CARBON SEQUESTRATION IN TASMANIA'S FORESTS: PERCEPTIONS, MISREPRESENTATIONS AND ECOLOGICAL REALITY

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ABSTRACT
Small areas of southeast Australia can support very tall eucalypt forests with large-diameter trees that store large amounts of C. In the public debate on ways to mitigate climate change these forests have received attention as current and potential stores of C. However, such tall eucalypt forests are not typical. Most forests in Australia and in the state of Tasmania are not nearly as C-dense. The capacity of Tasmanian forests to store C is often overestimated. Since eucalypt forests are among the most fire-prone ecosystems in the world, the C contained in them is not permanent and is likely to be released back to the atmosphere. Furthermore, Tasmania's wet forests are globally unique since large wet eucalypts are not the end point of forest succession but are eventually replaced by smaller rainforest trees, so that even if they could be protected from fire, these forests eventually return C to the atmosphere as they transition to rainforest. In addition, fire behaviour has altered as a consequence of the change from Aboriginal to European forest management, and this has influenced the character of Tasmania's forests. In this paper we review and correct some misconceptions and misrepresentations of the potential of Tasmania's forests to store C, discuss the ecological principles that need to be taken into account when estimating C storage and the potential for further C sequestration in Tasmanian forests, and summarise Tasmanian information on soil C that has been overlooked in several studies.

INTRODUCTION

Forests contain large amounts of carbon (C) in living biomass, dead organic matter, and soils. Growing forests generally accumulate C in these pools as older forests usually contain larger trees, contain more above-ground C, and supply more dead organic matter to the soil in the form of leaves, woody debris and dead roots. The tall eucalypt forests of southeast Australia including Tasmania have received particular attention by researchers because of their ability to store large amounts of C and their apparent usefulness for mitigating climate change induced by the effects of increased concentrations of greenhouse gases in the atmosphere. However, large discrepancies have emerged between the ecosystem C estimates of various researchers and in the ensuing debate some ecological processes which also have a bearing on the ability of Tasmanian forests to store C have been overlooked.

According to Mackey et al. (2008) and Keith et al. (2009) the tallest forests of southeastern Australia contain up to 2844 t/ha of living and dead biomass C which these authors claim to be the most C-dense forests in the world. These authors calculate that if soil C is taken into account, a maximum total ecosystem C figure of over 3000 t/ha can be reached. Sillett et al. (2015) showed that the biomass C figures of Mackey et al. (2008) and Keith et al. (2009) are almost certainly incorrect, finding above-ground biomass C in similar forests to be

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at most 706 t/ha, but probably lower (438 t/ha) due to the loss of mass in decayed hollow trunks and limbs. Sillett et al. (2015) also challenged the assertion that the southeastern Australian eucalypt forests are the most C-dense forests in the world, quoting measurements of North American redwood (*Sequoia sempervirens*) forests which contain more than 2000 t/ha of biomass C.

Mackey et al. (2008, pp. 11–12) acknowledged that the potential maximum ecosystem C content for most of the 14.5 million ha forest area studied is far lower than their 3000 t/ha figure: combining their estimated average of 360 t C/ha for biomass (live vegetation plus dead wood) and 280 t C/ha for soil, produced an average potential maximum ecosystem C figure of 640 t C/ha. They noted that this figure was almost three times the default 217 t C/ha figure for the actual (not potential) C in temperate forests as estimated in the Intergovernmental Panel on Climate Change (IPCC) report on land use change and forestry (IPCC 2000) and attributed the lower IPCC figure to its being based on measurements in managed forests.

The articles referred to above use the concept of carbon carrying capacity (CCC), which is defined as “the mass of carbon able to be stored in a forest ecosystem under prevailing environmental conditions and natural disturbance regimes, but excluding anthropogenic disturbance” (Keith et al. 2009). The difference between CCC and current C stocks is then described as the Carbon Sequestration Potential (CSP). It has been argued that to mitigate climate change southeast Australian native forests should be set aside in largely unmanaged and unharvested reserves in perpetuity, allowing ecosystems to accumulate C, so that forests reach their CCC.

