



Viewpoint

Interventions to better manage the carbon stocks in Australian *Melaleuca* forestsDa B. Tran^{a,d,*}, Paul Dargusch^a, John Herbohn^{b,c}, Patrick Moss^a^a School of Geography Planning and Environmental Management, University of Queensland, St Lucia Campus, Brisbane, QLD 4072, Australia^b School of Environment, Science and Engineering, Southern Cross University, Lismore, NSW 2480, Australia^c School of Agriculture and Food Sciences, University of Queensland, St. Lucia Campus, Brisbane, QLD 4072, Australia^d Department of Agroforestry, Vietnam Forestry University, Hanoi, Viet Nam

ARTICLE INFO

Article history:

Received 23 September 2012

Received in revised form 15 April 2013

Accepted 28 April 2013

Keywords:

Wetlands
Climate change
Carbon

ABSTRACT

Forests and woodlands dominated by tree species of the genus *Melaleuca* cover around 7,556,000 ha in Australia and predominantly occur as wetland ecosystems. In this *Viewpoint*, we use published secondary data to estimate that there is likely to be between 158 tC/ha and 286 tC/ha stored in *Melaleuca* forests. These estimates are at least five times greater than the previous estimate made by the Australian Government (about 27.8 tC/ha). There are 2.1 million ha of protected *Melaleuca* forest which likely stock between 328 M tC and 601 M tC; equivalent to between 2.7% and 5.0% of total carbon storage of all Australian native forests. These estimates are significant because it appears that carbon stocks in *Melaleuca* forests are currently dramatically under-estimated in Australia's national greenhouse gas emissions inventory reported under the United Nations Framework Convention on Climate Change (UNFCCC). Whilst the precision of the estimates is limited by the availability of rigorous primary data, we also argue that the estimates are indicative and meaningful, and this synopsis highlights the fact that this forest type should be considered a significant carbon store nationally and globally.

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Rationale

Melaleuca forests occur over a very broad area of Australasian and Southeast Asian countries (Blake, 1968; Brown et al., 2001; Craven, 1999). Within Australia, there are 7,556,000 ha of *Melaleuca* forests and woodlands (naturally occurring), equivalent to 5% of the total forest area (DAFF, 2010; MPI, 2008) (a distribution map of the Genus and example photographs of *Melaleuca* forests are provided in supplementary material – Supplementary 1 and 2). They are 7.7 and 2.3 times greater than the area of mangrove forests and rainforests in the country, respectively. *Melaleuca* forests in Australia mostly occur in a sub-tropical and tropical woodland habit (~97%) with around 84% of the forest type located on publicly owned land and the remainder on privately owned land (DAFF, 2010; MPI, 2008). Most of the publicly owned land covered by *Melaleuca* forests is leasehold land which is currently used for cattle grazing. Only about 4500 ha of plantations of *Melaleuca* have been established for the production of tea tree oil (RIRDC, 2006).

Of the total area of this forest type in Australia, over 5,698,000 ha are located in the state of Queensland, of which 2,104,000 ha are located in protected areas such as national parks (DAFF, 2010; MPI, 2008). *Melaleuca* forests in Australia are predominantly wetland forests, and occur in lacustrine and palustrine land systems (e.g. Supplementary 2). Common species of the genus *Melaleuca* in Australia include *Melaleuca viridiflora*, *Melaleuca leucadendra*, *Melaleuca argentea*, *Melaleuca quinquenervia*, *Melaleuca nervosa*, *Melaleuca preissiana*, and *Melaleuca raphiophylla*.

This paper collates secondary data on the carbon stocks¹ of *Melaleuca* forests in Australia, and estimates the current financial value of the carbon contained in these forests. Importantly, there is literally only a handful of papers and reports in the public domain that deal with the carbon stocks of *Melaleuca* forests. A discussion on carbon stocks in *Melaleuca* forests in Australia is therefore both timely and important for several reasons. Firstly, this forest type is likely to contain carbon stocks of global significance, because many freshwater wetlands are known to store high amounts of carbon [e.g. the rate of carbon accumulation estimated in the

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¹ Carbon stocks refer to those stores of carbon fixed within a forest ecosystem including standing, understorey, litter and deadwood biomass, and soil organic carbon that if released in their gaseous states would become greenhouse gas emissions [1 tC = 3.67 tonnes carbon dioxide equivalent (tCO₂e)].

