the non-commercial estate might be due to constantly rising yield tables in Woodstock. This assumption remains valid.

To address this issue in the present carbon estimates, FT applied their basic yield curves (as used for the commercial native forest), but have only allowed the forest to grow on for 20 years before constraining growth (Hans Drielsma, pers. comm.). This assumption was made in order to allow regrowth areas within the non-commercial forest to continue growing to maturity (Mike McLarin, pers. comm.) It is not possible for MBAC to review this assumption or the underlying growth model; however, this appears to be a reasonable assumption.

3 APPROACH 2 - FULLCAM

The following section reports MBAC's FullCAM analysis and identifies change in soil carbon and litter carbon, which we will added back into the above Woodstock data.

FullCAM[2] is the model contained within the National Carbon Accounting Toolbox (NCAT) developed by the Australian Greenhouse Office (AGO). FullCAM integrates a suite of component models to calculate carbon flows associated with biomass, litter and soil pools in forest and agricultural systems.[3] Its primary purpose is to report national carbon balance associated with land use change.

There has been some discussion that FullCAM can be manipulated to produce varying results and there will likely be differences between FullCAM outputs and other models. It is not surprising FT has derived different results when using their internal model (i.e. Woodstock) and FullCAM.

FT divided their estate into 21 strata - 14 commercial and 7 non-commercial strata as shown in Table 9. The softwood estate, plus approximately 100 000 ha of non-commercial native forest remains to be allocated to a stratum.

Table 9: FT FullCAM commercial and non-commercial strata

Commercial strata	Non-commercial strata
Wet eucalypt clearfell	High quality eucalypt – 100 yr fire
Wet eucalypt clearfell with thin	High quality eucalypt – 200 yr fire
Wet eucalypt aggregated retention	Low quality eucalypt – 20 yr fire
Wet eucalypt clearfell (past fire regrowth)	Low quality eucalypt – 100 yr fire
E. delegatensis shelterwood with removal	Rainforest – disturbed
E. delegatensis shelterwood without removal	Rainforest – undisturbed
E. delegatensis potential sawlog retention	Non-forest
Dry eucalypt clearfell	
Dry eucalypt seedtree	
Dry eucalypt advanced growth retention	
Rainforest/Special Timbers	
Eucalypt plantation pulp	
Eucalypt plantation low prune	
Eucalypt plantation high prune	

2 FullCAM integrates the AGO's CAMFor model with the 3PG forest growth model, the GENDEC litter decomposition model and the Rothamsted soil carbon model (RothC).

3 http://www.greenhouse.gov.au/ncas/activities/modelling.html

FullCAM provides a more comprehensive approach to forest carbon modelling than the Woodstock approach. FullCAM accommodates all potential carbon stores (trees, debris, soil and products). As a result, the model requires many more parameters, and hence is considerably more complex and more open to error. Notwithstanding, the model can be simplified to report only tree carbon in order to provide a comparison with the previous approaches.

Presently, the FullCAM modelling carried out by FT uses a generic tree yield formula to calculate growth. This formula is both intentionally conservative (Matt Searson, AGO, pers. comm.) but also subject to errors if the incorrect growth curve modifiers are specified (refer Table 10). FullCAM provides an option to model growth based on increment data. MBAC suggests that future modelling should implement this approach which could deliver a closer correlation with the Woodstock approach.

Stem biomass to total above ground biomass ratios used for all forest types in FullCAM are very close to those used in the FT approach and reported in NCAS Technical Report 17 pg 21 for eucalypts. Using *E. delegatensis* stands as an illustration, the aggregation of bark, branches and leaves (22.5% of total biomass compared to stem biomass of 66.7%) provides an expansion factor of 1.34 (22.5+66.7)/66.7. This is the same factor suggested in NCAS Technical Report 17 for eucalypt plantations, and used in the above Woodstock approach for this forest type. It is also close to the factor of 1.46 suggested for native eucalypt forest.

The root:shoot ratio for the simulated forest types is, however, significantly different. Again, using *E. delegatensis*, the aggregation of fine and course roots estimated in FullCam represents only 10.8% of total stem biomass. In contrast, NCAS Technical Report 17 suggests a factor of 25%. This difference likely accounts for the lower forest carbon estimates from FullCam than the Woodstock approach.

Notwithstanding the above differences, a strength of FullCAM is that is provides a more precise specification of carbon percentage for each tree component than the Woodstock or MBAC approaches. Modelled values range between 47% for branches and 52% for leaves. These values can be refined and incorporated in estimates as additional data comes to hand.

Table 10: Parameters used in FullCAM Modelling of commercial forests

	E. delegatensis shelterwood without removal	*E. delegatensis* shelterwood with removal	*E. delegatensis* potential sawlog retention	Dry eucalypt advanced growth retention	Dry eucalypt clearfell	Dry eucalypt seedtree	Eucalypt plantation low prune	Eucalypt plantation high prune	Eucalypt plantation pulp	Rainforest/Special Timbers	Wet eucalypt aggregated retention	Wet eucalypt clearfell	Wet eucalypt clearfell with thin	Wet eucalypt clearfell (past fire regrowth)
Productivity function														
Maximum aboveground forest biomass (tdm/ha)	200	220	200	150	170	170	220	250	180	170	320	320	280	320
Forest productivity index (annual rate)	11	11	11.7	9.5	10.5	9.5	12.5	13.4	13.1	10	13.5	13.5	14	13.06
Tree age of max growth in tree yield formula (G)	12 yr	10 yr	10 yr	10 yr	10 yr	10 yr	9 yr	9 yr	10 yr	10 yr	10 yr	10 yr	12 yr	10 yr
Non-endemic species multiplier of max aboveground biomass ®	1.2	1	1.1	1.1	1.2	1.1	2	2.5	1.9	1	1.4	1.4	1.5	1.3
Biomass Allocation														
Stem mass as % of maximum tree biomass	66.7%	66.7%	66.7%	59.7%	59.7%	59.7%	70.6%	70.6%	70.6%	70.6%	70.6%	70.6%	70.6%	70.6%
Branch mass as % of maximum tree biomass	10.7%	10.7%	10.7%	10.7%	10.7%	10.7%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%
Bark mass as % of maximum tree biomass	10.1%	10.1%	10.1%	17.1%	17.1%	17.1%	9.4%	9.4%	9.4%	9.4%	9.4%	9.4%	9.4%	9.4%
Leaf mass as % of maximum tree biomass	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%
Coarse root mass as % of maximum tree biomass	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%
Fine root mass as % of maximum tree biomass	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%
Stem Density														
Stem density (kgdm/m3)	700	700	700	600	600	600	524	500	524	600	524	524	524	524
Carbon % of biomass components														
Carbon % of stems	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Carbon % of branches	47%	47%	47%	47%	47%	47%	47%	47%	47%	47%	47%	47%	47%	47%
Carbon % of bark	49%	49%	49%	49%	49%	49%	49%	49%	49%	49%	49%	49%	49%	49%
Carbon % of leaves	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%
Carbon % of coarse roots	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Carbon % of fine roots	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%

3.1 PRELIMINARY FT FULLCAM RESULTS

1. Ignoring soil and debris related carbon

The preliminary FullCAM work provided to MBAC[4] did not include the softwood estate. In addition, 100 000 ha of non-commercial estate was yet to be allocated to a forest type stratum.