However, several studies in Tasmanian forests (Moroni et al. 2010, 2012a, b) indicate that these forests’ potential C storage has been overestimated, potentially generating a skewed public perception of the forests’ actual and potential C storage. Public perceptions may also be influenced by articles illustrated by untypical high-biomass forest types containing close to their maximum C; for example, the five forest stands illustrated by Mackey et al. (2008) were unrepresentative and contained 620 to 1800 t /ha of biomass C, much higher than the average biomass C (360 t /ha) of the undisturbed forests studied by these authors.

Moroni et al. (2012b) pointed out that although small areas of Tasmania forests contain very large eucalypts, including the tallest flowering plant in the world (a *Eucalypt regnans* about 100 m tall), these forests have attracted research and public attention disproportional to their cover in Tasmania. Public perceptions of the C-storage potential of Tasmania’s forests were tested during public talks given by M. Moroni from 2011–2015 (e.g. Moroni 2011) attended by a total of >5000 people. When audiences were asked what proportion of State forest looks like trees in Figure 1 (mature trees >55 m tall with high crown cover) professional Tasmanian foresters overestimated the occurrence of trees like this by a factor of 5 to 50, and the general public overestimated their occurrence by a factor of 50–400 (M. Moroni, unpublished data). The trees illustrated in Figure 1 are the tallest trees in the State, but mature trees >55 m tall with high crown cover represent only a small fraction of State forest (0.2%) by area, and inventory indicates that such trees could only occur in 1.6% of State forest, primarily due to limitations associated with site fertility, climate and exposure (Moroni et al. 2010).

The effects of disturbance in eucalypt forests, in which C sequestration into biomass and soils is limited by periodic emissions following wildfire (Attiwill and Adams 2008; Dore et al. 2008) is frequently underestimated in articles promoting the

CCC concept. Proponents of the CCC concept also underestimate the effects of natural succession on C storage and do not take into account local soil knowledge.

This article reviews the potential of Tasmania's forests to store C and corrects some misconceptions and misrepresentations published in the literature. It discusses the ecological principles that need to be taken into account when estimating C storage and the potential for further C sequestration in Tasmanian forests, and provides a summary of Tasmanian information on soil C that appears to have been overlooked in several studies.

Figure 1. Iconic Tasmanian wet eucalypt forests. The tree on the far left is 100 m tall.

REVIEW

Carbon in biomass

Moroni et al. (2010) estimated the C content of standing trees (live and dead) in State forest. In most mature wet eucalypt forests in Tasmania maximum achievable ecosystem carbon storage is much lower than that at the C-dense sites described by Mackey et al. (2008) and Keith et al. (2009). While *Eucalyptus regnans* forests containing up to 1000 t /ha of above-ground carbon as live biomass occur on deep soils containing large amounts of available water, generally on valley floors and protected slopes such as those at the Styx valley Big Tree Reserve, these stands cover only 2600 ha or about 0.2% of the State forest area and, although impressive, are unrepresentative (Wood et al. 2010, figure 9). Wet forests capable of sequestering more than 290 t/ha of biomass (i.e. the wet eucalypt forests mapped as Class 1–3 by Forestry Tasmania) in 2010 covered only 2.5% of State forest land and because of soil and climate limitations have the potential to cover at most 10–15% of State forest land (Moroni et al. 2010).

