Assessing potential carbon benefits of restoration forestry in the Wombat State Forest



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Introduction:

The Wombat State Forest is a 52,000ha, Messmate (*Eucalyptus obliqua)* dominated foothills forest, which straddles the Great Divide west of Melbourne (DSE 2004). The original Wombat Forest was destroyed during the Victorian gold rush. The regrowth forest came under increasing State control in the early 1900s and this resulted in a long term forest management program that successfully restored a tall forest structure whilst also providing timber to local mills. Forest management changed in the late 1970s with a shift away from uneven aged management and logging intensity progressively increased in the Wombat Forest from this time. Following several years of unsustainable logging (Vanclay and Turner 2001) and inappropriate silvicultural systems (Mark Stewart 2011 pers. com) that have reduced forest biomass, age, structure and complexity, the Wombat State Forest is once again in a degraded state and the local timber industry has collapsed.

There is considerable debate about the future of the Wombat Forest. Some conservationists believe that the best biodiversity and carbon mitigation outcomes can be achieved by changing the tenure of the forest to a state or national park and excluding all logging. Others believe that the best biodiversity and carbon mitigation outcomes can be achieved by actively restoring the forest whilst also producing low volumes of commercial timber and firewood to provide for local needs.

This report briefly discusses the rational for restoration of degraded forest areas to assist climate change mitigation and the effect of domestic climate change policy on restoration initiatives in Australia's degraded natural forests. The following section of the report discusses the background and requirements for a FullCAM carbon accounting program that could estimate the current carbon stock in the Wombat State Forest and predict the impact of a forest restoration program.

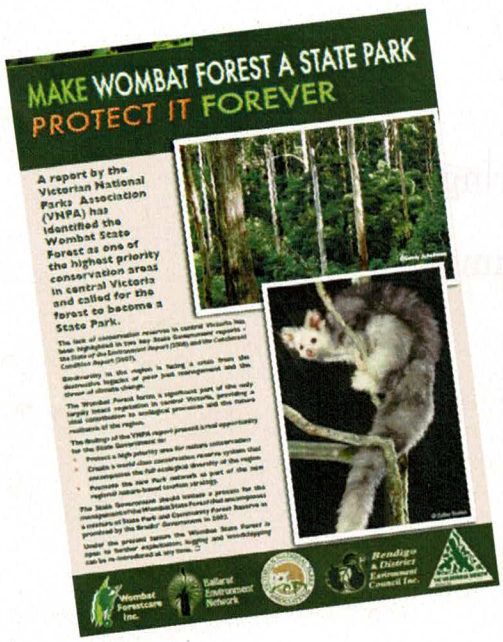


Figure 1: Pamphlet produced by conservationists who want the Wombat State Forest to become a conservation park. Producers of the pamphlet have refused to debate this proposal.

Rational for restoring degraded natural forest areas.

Forests sequester carbon from the atmosphere and store large amounts of terrestrial carbon in their soils, and above and below ground biomass. Forests can also act as a carbon source depending on rates of carbon uptake by photosynthesis and carbon losses due to respiration, fires and removal of biomass (Nabuurs et.al 2007, Bonan 2008, Jackson 2010). A major contributing factor to the current climate change problem is the fact large areas of the world's forests have been lost or degraded (Lamb et. al. 2003, Sayer 2004, Jackson 2010).

The Global Partnership for Forest Landscape Restoration estimates that "*there is 1 billion hectares of degraded forest lands and secondary forests worldwide that are potentially suitable for restoration*" (Jackson 2010). Mackay et. al. (2008) estimate that 8.1 million ha of natural forests in south east Australia have been logged commercially and are considered to be on average 40 per cent below the modelled carbon carrying capacity.

It is recognised worldwide that forest management practices can play a key role in the greenhouse gas budget of forest ecosystems by influencing the carbon stock and fluxes of forest landscapes (Nabuurs et.al 2007, Lindner et. al. 2008, Bonan 2008, Jackson 2010, Waterworth and Richards 2008). There are three ways that forestry practices can be applied to increase the contribution that forests can make to mitigating climate change impacts.

1. Maintaining or increasing forest areas.
2. Improving the carbon storage capacity of existing forests
3. Increasing carbon stocks in wood and substitution for more fossil fuel intensive products

Nabuurs et. al. (2007) produced the table below to illustrate the magnitude and timing of predicted carbon benefits and associated costs from different carbon mitigation options available to the forestry sector.