FT's FullCAM modelling estimated that carbon contained in the commercial estate ranged from a present mass of 48 million tonnes declining to 42 million tonnes in 2020 and then rising to 52 million tonnes by 2050 (Table 11). In a similar manner, the non-commercial estate was estimated to be 62 million tonnes carbon in 2007 remaining reasonably stable at this level to 2050. The latter would suggest the non-commercial estate was in a state of climax (rather than still growing as shown in the Woodstock approach). The total carbon balance was estimated at 110 million tonnes of carbon in 2007, rising to 117 million tonnes carbon by 2050 (Table 11) prior to accounting for the 'missing' 100 000 ha and the softwood estate.

Table 11: FT preliminary FullCAM derived carbon estimate excluding the softwood estate and 100 000 ha of the non-commercial estate – million tonnes carbon

Estate component	2007	2010	2020	2030	2040	2050
Commercial estate	48	45	42	43	49	52
Non-commercial estate	62	63	65	64	65	65
Total	110	108	107	107	114	117

The 'missing' 100 000 ha of non-commercial forest and the softwood plantation components can now be added to these data. The softwood estate carbon was adopted directly from the Woodstock modelling approach. Carbon in the 'missing' or unallocated 100 000 ha of non-commercial native forest was estimated by scaling up the projected FullCAM projections as a proportion of the total non-commercial estate. These estimates are simply added back in Table 12.

Table 12: FT FullCAM including the softwood estate and missing 100 000 ha of the non-commercial estate – million tonnes carbon

Estate component	2007	2010	2020	2030	2040	2050
Commercial estate	48	45	42	43	49	52
Non-commercial estate	62	63	65	64	65	65
Missing 100 000 ha within the non-commercial estate	9	9	9	9	9	9
Softwood	3	3	3	3	3	3
Total	122	120	119	119	126	129

[4] FullCAM Carbon Modelling Status 30Mar07.doc

These resulting carbon estimates of 122 million tonnes in 2007, declining to 119 million tonnes in 2020 to 2030, then increasing to 129 million tonnes in 2050 is 70 to 80% of the Woodstock approach. It appears likely this is because of more conservative root:shoot assumptions in FullCAM. In subsequent work by MBAC, we adjusted the root:shoot ratio to be less conservative than allowed in FullCAM and achieved results very similar to the revised Woodstock analysis.

2. Including soil and debris related carbon

While soil carbon may be a significant component of the total carbon store, it is far more difficult to measure and monitor over time than the carbon stored in trees. Also, there is an arbitrary element to soil carbon in deciding the depth to which soil carbon is accounted for. This may be offset, to some extent, as a large fraction of soil carbon resides near the soil surface. Notwithstanding, we include the FullCAM calculations for soil carbon and forest debris to show their importance as part of the overall carbon balance, although MBAC argues that soil carbon should not be reported as part of the total forest store.

When FullCAM is used for full modelling of carbon stores in soil, debris and products, less carbon lost in forest fires, total carbon stores are significantly higher than where these values are ignored. Table 13 indicates that in addition to trees, soil and debris are major carbon pools. Using this approach, trees comprise on average 39% of the total carbon pool, soils 27% and debris 33%. These results also support the following TimberCam analysis that forest products form only a small proportion of the total FT carbon pool (around 1%). Total carbon stores in 2007 were estimated by FullCAM at 286 million tonnes. Ignoring the base stores in carbon, debris and products, the value is 112 million tonnes, which is in very close agreement with FT's calculations Table 11.

Table 13: Full carbon store modelling results from FullCAM – million tonnes

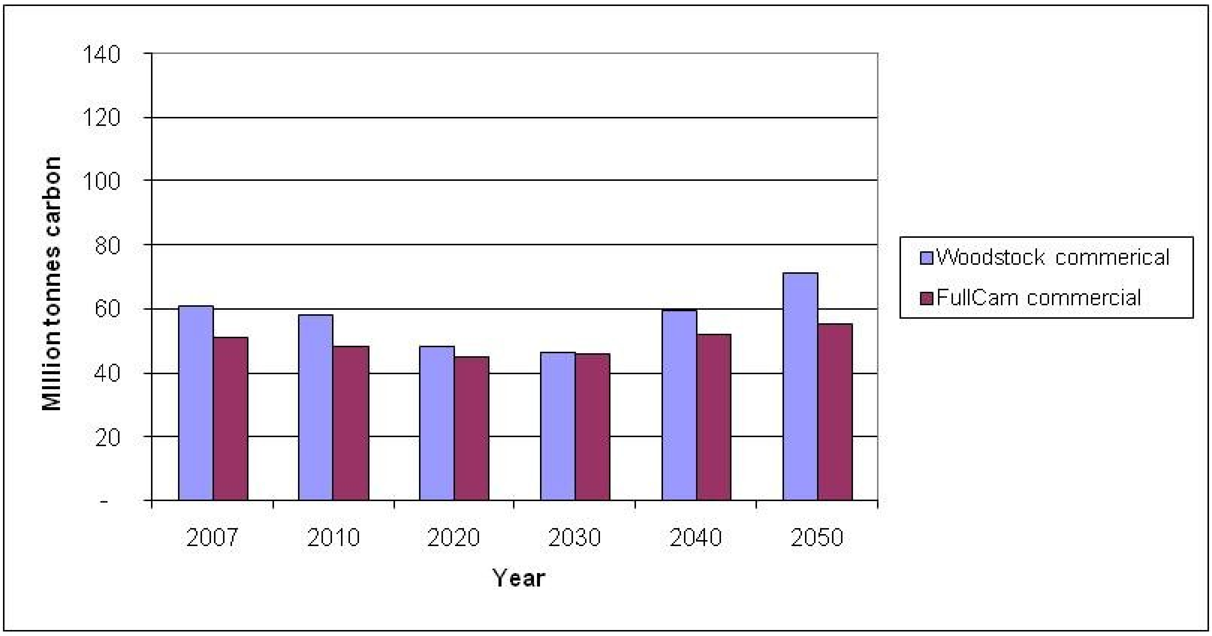
Year	2007	2010	2020	2030	2040	2050
Commercial estate						
C mass emitted by forest due to fire	0.6	0.4	0.4	0.3	0.1	0.4
C mass of forest products	4	4	5	5	4	5
C mass of forest soil	31	30	27	24	23	23
C mass of forest debris	38	37	37	35	38	40
C mass of trees	48	45	42	43	50	53
Sub-total	*120*	*116*	*109*	*107*	*115*	*120*
Non-commercial estate						
C mass emitted by forest fire	0.0	0.0	1.3	0.0	0.0	2.1
C mass of forest products	0	0	0	0	0	0
C mass of soil	46	46	46	46	46	46
C mass of debris	56	56	57	56	56	57
C mass of trees	64	63	64	64	65	62
Sub-total	*166*	*166*	*167*	*166*	*166*	*165*
Total	287	282	277	273	281	285
Total estate						
C mass emitted by forest fire	0.7	0.4	1.7	0.3	0.1	2.5
C mass of forest products	4	4	5	5	4	5
C mass of soil	77	76	72	70	69	68
C mass of debris	94	94	94	92	94	97
C mass of trees	111	108	106	106	114	115
Total	287	282	277	273	281	285
Soil and debris	172	170	166	162	162	166
Change in soil and debris	0	-2	-6	-10	-9	-6

A feature of Table 13 is the apparent change in soil and debris carbon, largely associated with operations in the commercial forest. Without trying to better understand the processes and ignoring these changes between 1989 and 2007, MBAC suggests it would be prudent to deduct this change (-2 million tonnes by 2010 and -6 million tonnes by 2050) from the Woodstock derived approach, given the greater precision of the estimate of volume available from this method and the inability of this method to account for this component. These values will be accounted for in the final calculations.