Quercus palustris forested wetland community in temperate region of USA was 4.73 tC/ha/yr (Bernal and Mitsch, 2012), and in the *Cyperus papyrus* tropical wetland in Uganda was 4.8 tC/ha/yr (Saunders et al., 2007)]. However, the carbon stocks of *Melaleuca* forests, including any change or disturbance to those stocks, appears to have been inadequately reported in Australia's national greenhouse gas emissions accounts, which is required under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). For example, the Australian Government estimated in 2004 that there was 210 million tC in Australian *Melaleuca* forests, equivalent to around 27.8 tC/ha (MPI, 2008, p. 117). This paper shows why this is likely to be a dramatic underestimate of the amount of carbon stocks in *Melaleuca* forests. Secondly, *Melaleuca* forests in Australia also have high conservation values [e.g. biodiversity, and as indigenous cultural and heritage sites (EPA, 2005)], high vulnerability but aggressive responses of adaptation to climate change (Tran et al., 2012), and occur in localities under pressure from mining and urban development. Management that aims to conserve the carbon stocks of *Melaleuca* forests should also work to conserve the ecological value of those forests. However, the development and planning controls in many jurisdictions in Australia do not give the carbon stocks in the soil components of *Melaleuca* forests adequate consideration, despite this pool containing substantial amounts of carbon in some *Melaleuca* forest types (Supplementary 4). Focus is primarily on the vegetative aspects of *Melaleuca* ecosystem, and little consideration is given to the development and drainage of areas of these forest types that might be cleared, even though such sites probably contain very large quantities of soil carbon.

Deriving an estimate of carbon stocks

Here we use published data and International Panel of Climate Change (IPCC) carbon stock estimation methods to derive an estimate of the carbon stocks of *Melaleuca* forests in Australia. As noted above, there is a stark paucity of published information on the carbon stocks of *Melaleuca* forests in Australia and this makes deriving a reliable estimate using existing data problematic. The estimate presented here needs to be considered in this context, and that whilst it is limited by lack of existing data, our estimate highlights the likely significance of *Melaleuca* forests as a carbon store and we use the estimate to call for more research and better policy intervention on this topic.

As per IPCC guidelines (IPCC, 2003), the carbon fraction of dry matter in above-ground biomass and litter can be assumed to be 50% and 45%, respectively. There is no published Australian data related to the biomass in the understorey and deadwood components of *Melaleuca* forests in Australia, so these two IPCC categories were not included in the estimates. The amount of carbon in *Melaleuca* forests was estimated as follows:

$$\text{C density (tC/ha)} = \text{C standing biomass} + \text{C litter biomass} \\ + \text{C soil organic.}$$

Soil organic carbon (SOC) content was estimated using the equation:

$$\text{SOC} = \text{Depth (m)} \times \text{bulk density (g cm}^{-3}\text{)} \times \text{C (\%)} \times 100$$

where the SOC formula derives from IPCC, and 100 is the default unit conversion factor.

Only one publication has to date presented an estimate of the amount of tree biomass in *Melaleuca* forest ecosystems in Australia based on forest inventory data collected in the field. Finlayson et al. (1993) estimated that the average above ground dry biomass in *Melaleuca* forests is approximately 132 t/ha [the value was