	Mitigation Activities	Type of Impact	Timing of Impact	Timing of Cost
1A	Increase forest area *(e.g. new forests)*	⇧	∫	↘
1B	Maintain forest area *(e.g. prevent deforestation, LUC)*	⇩	↘	↘
2A	Increase site-level C density *(e.g. intensive management, fertilize)*	⇧	∫	↘
2B	Maintain site-level C density *(e.g. avoid degradation)*	⇩	↘	↘
3A	Increase landscape-scale C stocks *(e.g. SFM, agriculture, etc.)*	⇧	∫	↘
3B	Maintain landscape-scale C stocks *(e.g. suppress disturbances)*	⇩	↘	—
4A	Increase off-site C in products *(but must also meet 1B, 2B and 3B)*	⇧	—	↘
4B	Increase bioenergy and substitution *(but must also meet 1B, 2B and 3B)*	⇩	—	↘

Legend

Type of Impact	Timing (change in Carbon over time)	Timing of cost (dollars ($) over time)
Enhance sink ⇧	Delayed ∫	Delayed ∫
Reduce source ⇩	Immediate ↘	Up-front ↘
	Sustained or repeatable —	On-going ↘

Table 1. Generalized summary of forest sector options and type and timing of effects on carbon stocks and the timing of costs. *(Source Nabuurs et. al. 2007 table 9.4)*

Preventing deforestation and degradation in existing forests provides large short-term gains in terms of emissions avoidance. Expanding forest cover through reafforestation is a more difficult task, requiring more resources and benefits are delayed until plantings gain sufficient size and leaf area. There are long and short term costs and benefits of improving the carbon storage capacity of existing forests through sustainable forest management techniques such as reduced impact logging, longer rotations and uneven aged management (Nabuurs et. al. 2007, Jackson 2010, Lamb et. al. 2003). There is short term and ongoing carbon mitigation benefits from replacing fossil fuel intensive products with timber products produced from sustainably managed forests that maintain or increase forest carbon stocks. Nabuurs et. al. (2007) found that '*In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual yield of timber, fibre, or energy from the forest, will generate the largest sustained mitigation benefit.*'

In degraded natural forests the biomass and soil carbon stocks are reduced to below their potential carbon carrying capacity providing the opportunity for carbon uptake and storage (Keith et. al.2009b, Mackay et. al. 2008). Degraded forests are more susceptible to pathogens and less resilient to predicted climate change impacts such as increased droughts and altered weather patterns (Nitchke and Hickey 2007). The ability to restore carbon stocks in degraded natural forests depends upon the degree of degradation and disruption to natural processes that impact on forest growth and health (Harris et. al 2007, Lindner et. al 2008). The main aim of restoration forestry is to reproduce and maintain natural ecosystem functions and processes whilst also providing some timber products and local fuelwood (Lamb et. al 2003).

Climate change policy and forest restoration initiatives in Australia

Australia's climate change response has been substantially informed by 'The *Garnaut Climate Change Review'* (Garnaut 2008). The Garnaut review modelled Australia's annual emissions reduction potential from forestry, based on a number of assumptions including, timber harvesting and other human disturbances would cease in 14.5 million ha of natural forests and that the growth potential of these areas has not been degraded by past practices (Garnaut 2008 p.543).

The Garnaut review completely ignored sustainable forest management in natural forests as an option for climate change mitigation and the review adopted a purely preservation scenario for all of Australia's natural forests. This assumption was based on a single reference, '*Green Carbon; The role of natural forests in carbon storage*' (Mackay et. al. 2008). The Green Carbon report was funded by the Wilderness Society, a vocal opponent of all native forest logging. The report states *"If logging in native eucalypt forests was halted, the carbon stored in the intact forests would be protected and the degraded forests would be able to regrow their carbon stocks to their natural carbon carrying capacity"* (Mackay et. al. 2008 p.37). The '*No native forest logging*' position taken by Mackay et. al. (2008) is not supported by a number of researchers who believe that managed natural forests have considerable potential to make an important contribution to Australia's greenhouse gas reductions (Wentworth Group 2009, Keenan 2005, Keith, H. et. al 2009b, Read undated).