3.2 COMPARING WOODSTOCK AND FULLCAM

The following analysis includes all changes made by MBAC. There is a reasonable correlation between the Woodstock derived estimate of in-forest carbon pool and the FullCAM derived values between 2007 and 2050 (with MBAC estimates for the softwood estate and 100 000 ha of non-commercial estate yet to be assigned). This relationship is shown in Figure 2. In this case, the FullCAM estimate ranges between 78% and 70% of the Woodstock output. However, both are well within the precision limits of the data. Some of this difference may relative to the lower carbon allocation to roots by FullCAM relative to that used in the Woodstock approach.

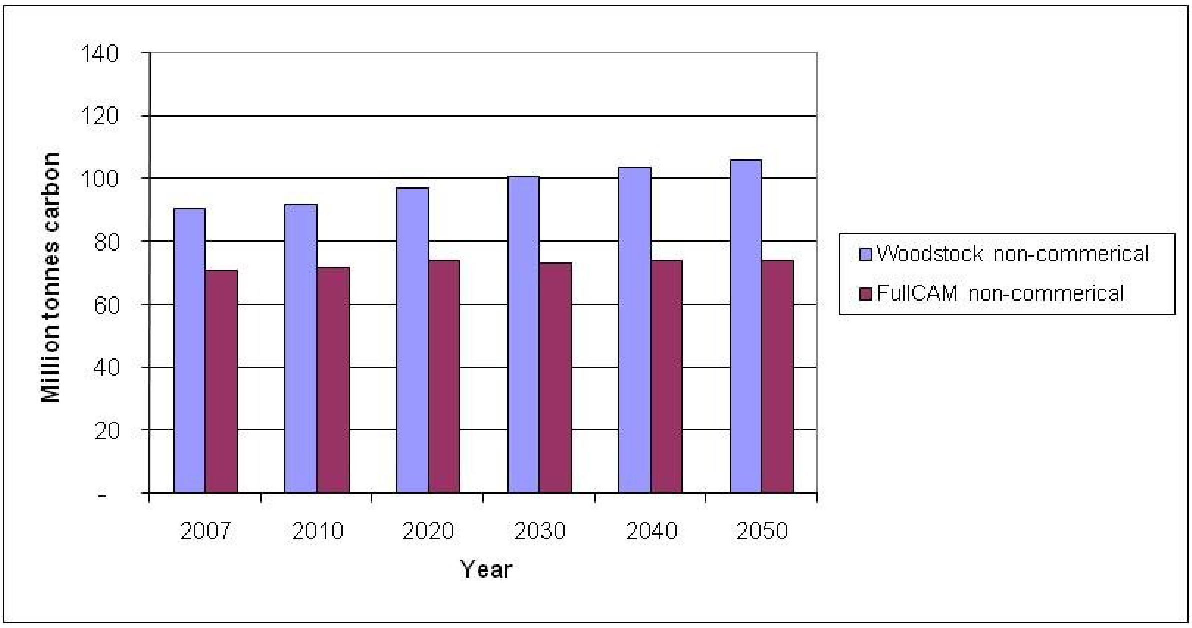
Figure 2: FT preliminary estimates of commercial estate carbon by approach



The correlation between Woodstock and FullCAM for the non-commercial estate is less well defined (many differences in approach here) as shown in Figure 3. The starting position for FullCAM is below the Woodstock estimate (78%), and progressively declines to 2050 (70%). Again, some of this difference may be related to the lower carbon allocation to roots by FullCAM relative to that in the Woodstock. In addition, the progressive increase in difference between the two approaches may indicate that FullCAM is not capturing the growth in the reserved native forest estate over the next 20 year period that is assumed to occur under the Woodstock approach, in order to allow regrowth areas within the non-commercial estate to continue growing until they reach maturity.

Given the relative complexity of FullCAM, then MBAC advises FT accept the Woodstock estimate of carbon for the non-commercial estate, as it is simpler, easily produced by FT and accounts for all forest carbon pools other than change in soil carbon, debris and effect of fires. These we suggest be accounted for separately (ie external to the Woodstock model).

Figure 3: FT preliminary estimates of non-commercial estate carbon by approach



4 APPROACH 3 – TIMBERCAM

4.1 BACKGROUND

Harvesting of wood products (HWP) is generally accepted as a legitimate carbon pool that can be quantified. However, under the Kyoto Protocol, HWP are treated as emissions and under the Intergovernmental Panel on Climate Change (IPCC) carbon in wood products is not considered and all carbon in biomass sold is lost to the system immediately upon harvest.[5] Of course, in practice this is not the case as the approach ignores carbon embedded in wood products and its subsequent decay over many years or decades.

It is possible that in subsequent (Kyoto) commitment periods carbon sequestered in forest products will be included in the calculations of the amount of carbon tradeable in the forest sector.[6]

At the 2006 National Emissions Trading Taskforce Forest Sinks Industry Consultation Workshop, it was suggested that quantification of the HWP pool could be based on product tracking, product half lives and decay rates.[7]

TimberCAM (Timber Carbon Accounting Model) was developed within the Cooperative Research Centre for Greenhouse Accounting (CRCGA). It tracks the fate of carbon stored in trees through their harvesting, conversion to wood products, use and end-of-life options. The main variables are recovery rates, fate of residues, service life and disposal options. Products are assigned to young, medium and old age carbon pools and materials leaving service to bioenergy, landfill, recycled or emitted to the atmosphere. Earlier work assigned products to five pools. MBAC updated this work for the AGO by including a 'landfill' pool and a 'bioenergy' pool.[8] One of the main findings in research work for TimberCam was that the decay rate for wood products (including paper) was much slower than previously thought, i.e. paper remained as paper for 20 years in some recovered samples from lanfill. Housing is the major carbon pool for wood products although the estimated carbon in landfill may be over two times the mass in housing (FWPRDC). TimberCam is an appropriate Australian wood products life cycle model although it does not handle estate woodflows.

