POTENTIAL CLIMATE CHANGE MITIGATION THROUGH CARBON STOCK ACCUMULATION BY *MELALEUCA CAJUPUTI* POWELL (GELAM)

Jamilah, MS[1]*;
[1]*Institut Penyelidikan Kenyir*
Universiti Malaysia Terengganu
Mengabang Telipot
21030 KUALA NERUS, TERENGGANU

Nur-Atiqah, MH[1];
[1]*Institut Penyelidikan Kenyir*
Universiti Malaysia Terengganu
Mengabang Telipot
21030 KUALA NERUS, TERENGGANU

Mohamad Hafis, M[1]
[1]*Institut Penyelidikan Kenyir*
Universiti Malaysia Terengganu
Mengabang Telipot
21030 KUALA NERUS, TERENGGANU

Sheriza, MR[2]
[2]*Institute of Tropical Forestry and Forest Products (INTROP)*
Universiti Putra Malaysia
43400 UPM SERDANG, SELANGOR DARUL EHSAN

ABSTRACT

Melaleuca cajuputi Powell or Gelam (in Malay) is an abundant tree species on the coastal plain of the East Coast of Peninsular Malaysia, dominantly in Terengganu. However, Gelam forest which occurs pocketed in parallel to the coast, is being considered as an unproductive forest, wasted land and increasingly being reclaimed for other land uses. Gelam trees also dominated Melaleuca swamp, one of the rare freshwater wetland due to its seasonality. Despite being seen as economically unimportant and receives little scientific attention, Gelam forest plays significant role in providing ecosystem services to coastal and inland community, namely in coastal protection and stabilization, supporting adapted biodiversity of plant and animal species, mitigating flood and accumulating above and below ground carbon stock. This paper reported the potential role of Gelam trees in climate change mitigation through carbon stock accumulation in their standing biomass in order to reinforce one of the many Melaleuca forest ecosystem services which is maintaining carbon stock in its biomass. This naturally available carbon stock could be used to sustainably manage Melaleuca forest as one of the efforts of Terengganu State to address climate change issues at local level. However, until present there is no quantitative study conducted to measure accumulated carbon stock in Melaleuca forest. Carbon stock of Gelam was calculated in the above ground biomass (ABG) using diameter at the breast height (DBH) as the main parameter in biomass allometric regression.Diameter was measured on Gelam trees grow on two contrasting microhabitats, depression (waterlogged) and ridge (dry) sites on beach ridge ecosystem of Terengganu. In total, 351 Gelam trees (196 in depression and 155 in ridge site) were measured their DBH and calculated the carbon stock based on the above ground biomass. In average, Gelam trees accumulated an estimated biomass of 7.22 and 4.10 Mg/ha, in depression and ridge sites, respectively. The amount of carbon stock in M. cajuputi is about half of these biomass value which is very much lower than typical lowland forest and other tree species. However, this study confirms the above ground biomass of M. cajuputi trees in similar diameter class is higher in depression (waterlogged) than ridge site. Thus, it is recommended that this species could better be conserved by conserving the Melaleuca swamp (waterlogged condition). Although M. cajuputi forest has low above ground carbon stock, its habitat of Melaleuca swamp or wetland should also be conserved for other vital ecosystem services.

Keywords: *Melaleuca cajuputi*, seasonal freshwater wetland, carbon stock, above ground biomass

INTRODUCTION

Melaleuca forest or 'hutan gelam' (in Malay) is dominated by a tree species from Myrtaceae family, *Melaleuca cajuputi* Powell, is forming a distinct and easily spotted landscape primarily along the coastal road of Dungun to Marang, Terengganu. Similar landscape is also prominent along the coastal road from Merang to Setiu, Terengganu. It is characterized by a stunted and clumping vegetation on the poor sandy soil, contrast to a common evergreen lowland tropical forest with four to five levels of canopy. of. *Melaleuca cajuputi* is also distributed in other state in Malaysia including of Sabah, Kelantan, Pahang, Johor and Melaka. Terengganu supports the most widespread distribution of this species due to the extensive occurrence of a soil type known as Beach Ridges Interspersed with Swales (BRIS) or locally called tanah bris or beris (**Figure 1**). Formation of *Melaleuca* forest can be found on two types of soil hydrology, which are ridge and depression (swales) and specific biological adaptations to each soil hydrology (Suzuki 1999) and microhabitats can be observed (Masitah *et al.* 2014). *Melaleuca cajuputi* ability to adapt on two contrasting microhabitats is an ecological advantage and thriving well on the sandy BRIS soil of Terengganu (Jamilah *et al*. 2011) (**Figure 2**). This species is also reported to be tolerant to waterlog and flood (Kogawara *et al*. 2006; Suzuki 1999), as well as able to withstand episodic fire due to its ability to coppice well by generating new shoots underneath its thick papery bark (Amiruddin, 2005).