Following the Garnaut review the Australian government drafted the Carbon Pollution Reduction Scheme (CPRS) Bill 2010 which was passed by parliament in February 2010 but implementation has been delayed until 2012. Section 259B of the CPRS Bill explicitly excludes offset from projects that result in the production of materials from harvesting native forests, from being included in a future emissions trading scheme (ETS). This removes an

important economic driver for forest restoration and ongoing sustainable management in natural forests and also creates a market distortion that favours plantation timbers over native forest timbers produced from sustainable sources. The only native forest that is included in the Australian ETS is new forest that has been established on previously cleared land after 1990 and is managed purely for conservation purposes with no commercial timber production allowed.

The National Carbon Accounting System & FullCAM

Australia has developed a National Carbon Accounting System (NCAS) to meet reporting requirements under the UN Framework Convention on Climate Change and the Kyoto Protocol (Richards and Evans 2004). NCAS undertook several research projects and programs to select and refine models to accommodate different biological and management processes which effect carbon pools and fluxes. The models, remote sensing spatial data and key data sets have been integrated into FullCAM, a single mass-balance model that tracks carbon in plants, products, debris and soils (Richards and Evans 2004, Waterworth and Richards 2008).

Ecosystem component	Models used	Reference
Forest growth	3PG (as a forest productivity index) and CAMFor	Landsberg and Waring (1997), Kesteven and Landsberg (2004) and Richards and Evans (2000b) Waterworth et al. (2007)
Agricultural growth	CAMAg	Richards and Evans (2000a)
Debris decomposition	CAMFor (for forest debris)	Richards and Evans (2000b)
	CAMAg (for agricultural debris)	Richards and Evans (2000a)
Mulch	GENDEC	Moorehead and Reynolds (1991)
Soil carbon	Roth C	Jenkinson (1990)
Product decomposition	CAMFor (for forest products)	Richards and Evans (2000b)
	CAMAg (for agricultural products)	Richards and Evans (2000a)
Product displacement and bioenergy	GORCAM	Schlamadinger et al. (1997)
Nitrogen cycle (implemented over the C cycle models)	Based on CENTURY	Parton et al. (1987)

Table 2: Models integrated into FullCAM. (*Source: Wentworth and Richards 2008. Table 1*)

The National Carbon Accounting Toolbox (NCAT) provides a user friendly internet interface that enables remote users to conduct site specific carbon assessments using default data and management regimes for key species. The NCAT Data Builder also enables users to vary management activities and add to input data to model different scenarios (Richards and Evans 2004). The NCAS and FullCAM model was initially developed to assess and report on carbon gains from Australia's afforestation and reafforestation efforts (Hunt 2009), the process of incorporating native forests into the FullCAM database is ongoing (Waterworth and Richards 2008).

Norris et. al. (2010) used the FullCAM model to generate an indicative estimate of carbon stocks in Victoria's public land. The Victorian model stratified public land according to historical events. Input data was stored in a geographic information system (GIS) and a database was developed to link the Victorian GIS to FullCAM. The Victorian model utilised FullCAM's geographic variables and forest productivity index (FPI), disturbance events were based on Victoria's historical data (Norris et. al. 2010).

Current conditions in the Wombat State Forest.

Large areas in the Wombat Forest are now single aged regrowth (CNR1995) resulting from unnatural regeneration events triggered by intense shelterwood logging and slash burning. The shelterwood system was introduced into the Wombat State Forest in 1976 and ceased in 2002. In this 26 year period approximately 80% of the available forest was logged under even aged silvicultural systems resulting in the current situation where 80% of the forest is now aged between 9 to 35 years. The purple areas on the map below show logging history in the Wombat State Forest since even aged silviculture was introduced. This map demonstrates that the rate of logging, particularly in the 1990s, was clearly unsustainable.