4.2 FT INFORMATION

FT has begun to develop life cycle analysis for a range of products. This is reproduced below in Table 14, which shows products produced for each commercial forest type (commercial native forest, eucalypt plantations and softwood plantations). This table also shows the basic density assumption used for each component. These values relate to 2006 and can be changed.

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5 Whittock S. et al (2004) p1.

6 Whittock S. et al (2004) p5.

7 National Emissions Trading Taskforce 2006 (a) p9

8 MBAC 2004

These product volumes are then assigned to processing options with assumptions as to what proportion of a product was converted into which end-market products. These data have been generated from FT information, although they have been further developed by MBAC. Refer Table 15 with MBAC inclusions for the eucalypt plantation component (Table 16) and for the softwood estate (Table 17).

Table 14: FT and MBAC product sales estimates (2006) – m^3

Product	Commercial native forest	Eucalypt plantations	Softwood plantations
Veneer logs	9 260	-	-
High Quality Sawlog (Cat 1 & 3)	320 720	-	-
Low Quality Sawlog (Cat. 2)	29 679	-	-
Cat 4.	8 484	6 932	224 675
Outspec. Sawlog (Cat. 8)	55 379	-	34 502
Peelers	150 934	-	3 834
Pulpwood	2 191 132	89 619	229 372
Firewood	-	-	-
TOTAL	2 765 588	96 551	492 383
Basic density	600	550	450
Carbon fraction	0.5	0.5	0.5

4.3 PRODUCT LIFECYCLE IN PERSPECTIVE

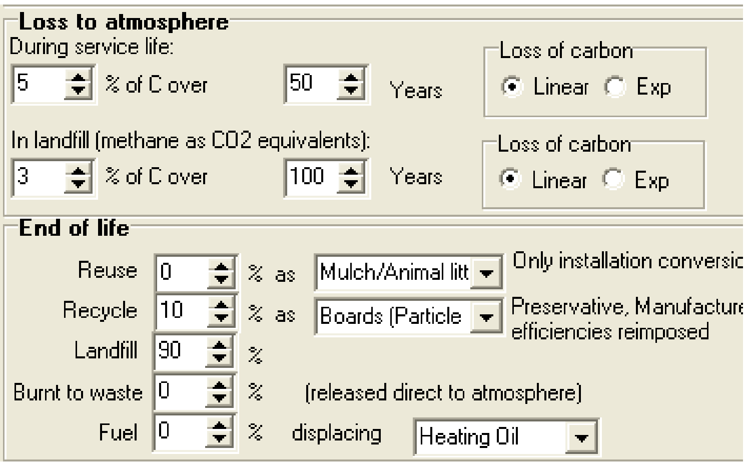
The important aspect of the above numbers is that FT produces approximately 3.35 million m^3 of forest products per year, based on 2006 values. In very approximate carbon equivalent terms, this is around 0.85 million tonnes. As shown in the previous section, the FT forest estate contains around 150 million tonnes of carbon. Hence, annual sales represent just 0.6% of FT's carbon store.

If all this was to 'survive' in service and/or landfill for (say) 50 years, then we could expect a maximum of around 42 million tonnes of carbon contained within products in service or landfill. However, not all these products survive that long. If it was 25 years, then the carbon stored in products would be around 20 million tonnes. Of course, some products survive longer (ie sawn timber in buildings), while other products, i.e. woodchips when converted into paper, are recycled and disposed in landfill i.e they survive for shorter periods. There is substantial research underway to determine the life cycle of the various products considering in-service life and decay rates, for example.

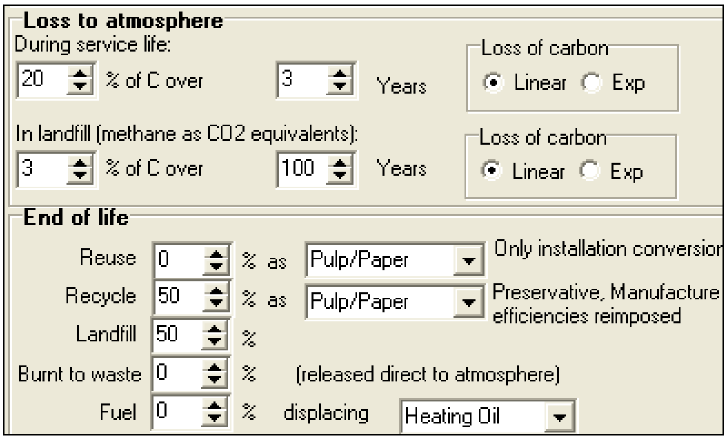
4.4 THE FT PRODUCT LIFECYCLE MODEL

MBAC has used TimberCam life cycle values for houseframing (called long cycle in the MBAC model), pulp/paper (called short cycle) and waste (called 1 yr cycle). All products have been assigned to one of these classifications. The major variables are summarised in Figure 4.

Figure 4: Life cycle assumptions (ex Timbercam)



Long Cycle



Short Cycle

Waste total loss to atmosphere in year 1

The production of carbon by each commercial component produced in 2006 is shown in Table 15, Table 16 and Table 17.

Table 15: TimberCAM FT data – Eucalypt coupe component

Forest product	Processed product	% Cut	Volume (m3)	Dry mass	Carbon
Veneer logs	Wtd. Average Leaf	16%	1 482	889	445
	Wtd. Average Sawn	15%	1 389	833	417
	Woodchip	35%	3 241	1 945	973
	Waste	34%	3 148	1 889	945
	Totals	100%	9 260	5 556	2 780
High Quality Sawlog (Cat 1 & 3)	Lumber - Select	15.8%	50 674	30 404	15 202
	Lumber - Standard	7.0%	22 450	13 470	6 735
	Lumber - Framing	8.8%	28 223	16 934	8 467
	Lumber - Utility	3.5%	11 225	6 735	3 368
	Woodchip	35%	112 252	67 351	33 676
	Waste	30%	96 216	57 730	28 865
	Totals	100%	321 040	192 624	96 313
Low Quality Sawlog (Cat. 2)	Lumber - Select	2%	594	356	178
	Lumber - Standard	5%	1 484	890	445
	Lumber - Framing	8%	2 374	1 424	712
	Lumber - Utility	10%	2 968	1 781	891
	Woodchip	45%	13 356	8 014	4 007
	Waste	30%	8 904	5 342	2 671
	Totals	100%	29 680	17 807	8 904
Cat 4.	Lumber - Select	20%	1 697	1 018	509
	Lumber - Standard	5%	424	254	127
	Lumber - Utility	3%	255	153	77
	Woodchip	40%	3 394	2 036	1 018
	Sawdust	25%	2 121	1 273	637
	Waste	7%	594	356	178
	Totals	100%	8 485	5 090	2 546
Outspec. Sawlog (Cat. 8)	Lumber - Select	0%			
	Lumber - Standard	2%	1 108	665	333
	Lumber - Framing	5%	2 769	1 661	831
	Lumber - Utility	8%	4 430	2 658	1 329
	Woodchip	55%	30 458	18 275	9 138
	Waste	30%	16 614	9 968	4 984
	Totals	100%	55 379	33 227	16 615
Peelers	Export Peelers	100%	150 934	90 560	45 280
Pulpwood	woodchip	100%	2 191 132	1 314 679	657 340