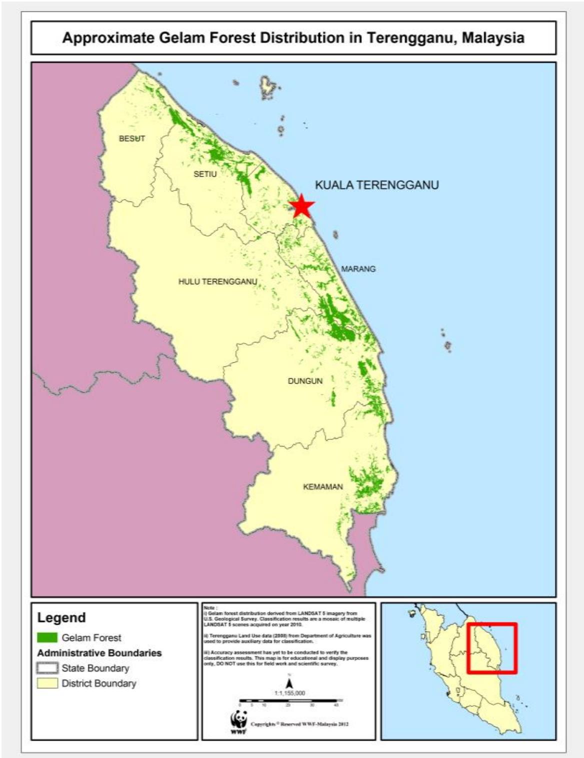

Figure 1 Distribution of *Melaleuca cajuputi* (Gelam) in Terengganu (WWF Malaysia, 2011).

A

B

C

Figure 2 *Melaleuca cajuputi* (Gelam) trees in Terengganu, *Melaleuca* swamp during monsoon with waterlogged condition (A), dry season (B) and on dry ridge (C).

Various parts of *Melaleuca cajuputi* are utilized by local fisherman and coastal community for their activities, for example *M. cajuputi* bark (fiberous part) is used for boat caulking to fill up holes in between boat walls (Burkhill 1966) and poles are used for piling and boat anchoring (Giesen, 2015). *Melaleuca cajuputi* woods is classified as medium hardwood with a density of 800 kgm^{-3}, reasonably high resistant to termites and other wood borers (Lim & Mohd Shukari Midon 2001). Large and medium size wood is harvested for charcoal industry, poles for piling and scaffolding in the mangrove area *and for fishing industry. Melaleuca* forest is also benefitting locals from a honeybee collection. *Melaleuca* swamp is supporting a habitat for freshwater fishes. A total of 21 primary freshwater fishes are found in *Melaleuca* swamp in Jambu Bongkok, Dungun, Terengganu (Amirrudin *et al.* 2011). Natural resources harvested from *Melaleuca* forest and swamp are important for the local community to generate additional incomes on top their main economic activities.

Melaleuca cajuputi is reported to be able to thrive well in both sandy BRIS soil on depression and ridge sites. In Thailand, it is reported it can maintain its height growth in waterlogged or hypoxia condition (Kogawara *et al.* 2006). This attribute enable this species to be used in restoration of degraded BRIS soil, as well as to sequester carbon in its tissues or standing biomass. Conserving *Melaleuca* forest and replanting of this species could assist Malaysia in her effort to achieve our target in reducing the emission as agreed in Conference of the Parties (COP) (in December 2007) through reducing emissions from deforestation and degradation or REDD effort as suggested by climate change regime post 2012 underlined by UNFCCC (UNFCCC, 2007). This species is also suggested to be considered for paludiculture or using it in swamp cultivation to restore a degraded wetland areas (Giesen, 2015). It is based on the multipurpose utilization of this species across Southeast Asia. *Melaleuca* forest that grows on depression area on BRIS soil with a waterlogged condition formed a rainfeed and seasonal freshwater swamp. However, in some areas this *Melaleuca* swamp is connected to a small river tributary, thus the water is also contributed by the river. Similar to other types of wetland, *Melaleuca* swamp offers an ecosystem services of flood mitigation and local hydrology regulation, particularly in the East Coast of Peninsular Malaysia during the monsoon months.