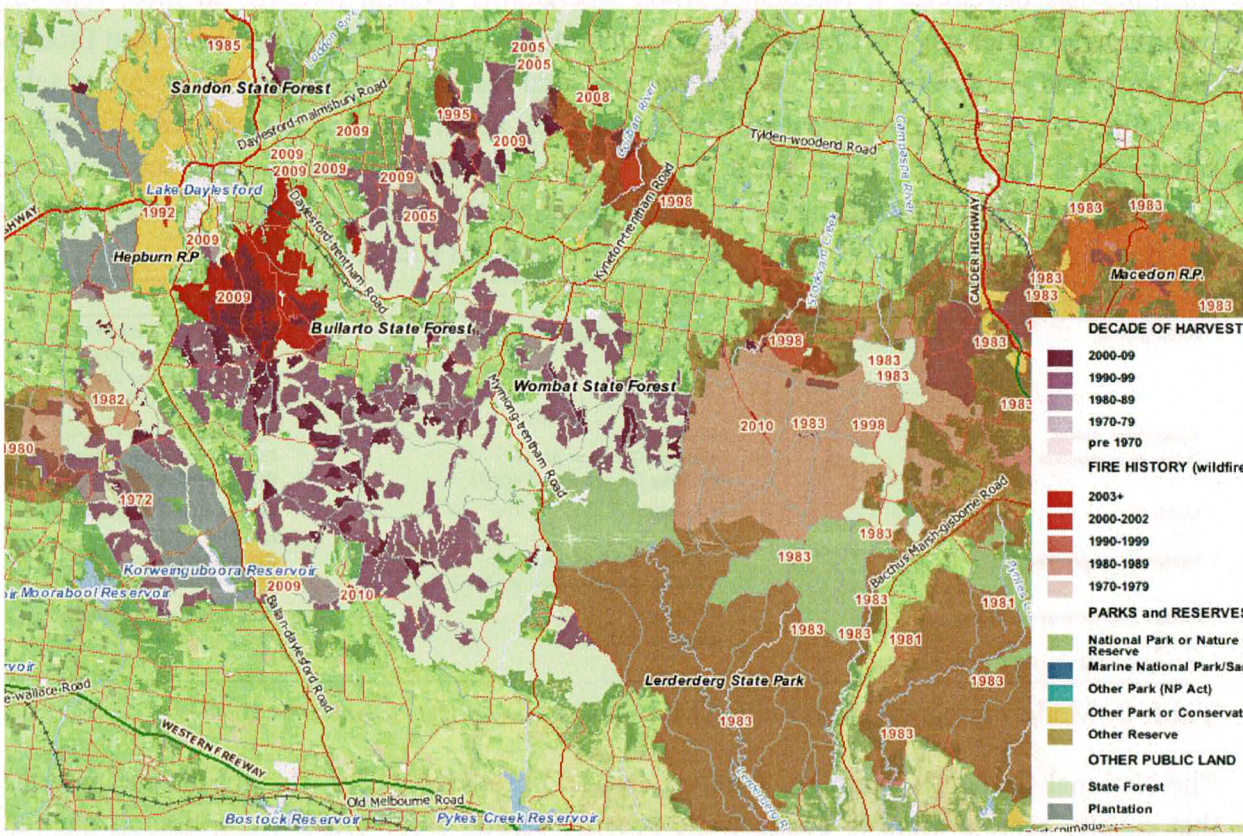


Figure 2: Wombat State Forest logged areas by decade of harvest and history of wildfire events. *(source www.dse.vic.gov.au Forest Explorer)*

Up to 70% of these logged areas are now vastly overstocked and growth is likely to be suppressed due to competitive pressures (ex timber worker Dick Suckling pers com.). Photos 1 and 2 (over the page) show examples of degraded sites with reduced biomass and simplified forest structure caused by even aged silviculture and intensive logging operations.

Wildfire has also impacted on forest growth in some parts of the Wombat State Forest (see red areas in Figure 2 above). The area north of the Lerderderg State Park was severely affected by the 1983 East Trentham fire and regrowth in this area has remained stunted and suppressed. Whilst trials were conducted in the 1990s, to examine different methods to thin and restore the Trentham fire affected areas, thinning programs never really eventuated. The 2009 Daylesford fire burnt through logged areas with young (10-15yo) regrowth that had not reached a stage of maturity to set seed nor had it reached sufficient size to withstand the effects of wildfire.