As noted by Mackey et al. (2008) and Keith et al. (2009), the highest live biomass C (above-ground and roots) occurs in mature eucalypt forests >55 m high, with >40% crown cover (Class 1 forests): these contain 470 t C/ha (Moroni et al. 2010). If forests supporting all mature trees >55 m are considered (Class 1 and 2 forests) the figure is slightly lower: 387 t C/ha. Among mature eucalypt forests in the State forest area most of the C is in medium-stature forests 41–55 m high, which contain 22 million t of C (22 Tg), four times as much as that in mature forests >55 m tall (5.2 Tg) (Moroni et al. 2010). To put these figures in context, all eucalypt forests (wet and dry) on State forest land contain about 139 Tg of C. Rainforests contain on average about 72 t C/ha in the form of biomass and over the total State forest area contain 17 Tg of C. Other forests contain 5 Tg of C. The total carbon in all State forest (trees only) was estimated to be 139+17+5 = 161 Tg

May et al. (2012) estimated the C content of all the live vegetation in Tasmanian native forests (public and private) based on published estimates of forest type C content and forest type area. The State-wide total was in the range 380–500 Tg, with about half (177–230 Tg) being harvestable (May et al. 2012, p. 54). The latter range of figures is larger than the 161 Tg figure calculated by Moroni et al. (2010) for State forest because it includes native forests on private land (10 Tg C) and the C in shrubs and understorey vegetation like tree ferns.

Carbon in soils

The C content of several soil types in Tasmania can be calculated from information in published soil surveys in northern Tasmania (Grant et al. 1995; Hill et al. 1995; Laffan et al. 1995), as well as that from later profile analyses (McIntosh 2010; P. McIntosh, unpublished data). Analyses are available from nineteen sites under wet forest, fourteen under dry forest, three under rainforest and two under swamp forest (forest growing on soils which are waterlogged for most of the year). Comprehensive soil maps for Tasmanian forests are not available, so profile analyses cannot be expressed as area-weighted means. Instead indicative means for carbon storage to 1 m depth under four broadly defined forest groups have been calculated (Table 1).

Table 1. Mean carbon and nitrogen to 1 m depth for four forest groups and carbon to 1 m depth for all eucalypt forests.

	Analyses to 1 m depth			**A1 horizon only**
	C (t/ha)	**N** (t/ha)	**C/N**	**C/N**
Wet eucalypt forest *(n=19)*	147	9.9	15	22
Dry eucalypt forest *(n=14)*	92	4.1	21	24
All eucalypt forests (*n*=33)	123			
Rainforest *(n=3)*	208	11.9	18	15
Swamp forest *(n=2)*	462	20.9	22	20

Note: means are arithmetical and not area-weighted.

Soil C levels are highest in swamp forests, where high water tables inhibit organic matter breakdown, and lowest in dry forests, where low biomass production and frequent fires inhibit accumulation of organic matter. The high C/N ratio of the soil organic matter to 1 m depth under dry forests is probably due to the presence of charcoal in these soils, but the C/N ratios of >20 in topsoils of both wet forests and dry forests indicate the presence of topsoil charcoal in both forest groups. In contrast rainforests, which have probably not been burnt for at least 400–800 years, have topsoil C/N ratios of 15, similar to the topsoil C/N ratio of 16 in the Edendale soil under a temperate rainforest remnant on a well-drained soil in the South Island of New Zealand which may have never been burnt and contains 248 t C/ha (McIntosh 1995, p. 31). Rainforest soils analysed contain 41% more soil C to 1 m depth than wet eucalypt soils, but the three rainforest profiles sampled were at 580–680 m altitude in northeast Tasmania and not representative of Tasmanian rainforest soils in general.

The long-term soil C changes following fire cannot be calculated as no studies of fire chronosequences in Tasmania have tracked soil C levels over time. In regenerating Victorian *E. regnans* forests Polglase et al. (1994) found that soil carbon reached 86% of equilibrium values when the forest was aged 30 years, with true equilibrium not being reached until about 150 years. At a high-rainfall southwestern Tasmanian site at Warra that was burnt in both the stand-replacing 1898 bushfire and the less intense 1934 bushfire, soil A1 horizons are still only 10 cm thick and the total soil C to 1 m depth is 161 t C/ha (McIntosh 2012), close to the mean for all wet forests in Tasmania (147 t C/ha).