Table 16: TimberCAM MBAC data – Eucalypt plantation component

Forest product	Processed product	% Cut	Volume (m3)	Dry mass	Carbon
Plantation sawlogs	Lumber - Select	0%			
	Lumber - Standard	10%	693	381	191
	Lumber - Utility	18%	1 248	686	343
	Woodchip	40%	2 773	1 525	763
	Sawdust	25%	1 733	953	477
	Waste	7%	485	267	134
	Totals	100%	6 932	3 812	1 908
Pulpwood	woodchip	100%	89 619	49 290	24 645

Table 17: TimberCAM MBAC data – Softwood plantation component

Forest product	Processed product	% Cut	Volume (m3)	Dry mass	Carbon
Plantation sawlogs	Lumber - Select	20%	44 935	20 221	10 111
	Lumber - Standard	10%	22 468	10 111	5 056
	Lumber - Utility	10%	22 468	10 111	5 056
	Woodchip	33%	74 143	33 364	16 682
	Sawdust	20%	44 935	20 221	10 111
	Waste	7%	15 727	7 077	3 539
	Totals	100%	224 676	101 105	50 555
Export sawlogs	Lumber - Select	0%			
	Lumber - Standard	24%	8 280	3 726	1 863
	Lumber - Framing	40%	13 801	6 210	3 105
	Lumber - Utility	8%	2 760	1 242	621
	Woodchip	25%	8 626	3 882	1 941
	Waste	3%	1 035	466	233
	Totals	100%	34 502	15 526	7 763
Roundwood	Treatment	100%	3 834	1 725	863
Pulpwood	woodchip	100%	229 372	103 217	51 609

4.5 LIFE CYCLE ANALYSIS RESULTS

The major factor impacting on life cycle is the number of years in-service for the various products produced from FT's forest products. All woodchip were assumed to go to a short life cycle emissions profile consistent with TimberCam's pulp and paper scenario. The emissions for one year are shown in Figure 5. The total carbon generated from woodchips in 2006 was around 802 000 t and it takes nearly 100 years for this to be converted into CO_2-e emissions. The emissions for all sawn/panel products is shown in Figure 6 and for waste in Figure 7.

Note a limitation of these data is that they assume production from 1990 is the same each year as occurred in 2006.

Figure 5: Woodchip emissions for 1 year

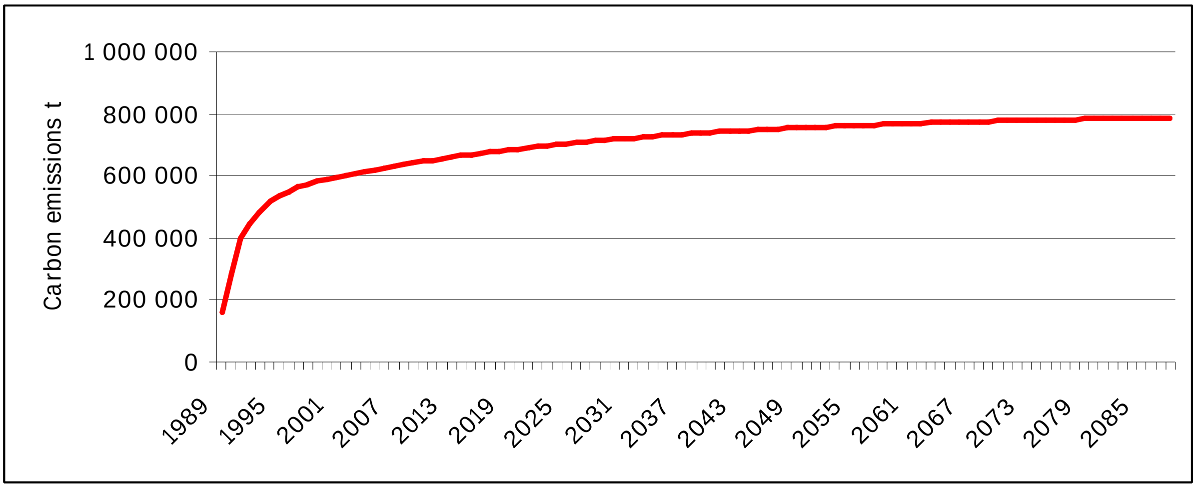


Figure 6: Sawn/panel product emissions

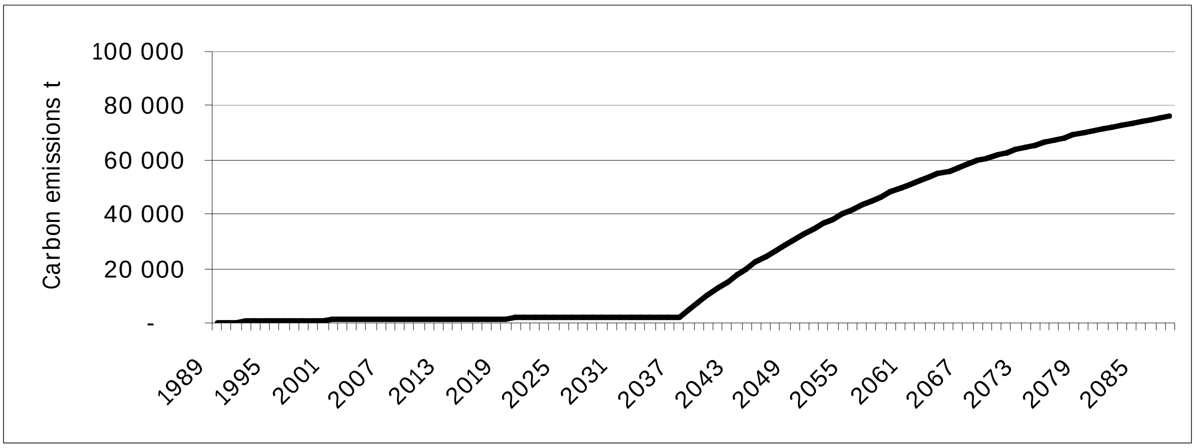
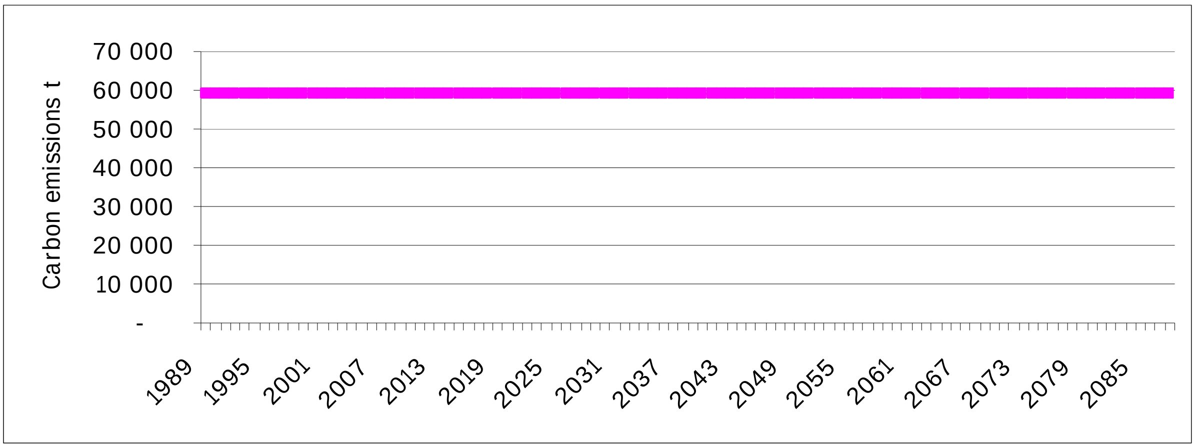