Photo 1: mass single aged regeneration below a sparse over story of retained mature trees that were substantially damaged during a post logging slash burn, Cockatoo Creek near Daylesford. **Photo 2:** suppressed 17-year old even aged regrowth, Kangaroo Creek Rd, Wheatsheaf. (*Photos by Tim Anderson*)

Degradation in the Wombat Forest needs to be addressed in a variety of ways and at a range of scales. Site-level data is key to understanding carbon sequestration processes and implementing management changes but this needs to be coordinated within landscape level planning (Lamb and Gilmour 2007) to maximise carbon mitigation options and other conservation outcomes.

Forest inventory data for the Wombat Forest,

Carbon assessment in forests is underpinned by the quality of available forest inventory data (Keith, H. et. al 2009b). Victoria's State of the Forests Report 2008 (DSE 2009) gives the impression that forest inventory data is currently only available for the east of the State and information on the west of the State is not available (Wallace 2010). This is not the case in the Wombat Forest where a community campaign against unsustainable logging in the 1990s led to this forest having the most intense Statewide Forest Resource Inventory (SFRI) assessments in Victoria.

The Statewide Forest Resource Inventory (SFRI) is a program of information collection and analysis of Victoria's native forests that aims to *'provide forest managers with a reliable, timely and complete set of forest resource information for making informed and consistent sustainable yield forecasts, and decisions on forest land-use planning and resource allocation'* (DSE 2004).

In the Wombat Forest the SFRI program mapped forest characteristics including species, crown cover, crown form and height, evidence of disturbance was also noted. This information was used to derive growth stage maps and to stratify the forest for volume sampling. Detailed ground truthing was undertaken and sample plots were established to collect tree numbers and species data. TREEMAP stem profiling technique was used to record tree dimensions, stem features and information about tree hollows. Tree ring analysis provided age and growth information for stands of unknown age, providing data for yield curves (DSE 2004). The SFRI

program also remeasured several Continuous Forest Inventory (CFI) plots that were established in the Wombat Forest in the 1960s this information was used to improve growth models and volume predictions (DSE 2004).

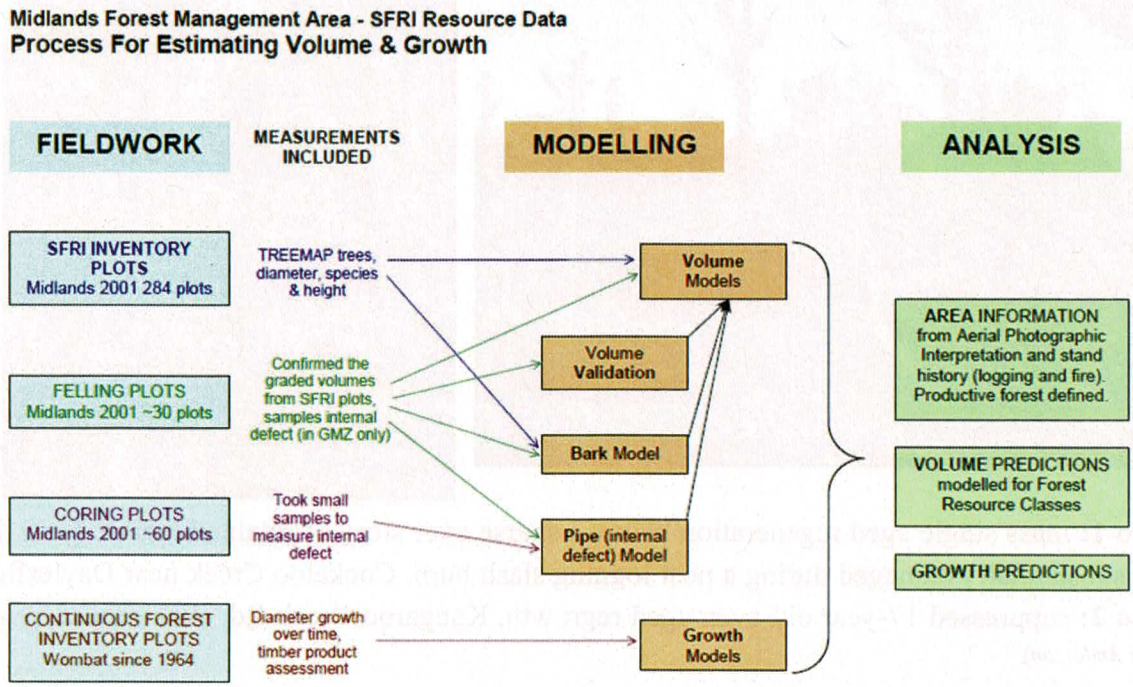
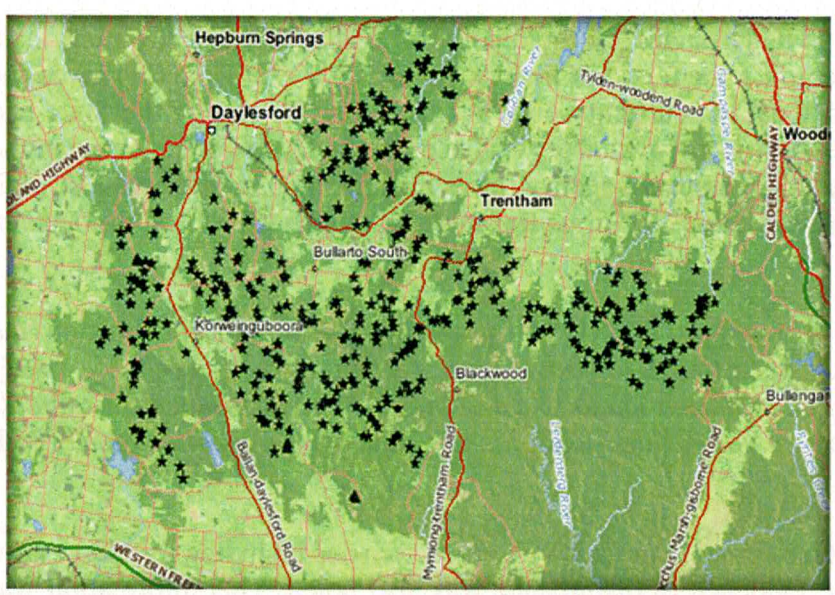