Measures of short-term soil changes resulting from fire have yielded ambiguous results: Pennington et al. (2001) noted a 6% decline of topsoil C after a regeneration burn at Warra in Tasmania's southern forests. The effect was confined to the 0–10 cm layer and was not statistically significant once bulk density had been taken into account. In contrast, in a study spanning three coupes at Warra, Slijepcevic (2001) noted a 4% increase in topsoil C (0–10 cm) after burning. The results probably reflect the difficulty of adequately covering soil variation by the sampling methods used. Neither result should be used to define the short-term effect of burning on soils.

There is a regrettable lack of information on soil C responses to ecosystem change, and we concur with Norris et al. (2010) that "the uncertainty around soil carbon represents a priority for further work". Nevertheless, it is likely that after fires soil C increases (after an initial topsoil C loss) as eucalypt biomass inputs increase and dead organic matter is returned to the soil. Whether soil C increases or decreases as rainforest succeeds eucalypts has not been studied.

Soil C in deep soil layers resists change and has a long residence time. Humus in a podzol in northeast Tasmania was dated 3356±42 cal yr BP (Wk17421; P. McIntosh, unpublished data), which is the average age of translocated humus in this horizon. If it is assumed that humus contributions have continued to the present, the residence time of this resistant organic matter may be >6000 years.

Soil C is inadequately considered by most researchers. Dean and Wardell-Johnson (2010) derived a figure of 271 t C/ha for soil organic C to 30 cm depth under tall old-growth forest in Tasmania but did not indicate their data source. The figure appears to be too high as the highest measured C value for 0–30 cm soils in Tasmania (in a Stronach soil (Dermosol) formed in granite in northeast

Tasmania) is 121 kg/ha (Grant et al. 1995). Likewise their derived figure for rainforest soils (369 t C/ha to 30 cm depth) is almost certainly too high because the mean measured C value for 0–30 cm soils at three rainforests sites (Grant et al. 1995) is 102 t C/ha. There are numerous references to total soil C by May et al. (2012) but the actual depth to which their figures refer is not specified, although one estimate (on p. 17) refers to <30 cm soils. Whether the average soil figure of 280 t C/ha “assumed to represent all eucalypt forests in southeast Australia” (May et al. 2012, p. 274) refers to 0–30 cm or 1 m depth, it is too high for Tasmanian eucalypt forests, in which the mean soil C to 1 m depth is 123 t C/ha and 64 t C/ha for 0–30 cm soils (*n*= 33; means not area-weighted). This lower figure has a bearing on modelled carbon sequestration figures (May et al. 2012, figure 4 and table 5).

May et al. (2012) used the Roth C model, developed for arable land and woodland, to model soil carbon stocks over time but noted (p. 258) that “no studies have investigated whether [the parameters required to run the model] are suitable for native forest”. They also found that it was “difficult to obtain amounts of soil carbon that consistent [sic] with actual soil carbon in high carbon soils” which indicates that there may be biochemical limitations to eucalypt organic matter breakdown in soil (Barrett 2002) which are not taken into account in the Roth C model.

The soil C decline after intensive forest management that Dean and Wardell-Johnson (2010) derived from Ferré et al. (2005) and Pennington et al. (2001) is not soundly based: the Ferré et al. (2005) figure is derived from short-rotation unburnt poplar plantations established after ploughing on an active floodplain in Italy and is of doubtful relevance to old-growth eucalypt forests in Tasmania. Dean and Wardell-Johnson (2010) omit to mention that the 6% organic carbon decline calculated on a kg/ha basis by Pennington et al. (2001) after a clearfell, burn and sow operation in Tasmania was not statistically significant. In addition, as mentioned above, Slijepcevic (2001) found an increase in soil C after clearfell, burn and sow but Dean and Wardell-Johnson (2010) make no mention of this figure. Although the w/w C values for 0–10 cm soils analysed by Pennington et al. (2001) were significantly different by 5%, this 5% difference (amounting to only 2 t/ha) cannot be translated to a “conservative” 2.5% loss “over the whole profile” (Dean and Wardell-Johnson 2010). The highest measured soil C figure to 1 m depth in Tasmanian wet forests (tall forests) is 272 t/ha (Grant et al. 1995) so the c. 700 t/ha baseline figure for the undefined “full soil profile” used by Dean and Wardell-Johnson (2010, figure 8) is not only too large but also unrepresentative.