Figure 7: Waste emissions



5 GAP ANALYSIS

Comparing any model requires a careful understanding of the inclusions and exclusions as well as different assumptions. The FT advised differences have been compared at the approach level and broad type (commercial vs non-commercial) as summarised in Table 18. Where there is a match with an item included in both approaches, such as eucalypt plantations 100% FT owned being included in the Woodstock approach and the FullCAM approach, MBAC has assigned a "B" for balanced. Equally, where an item has been included in one approach and not the other, MBAC has assigned an "N", for no likely impact, an "S" for a small impact and "M" for a material impact.

Table 18: FT model approach exclusions and inclusions

			Y=Included		N=Excluded	
			Commercial		Non-commercial	
Item	Category	Impact M=material S=small N=nil B=balanced	Estate Model	FullCAM	Estate Model	FullCAM
Eucalypt native forest coupes	area	B	Y	Y		
Eucalypt plantations 100% FT owned	area	B	Y	Y		
Eucalypt plantations share FT ownership	area	B	Y	Y		
Eucalypt plantations 0% FT crop ownership	area	S	N	Y		
Special Timbers coupes (excl blackwood coupes)	area	S	N	Y		
Special Timbers blackwood coupes	area	B	N	N		
Softwood plantations (commercial)	area	M	N	N		
Non-comm estate area yet to assign c. 100 000 ha	area	M			Y	N
State forest land outside provisional coupes	area	B			Y	Y
Regeneration and growth	Vol/mass	B	Y	Y	Y	Y
Standing woody biomass (stems and branches)	Vol/mass	B	Y	Y	Y	Y
Live roots	Vol/mass	B	Y	Y	Y	Y
Foliage	Vol/mass	B	Y	Y	Y	Y
Coarse Woody Debris (CWD) [9]	Vol/mass	M	N	Y	N	Y
Leaf litter	Vol/mass	M	N	Y	N	Y
Soil carbon[10]	Vol/mass	M	N	Y	N	Y
Carbon stocks in soil re-set to zero at harvest	Vol/mass	M	Y	N		
Biomass removal by harvesting and regeneration burning	Debits	B	Y	Y		
Natural disturbances - wildfire	Debits	M	N	Y	N	Y

As can be seen in Table 18, there are several differences in the approaches which are likely to have a material impact ("M") on the outputs of the two models. These have been extracted in Table 19. The main observation here is that for both the commercial and non-

[9] Up to 21% of biomass in some stands

[10] Organic matter, non-living root, charcoal, inorganic C

commercial estates, FullCAM is taking into account carbon stored in foliage, coarse woody debris, leaf litter and soil. Conversely, the Woodstock approach has yet to include these same values and is 'losing' the stored carbon at harvest. The major omissions, which must be included, are the softwood plantations, and the 100 000 ha shortfall in the non-commercial estate. These can be accommodated in FullCAM, and have already been included in the FT Woodstock Carbon Model.

Table 19: Differences in the approaches likely to have Material impact on the answers

			Y=Included		N=Excluded	
			Commercial		Non-commercial	
Item	Category	Impact M=material	Estate Model	FullCAM	Estate Model	FullCAM
Non-comm estate area shortfall c. 100 000 ha	area	M			N	Y
Coarse Woody Debris (CWD) [11]	Vol/mass	M	N	Y	N	Y
Leaf litter	Vol/mass	M	N	Y	N	Y
Soil carbon[12]	Vol/mass	M	N	Y	N	Y
Carbon stocks in soil re-set to zero at harvest	Vol/mass	M	Y	N	Y	N
Natural disturbances - wildfire	Debits	M	N	Y	N	Y
Softwood plantations (commercial)	area	M	N	N	N	N

MBAC has treated these in the following manner:

- Non-commercial estate area shortfall c. 100 000 ha – included in MBAC FullCAM estimates by pro-rata calculation
- Foliage – included in Woodstock (once root:shoot ratio changed)
- Coarse Woody Debris (CWD) - change included in FullCAM approach
- Leaf litter – change included in FullCAM approach
- Soil carbon – change included in FullCAM approach
- Carbon stocks re-set to zero at harvest – forest only
- Natural disturbances – wildfire – ignored in Woodstock, included in FullCAM approach
- Softwood plantations (commercial) – included using Woodstock approach only

Equally, those differences that are likely to have a small impact have been extracted into Table 20.

[11] Up to 21% of biomass in some stands

[12] Organic matter, non-living root, charcoal, inorganic C

Table 20: Differences in the approaches likely to have Some impact on the answers

			Y=Included		N=Excluded	
			Commercial		Non-commercial	
Item	Category	Impact S=small	Estate Model	FullCAM	Estate Model	FullCAM
Eucalypt plantations 0% FT crop ownership	area	S	N	Y		
Special Timbers coupes (excl blackwood coupes)	area	S	N	Y		

The minor issue here is the inclusion of the JV crops on FT land when FT has no ownership of the crop. If this area is large, then it is a significant problem. If not, it can be ignored.

Based on the 'gap-analysis' MBAC recommends the use of the Woodstock outputs which have been adjusted by MBAC to include the exclusions derived from FullCAM (change in soil carbon) which are likely to be material to the outcome.

6 BENCHMARKING

6.1 GLOBAL

Global carbon stocks in vegetation (including forests) has been estimated to be 466 Gt or 466 billion tonnes.[13] The same report suggests 1.04 billion ha of temperate forests contains 59 billion t carbon in the vegetation and the top 1 m of soil – an average of 57 t carbon/ha. While this appears low for Australian forests, this is what is reported. In other references, there is estimated to be around 360 Gt carbon contained within forest vegetation, a further 787 Gt contained within forest soil and another 2-8 Gt contained with wood products. The largest global store of carbon in the oceans is 40 000 Gt while the atmosphere contains 780 Gt of carbon.[14]

6.2 CHINA

In 1998, China had approximately 160 million ha of native forests and around 47 million ha of plantations for a total of 205.6 million ha. The reported forest growing stock was around 11 270 million m^3, suggesting around 55 m^3/ha.[15], which appears reasonable. The article reported the carbon stock as 4.75 billion tonnes (Gt). Using simple maths, MBAC calculated a figure of 4.79 billion tonnes, based on assumed basic density, non-stemwood ratios and a 0.48 carbon fraction as shown in Table 21. This equates to around 23 tonnes of carbon per ha.