converted from the original fresh biomass value by Van et al. (2000), and did not include root mass]. Additionally, based on the values of diameter at breast height and tree densities from Franklin et al. (2007), biomass of five species including *M. argentea*, *M. cajuputi*, *M. dealbata*, *M. leucadendra* and *M. viridiflora* were converted and estimated accounting for approximately 168 t/ha, 81 t/ha, 54 t/ha, 96 t/ha, and 80 t/ha, respectively. These compare with introduced *Melaleuca* forests in Florida USA, for which the estimates are 181 t/ha (Van et al., 2000), and 331 t/ha (Rayamajhi et al., 2008) (Supplementary 3). Assuming that the estimates from values of Franklin et al. (2007) (with the lowest and highest records 54 t/ha and 168 t/ha, respectively) are representative of the above ground biomass in *Melaleuca* forest ecosystems in Australia, then the typical carbon stocks in tree biomass in *Melaleuca* forests is likely to be between 27 tC/ha and 84 tC/ha.

Four studies have examined the dynamics of litter fall (leaves, bark, fruit and branches) and accumulation in *Melaleuca* forests. Congdon (1979), Finlayson et al. (1993) and Greenway (1994) examined litter dynamics in *Melaleuca* forests in Australia, while Rayamajhi et al. (2006) examined the litter dynamics in *Melaleuca* forests in Florida, USA. The rate of litter fall in *Melaleuca* forests in Australia has been estimated to be between 7.00 and 7.67 t/ha/yr in the floodplains of Northern Queensland (Finlayson et al., 1993) and Southeast Queensland (Greenway, 1994), respectively. Litter accumulation was 23.20 and 34.57 t/ha/yr on the floodplain and the forest floor, respectively, based on data from eight 0.0625 m² quadrat samples at each site in Native Dog Creek/Logan River floodplain, southeast Queensland (Greenway, 1994). Greenway (1994) also reported various indicators of high carbon content in the forest litter components of *Melaleuca* forests (notably C:N=60:1, C:P=1400:1 for litter with decay size \geq 5 mm, and C:N=25:1 and C:P=300:1 for litter decay size <5 mm). This probably reflects slow rates of litter decomposition. For instance, Rayamajhi et al. (2006) recorded that after 322 weeks, 14% of litter fall had not decomposed in the Floridian *Melaleuca* forests.

If we assume that the estimates of accumulated forest litter range from 7.00 t/ha/yr to 34.57 t/ha/yr in Australian sites [as per the studies of Finlayson et al. (1993) and Greenway (1994)] are representative of the amount of accumulated forest litter in *Melaleuca* forests, then it is reasonable to estimate that the typical carbon content in the litter of *Melaleuca* forests is between 3.15 tC/ha and 15.56 tC/ha.

The following estimates of soil carbon stocks are based on the results of soil analyses reported by the Queensland Wetlands Programme using samples taken in *Melaleuca* forest sites located in different parts of Queensland, Australia. The soil organic carbon content (C%) and C:N ratios of the soil samples are presented in Supplementary 4. Studies on soil properties conducted around Australian wetlands show that soil bulk density ranges from 1.5 g/cm³ at 0.1 m depth in the coastal lowlands of southeast Queensland (Costantini, 1995), to 1.6 g/cm³ at 1 m depth in woodland-open forest landscape within the Brigalow Belt South bioregion of Queensland (Roxburgh et al., 2006), to 0.55 g/cm³ at 0.25 m depth in hydrosols in Darwin Harbour (Hill and Edmeades, 2008); the latter being consistent with other reported values from North Queensland (McKenzie et al., 2000), and the Hunter River estuary in Southeast Australia (Howe et al., 2009). Therefore, assuming that *Melaleuca* forest soils have a bulk density of ranging from 0.55 g/cm³ (Hill and Edmeades, 2008) to 0.8 g/cm³ (personal record) with mean average carbon concentration of 7.75% (Supplementary 4), and these data are representative of *Melaleuca* forest soils, the typical soil carbon content in at 0–30 cm depth of *Melaleuca* forests in Australia is likely to be range between 128 tC/ha and 186 tC/ha. These estimates are consistent with those reported by Page and Dalal (2011) for soil carbon stocks in wetlands of other vegetation types in Queensland (from 12 to 557 tC/ha).

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