Forest succession in Tasmania

The forests of Tasmania and southeast Australia are globally unique in that forests dominated by the tallest trees (eucalypts) containing the highest C density are, in the absence of disturbance, eventually replaced by forests containing significantly shorter and smaller-diameter rainforest trees. Provided there is a seed source nearby (for example a rainforest-dominated gully, shady slope, or nearby unburned patches), wet eucalypt forests will transition to rainforests.

The process has been described in the classic paper by Gilbert (1959). After fire a eucalypt forest will normally rapidly establish. By the time the eucalypt forests are about 100 years old, shade-tolerant rainforest species may already be a significant understorey. As the eucalypts reach maturity the rainforest will form a continuous understorey and a mixed forest results (Gilbert 1959, figure 1.10). The eucalypts cannot regenerate under the rainforest canopy. Hence, once the eucalypts reach their maximum age of 300–500 years and progressively die, they are replaced by the rainforest understorey. To maintain eucalypt cover, fire must return before the eucalypt overstorey (the seed source), dies (Gilbert 1959, Jackson 1983).

The transition of eucalypt forest to rainforest has been estimated to reduce standing tree C stocks by 50–60% (Moroni et al. 2010). On average, across State forest, live and dead standing trees contain 232 t C/ha in mature wet eucalypt forests and 72 t C/ha in rainforests (Moroni et al. 2010). Unpublished measurements indicate that the above reductions in forest C storage are conservative for fertile Tasmanian wet forests (M. Moroni, unpublished data), i.e. the reduction of above-ground biomass-C as a consequence of the eucalypt-rainforest transition may exceed 170 t/ha. Hence the transition of eucalypt-dominated wet forest to rainforests will result in the release of large amounts of C from above-ground biomass. This is contrary to expectations from most of the world's forests that tend to accumulate C with age (Luyssaert et al. 2008) and has significant negative implications for land managers expecting C credits as a result of reserving wet eucalypt forests; some forests being set aside to accumulate C are likely to be actually releasing C to the atmosphere as they transition to rainforest.

Fire

Fire has had a profound effect on the ecology of Tasmanian forests. This was realised in the 1960s, when studies showed that most commercially valuable eucalypts require fire and bare mineral soil for successful regeneration, whether they are part of managed or entirely natural forests (Cremer 1960, 1962a,b, 1965; Cremer and Mount 1965; Cunningham 1960; Cromer 1967).

There is evidence of fire going back at least 200 000 years in the Arve Valley (P. McIntosh, C. Neudorf and O. Lian, unpublished information) and there are indications that fire (and associated erosion) increased with arrival of people in Tasmania 40 000 years ago (McIntosh et al. 2012). Gammage (2011) provided evidence that the Aborigines used fire extensively for managing land in Tasmania in order to produce open areas attractive to game and to suppress dense understorey and eucalypt regeneration. Even in areas that “should” be dense rainforest (such as Surrey Hills, at 600 m altitude in the northwest), early European explorers such as Hellyer came across open grasslands with occasional eucalypts which reminded them of a nobleman's estate in England (Onfray 2010) and pollen preserved in deep peats on Surrey Hills provides evidence of fires and fire-induced eucalypt woodlands being present for at least 10 000 years (Watson 2013; McIntosh et al. 2014). We can conclude that many eucalypt forests had a more open character under Aboriginal management than they do at present.