Table 21: China's in-forest carbon estimate (an example)

Forest area	205.61	million ha
	205 610 000	ha
Forest growing stock	11 270	million m^3
	11 270 000 000	m^3
	11 270 000 000	t
Growing stock/ha	55	m^3/ha
Expansion factor roots & stump (0.2)	2 254 000 000	
Expansion factor bark, branch, leaves (0.3)	3 381 000 000	
basic density growing stock	650	kg/m^3
basic density roots	500	kg/m^3
basic density bark, leaves, branches	450	kg/m^3
Dry biomass - growing stock	7 325 500 000	t
Dry biomass - roots	1 127 000 000	t
Dry biomass - bark, leaves, branches	1 521 450 000	t
Total dry biomass	9 973 950 000	t
Calculated carbon Carbon fraction 0.48	4 787 496 000	t
Reported carbon stock	4.75	billion tonnes
	4 750 000 000	t

[13] IPCC 2000 p3.

[14] Kirschbaum, M. (2003) p1

[15] Zhang Xiao-Quan (2003)

While obviously very coarse numbers (i.e. broad estimates), it is reassuring that some basic calculations can match reasonably with more complex and scientific assessments, such as occurred with the China example.

6.3 AUSTRALIA

Australia's plantations, commercial and conservation forests cover about 164 million ha or 21% of the country and store an estimated 10.5 billion tonnes of carbon (excluding soil carbon).[16] Of course, this includes all definitions of forests (i.e. woodlands). This equates to around 64 tonnes of carbon per ha. This is around three times the estimated carbon sequestered in China's forests, which appears reasonable.

The UN-ECE/FAO Forest Resources Assessment Report[17] separates forests from woodlands and reports 4.5 billion tonnes (above stump) in "forests" on 157 million ha. Assuming the below ground ratio is 0.5 (of stemwood mass), the total carbon (above and below ground) could be around 6.8 billion tonnes (±20%). This equates to around 43 tonnes of carbon per ha. CSIRO[18] states there are no published estimates of carbon stored in the 15 million ha of commercial forests in Australia. However, based on the published estimates of carbon stored in Australia's conservation forests (Australia's State of the Forests Report 2003), it is conservatively estimated that commercial forests potentially contain around 1 billion tonnes of carbon. This equates to around 67 tonnes of carbon per ha. This 'looks' about right when compared with the total forest estate estimate of 43 tonnes of carbon per ha.

Tasmania

Approximately 3.3 million hectares of Tasmania's land area is forest, of which 3.1 million hectares are native forest. Assuming 67 tonnes carbon per ha, in very general terms, there could be around 0.220 billion tonnes (or 220 million tonnes). However, it is likely the volume per ha of Tasmanian forests is higher than the national average.

Forestry Tasmania

Forest Tasmania's forest estate is 1.5 million ha or 45% of Tasmania's forest area. On this basis, a 'back-of-the-envelope' estimate of carbon stored in FT's estate could be 45% of 220 million tonnes ±20% i.e. anything between 80 and 120 million tonnes[19]. This range would appear consistent with Australian estimates and global estimates. The work undertaken in this report suggests a carbon store (ignoring products) of around 154 million tonnes, with a likely 'confidence interval' of 123 to 185 million tonnes. The two confidence intervals nearly cross over suggesting FT's forests are more productive than Australia's (which would be correct). On this basis, it would appear to be very difficult for someone from outside FT to have sufficient information to question any values within this range.

[16] CRC Greenhouse Accounting (2005)

[17] United Nations (2000)

[18] CRC Greenhouse Accounting (2005) p8

[19] in-forest and above and below ground not including soil carbon

7 FINAL MODEL

The final model:

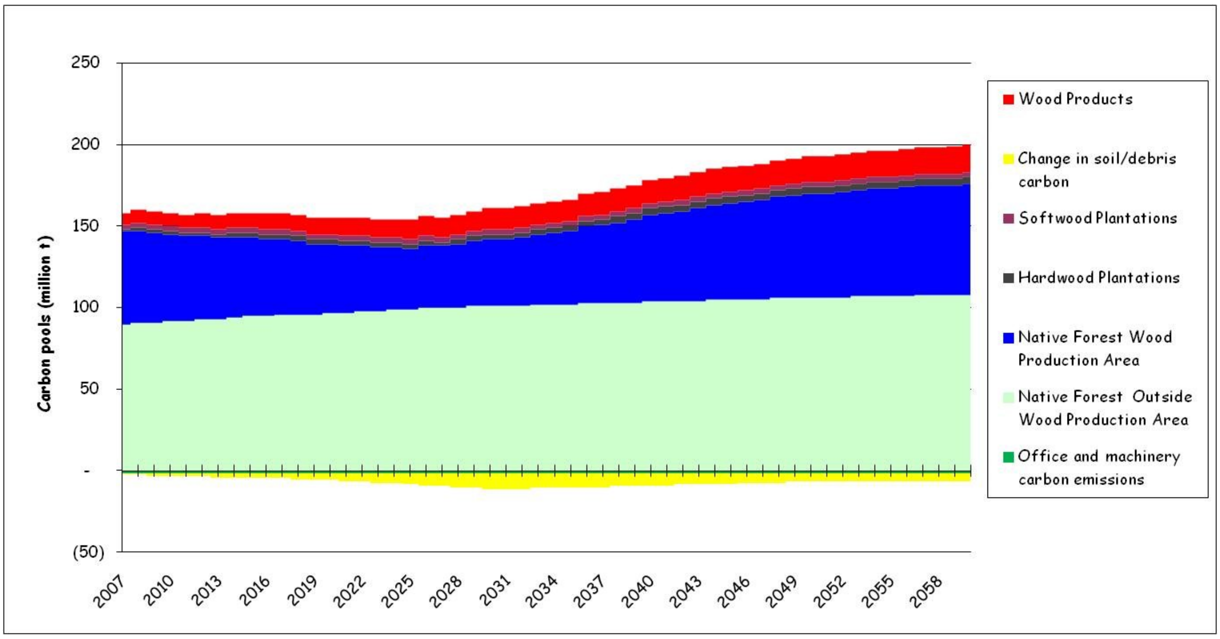
- Combines the Woodstock derived estimate of commercial forest carbon, with the Woodstock estimate of non-commercial forest carbon, the latter with growth constrained beyond 20 years from 2007.
- Includes the slight negative from change in soil/debris carbon (FullCAM)
- Includes the product life cycle assessment (very preliminary).
- Includes a line entry for carbon generation from harvesting, vehicles, office etc. (nominal).
- Ignores the impact of wildfire.

This provides a preliminary picture of FT's entire carbon estate without considering the mass of carbon in the soil (i.e. only the change in carbon in this component).