Figure 3: Wombat Forest SFRI process for estimating volume and growth. *(source: DSE 2004)*

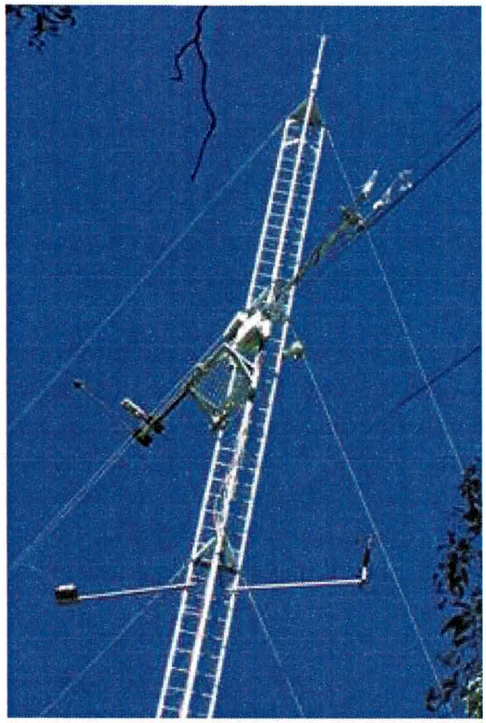
DSE packaged the SFRI information and other Wombat Forest data into an interactive CD called "Wombat Forest Explorer" (DSE 2004), this was licensed to the Wombat Community Forest Management group. DSE ran workshops to teach interested locals how to use the software to access Meta data and build and map different parameters and scenarios in the forest.



The SFRI program in the Wombat Forest resulted in an extensive data base, high quality spatial information and statistically valid estimates and predictions for forest growth.

Figure 4: Continuous Forest Inventory (CFI) plots in the Wombat Sate Forest. *(source: DSE 2004).*

In 2010 the University of Melbourne and Monash University jointly established a Flux tower research site in the Wombat State Forest. The Wombat research site investigates complex ecosystem processes in a dry-sclerophyll forest to increase understanding about the impact of future environmental changes in this forest type. The Wombat Forest research site aims to:



- *Quantify the carbon sink/source strength of a dry sclerophyll forest and identify the contribution of such forests to the Australia's National Carbon Inventory.*
- *Quantify the emission and/or uptake of non-CO2 greenhouse gases, such as nitrous oxide and methane of the forest.*
- *Assess the role of climate variability and drought on ecosystem processes.*
- *Assess the impact of disturbances (such as fire) on ecosystem processes.*
- *Provide a database of microclimate and ecological parameters for use in carbon and water modelling projects.*