In the European era in Tasmania there have been a number of large fires. The largest was in 1898 when over 1 million ha, and possibly up to 2 million ha, of forests in the southwest burned (May et al. 2012). Other very large fires were in 1934 when 800 000–900 000 ha burned (Marsden-Smedley 1998) and in 1967 when approximately 250 000 ha burned (Walker and Fenton 2007). Recently the fires in northwest Tasmania which began after more than 80 lightning strikes in January 2016 burned for 2 months and covered about 100 000 ha of forests and moorland[1]. In Victoria landscape-scale forest fires occurred in 1851 (5 million ha), 1938–1939 (2 million ha), 1944 (1 million ha), 1983 (510 000 ha), 2003 (1.3 million ha) and 2009 (450 000 ha)[2].

McIntosh et al. (2003) proposed that in the drier parts of the state frequent fires have played a role in the irreversible development of texture-contrast soils from more fertile gradational soils by destroying stable clay-organic matter complexes. Such texture-contrast soils dominate in the drier areas of Tasmania, and because they are less fertile and hold less available water than deep gradational soils they favour dry open forest types (dry eucalypt forest) with heathy understorey. A feedback mechanism operates: frequent fires induce low fertility and dry heathy vegetation, which favours more fires, sustaining the dry forest/texture-contrast soil ecosystem indefinitely.

Thus a picture of forest cover over time in Tasmania can be built up. In the middle of the Last Glacial period tall forest cover was limited to lowlands and near-coastal sites. As the climate warmed and got wetter about 12 000 years ago eucalypts would have spread quickly. Aborigines tried to protect their traditional hunting grounds by suppressing eucalypt spread using the only means available to them: frequent fires. Consequently, when the early European explorers visited they found vast areas of open woodlands in the drier areas of the state, and in wetter areas they found similar woodlands in certain areas. We can be reasonably certain that at least during the Holocene the Tasmanian forest pattern has been a mosaic of fire-induced forest of different ages – a managed anthropogenic landscape. For a brief period from approximately 1825 to 1920 (when mechanised harvest began in earnest) forest cover was neither limited by frequent Aboriginal land management nor disturbed by clearfelling operations, although timber was extracted from more accessible sites (Kostoglou 1996). In this period, for the first time in 12000 years, many forests previously managed by Aboriginal burning grew and regenerated without large-scale human intervention, greatly increasing above-ground biomass and C and fuel for fires.

The concept of carbon carrying capacity

Mackey et al. (2008), Keith et al. (2009; 2010), May et al. (2010) and Dean (2011) stress the value of the concept of Carbon Carrying Capacity (CCC), and the derived Carbon Sequestration Potential, for determining how much C Tasmanian forests can absorb to mitigate the effects of climate change. CCC is defined as "the mass of carbon able to be stored in a forest ecosystem under prevailing environmental conditions and natural disturbance regimes, but excluding anthropogenic disturbance" (Keith et al. 2009, with wording closely following that of Gupta and Rao 1994). CCC is described as "a *landscape-wide metric* [our italics] that provides a baseline against which current carbon stocks (that include anthropogenic disturbance) can be compared" (Keith et al. 2009). The difference between CCC and current C stocks is then described as the Carbon Sequestration Potential (CSP). The weaknesses inherent in these concepts were highlighted by Moroni (2012) and are summarised below.

(1) *Forest succession*. The primary flaw in the CCC concept is that it assumes that eucalypt forests are the steady-state end point of forest

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[1] https://en.wikipedia.org/wiki/2016_Tasmanian_bushfires

[2] https://en.wikipedia.org/wiki/Bushfires_in_Victoria#Most_extensive_fires

succession. In fact, as shown above, tall eucalypt forests occur at about the mid-point in the succession from new (fire-induced) eucalypt forests to old rainforests (those forests which have neither a tall eucalypt overstorey nor eucalypt debris on the forest floor). The area of tall wet eucalypt forests that can transition to rainforest is large: about 0.56 million ha (Moroni et al. 2010). The succession takes about 700 to 800 years. Remarkably, as noted above, Tasmania and southeast Australian forests are globally unique in that steady-state rainforests have about half the height and half (or less than half) of the biomass of the tall eucalypt forests they replace. Defining a "Carbon Carrying Capacity" based on maximum C in tall eucalypt forests is therefore an academic construct and ecologically meaningless: this figure is only true for a brief instant in time – once reached it cannot be carried forward. The consequence is that well-intended forest management aimed at achieving maximum biomass C by reserving tall eucalypt forests will fail. The promotion of CCC as an ideal and desirable end point of land management in Tasmanian forests has no scientific ecological basis.