Another ecosystem service provided by *M. cajuputi* is its ability to sequest carbon, keeping the carbon stock in its standing biomass. This can help in reducing the carbon emission and at the same time combating the effect of local and global climate change. Above ground biomass of the trees is still the major component of carbon stock (Ngo *et al.* 2013, Jeyanny *et al.* 2014). Various equation and allometric regression used to calculate carbon accumulation by trees (Vashum & Jayakumar 2012, Ratnasingam *et al.* 2015). This study applied one of the simplest non-destructive method to calculate the above ground biomass of trees using diameter at breast height (DBH) as the main parameter and not including other parameters, for examples, soil carbon, coarse and fine roots and coarse woody debris). Despite this simplification, finding reported in this study is still important due to lack of information on the quantity of carbon in the standing biomass of *M. cajuputi*. Insufficient of data partly resulted in the misunderstanding, where *M. cajuputi* forest is seen as a waste land, is continuously being reclaimed without considering its ecosystem services. No management or monitoring plan outlined to date for *Melaleuca* forest and swamp. Only recently in the year 2014, 100,000 hectares of *Melaleuca* forest in Jambu Bongkok, Dungun, Terengganu is gazetted as a Permanent Forest Reserve under the Forestry Act (1984).

The loss of *Melaleuca* forest gives a negative impact to the environment where the cost to counter such impact is higher than the cost to conserve the forest itself. The ability of *M. cajuputi* adapts to both condition of waterlogged and dry sites could be exploited for its ecosystem services, particularly for local hydrology regulation, flood mitigation and as a carbon stock. This research is important to reinforce *Melaleuca* forest ecosystem services in reducing the impact of climate change through carbon stock accumulation and may strengthen the justification to conserve this forest for various ecosystem services it offer and no longer be seen as unproductive forest or waste land. The objective of this paper is to determine the carbon stock in standing biomass of *M. cajuputi* in two contrasting microhabitats of ridge (dry) and depression (waterlogged) on BRIS soil ecosystem of Terengganu.

METHODOLOGY

Six study areas with natural stand of *M. cajuputi,* three from each ridge and depression sites were selected for the measurement of stem standing biomass which were located in Kg. Kuala Abang 1, Kuala Abang 2 dan Kg. Beris Tokku (for depression site) and Kg. Pasir Puteh, Kg. Lembah Bidong dan Kg. Bari Besar (for ridge site). All trees with stem diameter at breast height (DBH) of 2.0 cm and higher were marked measure their DBH using diameter tape (Forestry Service®) at standard height of the tree at 1.3 cm from soil base.

Calculation of carbon stock is calculated using biomass of the tree as an analogy. Above Ground Biomass (ABG) of *M. cajuputi* is calculated using DBH as a factor for ABG formula developed by Crow (1978) to calculate ABG for Malaysian forest, i.e :-

$$\textbf{Log (biomass)} = \mathbf{2.1517 + 2.4423 \log (DBH)}$$

The above formula has been applied to calculate the above ground biomass of Malaysian forest trees (Nizam *et al.* 2002). Biomass in this formula is given in g/ha of trees, but converted to Mg/ha of trees for carbon stock calculation purpose. Carbon stock calculated by multiplying biomass value with 0.5 as recommended that about half of the total tree biomass is build up with carbon (Brown 1986 cited in Vashum & Jayakumar 2012). Along with the measurement of DBH, environmental parameters of air temperature and relative humidity were also recorded using Whirling Hygrometer. Soil temperature and pH recorded using Soil Tester®.

RESULTS AND DISCUSSION

Soil at the study areas are characterized and dominated by the marine deposit parental material, consisted of more than 95% of sand as recorded for BRIS soil system (Mohd Ekhwan *et al.* 2009). Soil temperature recorded at noon was more than 30 C and having soil which was slightly acidic (**Table 1**). Microhabitat in the depression areas which is usually waterlogged has a slightly lower soil temperature than the microhabitat on the ridge areas.

A total of 351 individuals tree of *M. cajuputi* were measured their DBH for carbon stock determination (**Figure 3**). There were more trees with smaller diameter in the ridge areas compared to the depression areas, where trees were bigger but lesser number of individual trees. Results obtained are in agreement with previous works where *M. cajuputi* grows better in waterlogged habitat relative to drier part of BRIS soil. This is strongly related to *M. cajuputi* structural adaptations to waterlogging by having efficient adventitious roots (Yamanoshita *et al*. 2001). This adaptation enables *M. cajuputi* to thrive well in the wetlands without a negative impact on its growth. Roots of *M. cajuputi* could survive hypoxia condition without affecting its photosynthesis rate under waterlogged condition (Kagowara *et al*. 2006).