Table 22: FT's forest and product carbon balance (as estimated by MBAC)

Year	Comm-ercial native forest	Euc pltns	SWD pltns	Non-commercial Native forest	Change soil/debris carbon	Products	Other	Total C
2007	57	1	3	90	-1	7	-1	156
2010	53	2	3	92	-2	8	-1	155
2020	42	3	3	97	-4	10	-1	150
2030	41	3	3	101	-10	13	-1	150
2040	53	4	3	104	-8	14	-1	169
2050	64	4	3	106	-5	16	-1	187

Figure 8: FT's forest and product carbon balance (as estimated by MBAC)



This analysis suggests the FT carbon estate is presently around 156 million tonnes (±?%) increasing to 187 million tonnes (±?%) in 2050. This assumes:

1. That the yield of forest products between 1990 and 2005 was the same as occurred in 2007.
2. That the yield between 2008 and 2050 remains the same as occurred in 2007.
3. Forest products are sold to the same destinations and processed into the same products.
4. The life cycle of forest products is as reported in this report and the proportions into landfill and their decay rate is as interpreted from TimberCam by MBAC.
5. There are no changes in the forest area, management or silviculture.
6. There is no allowance for wildfires on the timing of carbon balance.
7. Ignores total carbon mass in soil and debris – rather only considers change in carbon mass.

7.1 FT'S MAJOR CARBON COMPONENTS - 2007

The major FT carbon pool consists largely of:

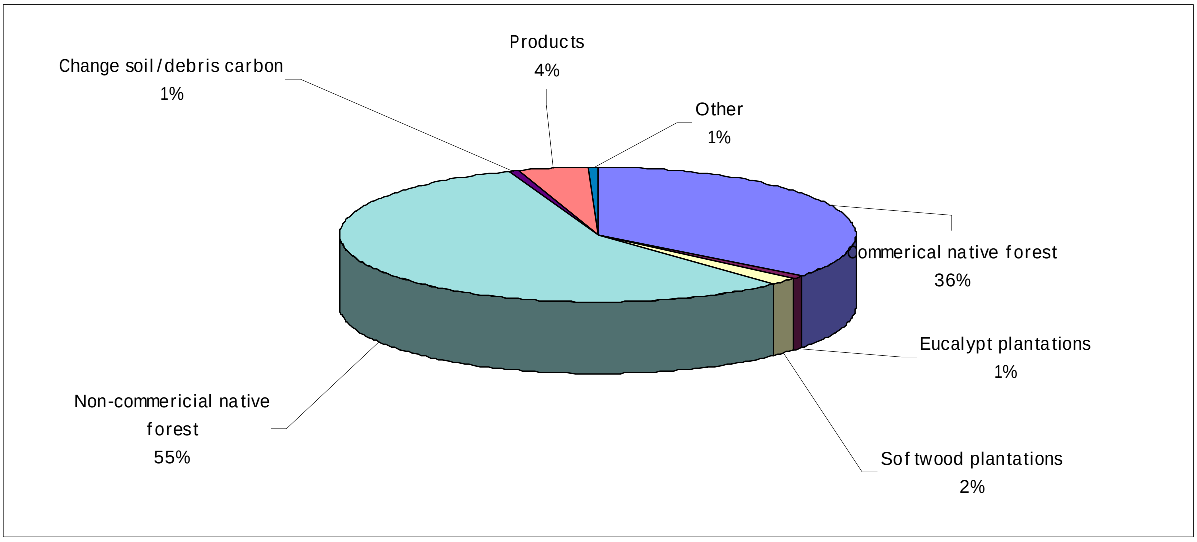
- Non-commercial native forest (57.7%)
- Commercial native forest (36.5%)

These two components account for around 94% of FT's carbon estate. The lesser pools are:

- Eucalypt plantations (0.6% - rising to 2.1% over time)
- Softwood plantations (1.9%)
- Products in-service (4.5%)

These are all shown in Figure 9.

Figure 9: FT's major carbon pools (in 2007)

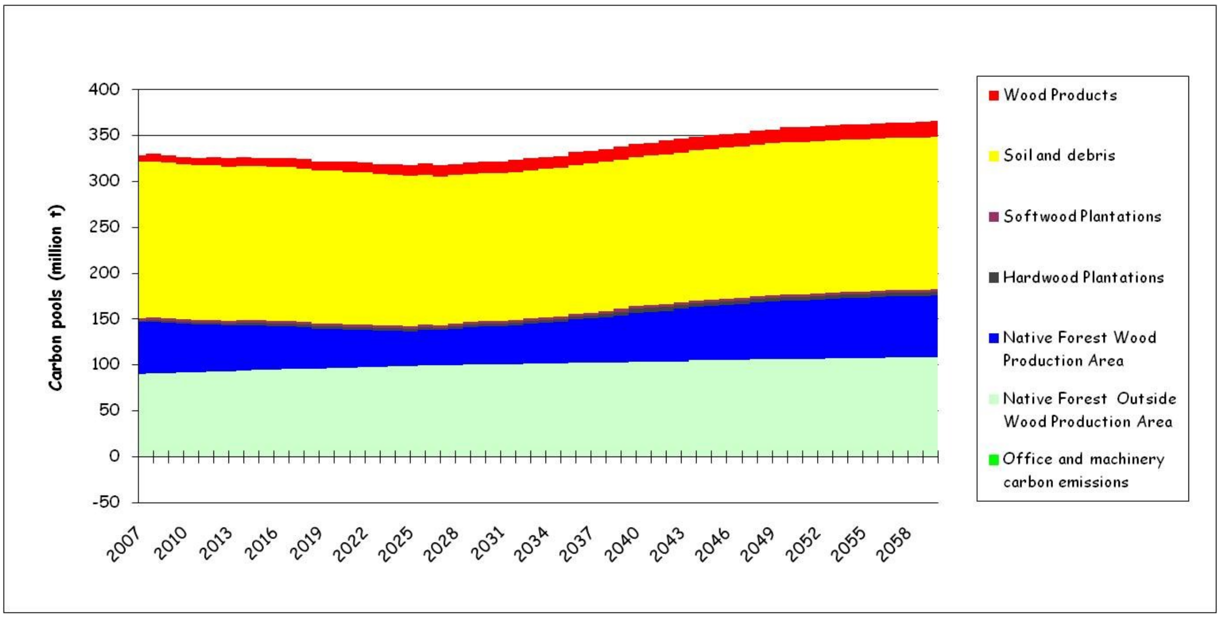


7.2 SOIL AND DEBRIS CARBON

As indicated earlier in the report, soil carbon and carbon in debris has been ignored on the basis that it is far more difficult to measure and monitor over time than the carbon stored in trees, and that there is an arbitrary element to soil carbon in deciding the depth to which soil carbon is accounted determined.

However, for completeness Figure 10 illustrates the total carbon store when FullCAM estimates for these components of the system are included. A key feature is the fact that soil and debris potentially represent a significant proportion of the total forest carbon pool (52% in 2007). Another key feature of these components is that estimated fluctuations in soil carbon with forest operations are effectively buffered by the large total soil carbon store, the former being a relatively small proportion of the latter. However, as estimation of soil carbon is not well developed, these figures should be treated with caution.

Figure 10: FT's forest product and soil carbon balance (as estimated by MBAC)



7.3 MBAC'S FT CARBON MODEL

This has been provided.

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