(2) *Extrapolation to landscape scale.* Another flaw in the CCC concept as used by Mackey et al. (2008), Keith et al. (2009, 2010) and Dean (2011) is its application at the landscape scale. We note that CCC was originally defined by Gupta and Rao (1965) as applying to ecosystems, not landscapes. As mention above, its application to landscapes creates problems, because landscapes support different ecosystems at different times and they are prone to disturbances such as fire, erosion and storm damage which do not affect all component ecosystems equally or predictably. A case in point is the highly productive forests of the O'Shannassy catchment in Victoria which contained huge amounts of biomass (1800 t C/ha) in 2008 (Mackey et al. 2008, p. 41). One year later, after the January-February 2009 fires, they contained much less. The biomass present in 2008 and that present in 2009 represent the extreme maximum and minimum for this ecosystem (fire-induced mountain ash forest) and neither biomass value can be presented as an achievable target for the landscape as a whole. Surprisingly, Keith et al. (2010, table 6) do not mention such fires as uncertainties to take into account when measuring CCC in landscapes.

It is evident from the above discussion that not only has CCC in ecosystems been overestimated, but also that CCC is impossible to apply at the landscape scale because it has no basis in ecological reality. The concept cannot and should not be used as a guide for land managers wishing to maximise C storage in the landscape. As Moroni et al. (2010) have written: "It is quite inappropriate . . . to subtract the current C content of wet eucalypt forests from an estimated CCC derived from mature forest site values, and present the answer as a putative landscape C loss from forest harvesting". Tasmanian forests have always consisted of a mosaic of eucalypt age classes and rainforests, and we can be confident that they have never consisted of uniform old-growth eucalypt forest.

CONCLUSIONS

- Many members of the public, and foresters and researchers overestimate the area that presently supports tall C-rich forests, and the potential cover of these forests. The actual area that can support tall C-rich forests is limited by soil properties and climate.

- The biomass carbon stored in tall eucalypt forests has been overestimated in many studies. Mature eucalypt forests >55 m high, with >40% crown cover (Class 1 forests) contain about 470 t C/ha in total live biomass (above-ground biomass and roots).
- All published studies appear to have disregarded Tasmanian soil survey information and have overestimated the actual amount of C stored in Tasmanian forest soils.
- Many Tasmanian wet eucalypt forests are returning C to the atmosphere as they transition to rainforests.
- The concept of carbon carrying capacity (CCC) promoted by many authors cannot be applied at the landscape scale because it ignores the facts that: (1) fire is a natural part of eucalypt forest ecology and maintains many forests in a juvenile state and creates a mosaic of forests of different ages; and (2) in the absence of fire, eucalypt forests with the largest trees are not the end point of forest succession, but are replaced by rainforest containing about half the biomass and half the C.
- Tasmanian forests are adapting to European management following about 12 000 years of Aboriginal management. Fewer low-intensity fires in the last 200 years have increased both forest and understorey cover in many forests, and consequently, when fires now occur they are probably more intense than those that occurred under Aboriginal management.
- Setting aside large areas of Tasmanian wet eucalypt forests as reserves to increase national C storage is not a scientifically sound policy; the unmanaged forests will either burn, releasing large amounts of C to the atmosphere, or they will transition to rainforests containing less C than the eucalypt forests they replace.
- Tasmanian forests are best managed for C storage by maintaining a mosaic of forests of different ages, maintaining access for fire control, and utilising harvested timber for long-life timber products and through using wood for construction instead of materials such as concrete and metals produced by intensively C-emissive methods.

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