(www.forestscience.unimelb.edu.au/wombatflux/#onlinedata)

Photo 3: Eddy Covariance tower with attached automated instruments that are used to measure greenhouse gas fluxes in the Wombat State Forest.
(*photo sourced from www.forestscience.unimelb.edu.au/wombatflux/#onlinedata with permission from S Arndt).*

The Wombat research site generates a variety of real time data that can be publically accessed via the Monash University website. It is expected that over time analysis of this data will considerably increase the understanding of carbon fluxes in this forest type.

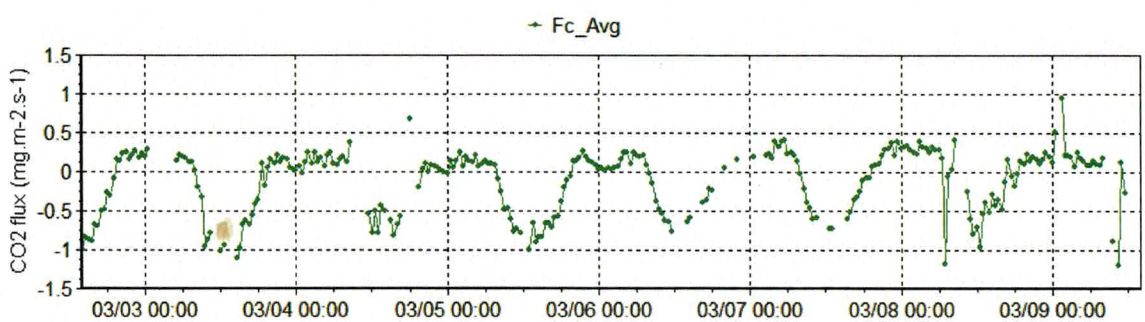


Figure 5: Graph showing CO_2 flux (mg m^2 s^1) at the Wombat research site between 3rd and 9th of March 2010. This information is automatically updated at 30min intervals.
(Source http://arts.monash.edu.au/ges/research/climate/wombat/index.php accessed 10/3/2010)

The Wombat State Forest has a considerable amount of SFRI data that could be used to modify default values in the FullCAM model. The Wombat flux tower research site should provide a better understanding of ecosystem process and how they are impacted on by different environmental conditions and management practices.

Conclusions

Restoration of degraded natural forests is an internationally accepted conservation practice. The effects of forest related carbon offsets are substantially increased if products from sustainably managed forests replace carbon intensive products. In Australia there is a political bias against human intervention in native forests and the use of native forest timbers, this paradigm has dominated and influenced the evolution of domestic climate change policy.

Putting aside the climate change mitigation benefits, there is a clear moral obligation for restoration in the Wombat State Forest. Our forefathers grew back a tall healthy Wombat forest after it had been destroyed during the 1800's gold rush. This provides historical evidence that forest management aimed at restoring this forest type actually works. The State forest agency oversaw unsustainable logging in the Wombat Forest during the 1980s and 90's whilst they told the community that the forest was managed sustainably. Biomass in the Wombat Forest was substantially reduced at a time when the State and Federal governments had committed to maintain forest contribution to carbon cycles.

Australia has developed the sophisticated FullCAM model to assess the impacts of different land uses on greenhouse gas emissions. It would be prudent to use FullCAM as a basis for carbon accounting in the Wombat State Forest, it contains useful default data and the ability for modeling to evolve as new information becomes available.

There is a considerable body of forest inventory data and other information about the Wombat State Forest. The SFRI data provides a good starting point, The Wombat flux tower research site will provide better information in the future which can be used to adjust and refine the model.

To gain an understanding of the potential carbon benefits of ecological restoration in the Wombat State Forest it would be necessary for a FullCAM carbon assessment to provide indicative estimates of four different trajectories.

1. Carbon carrying capacity
2. Current carbon stock
3. Effect of no forest management on carbon stocks
4. Effect of restoration program on carbon stocks

The next step in a Wombat carbon assessment program would be to examine the available SFRI data, select the appropriate data for a FullCAM model and identify where information gaps occur.

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