Table 1 Physical environment parameters recorded at two microhabitats of *M. cajuputi* on BRIS soil of Terengganu

Site	Microhabitat	Soil Temperature	Soil pH	Relative Humidity
Kg. Kuala Abang 1	Depression	31.6	6.0	59
Kg. Kuala Abang 2	Depression	32.7	5.8	61
Kg. Beris Tokku	Depression	30.0	59	59.5
Kg. Pasir Puteh	Ridge	33.5	6.2	62.2
Kg. Lembah Bidong	Ridge	33.5	6.4	62.3
Kg. Bari Besar	Ridge	35.4	6.2	66.3

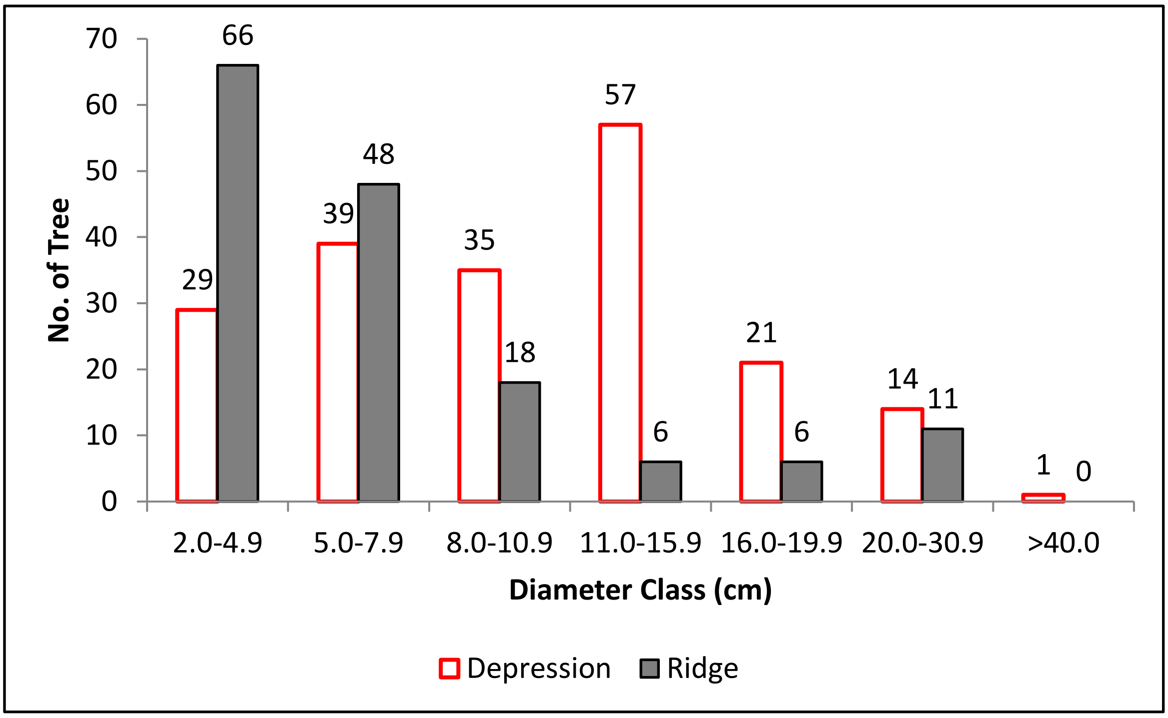

Figure 3 Frequency of *Melaleuca cajuputi* trees in each stem diameter class for each microhabitat of ridge and depression site on the BRIS soil of Terengganu

In general, the standing biomass of of *M. cajuputi* varies across microhabitats on BRIS soil of ridge and depression with and estimation of 7.22M g/ha compared to trees on the drier sites with an average of 4.10 Mg/ha (**Figure 4**). Based on those values, carbon stock of *M. cajuputi* is estimated to half of its above ground biomass which are 3.61 Mg/ha compared to trees on the drier sites with an average of 2.05 Mg/ha. Carbon stock value calculated by this study is very much lower compared to typical lowland and primary tropical forests, which are mostly in a scale of 100 M g/ha and higher (Ngo *et al.* 2013, Jeyanny *et al.* 2014, Leduning 2014). In comparison to other tree species, carbon stock of *M. cajuputi* is also much lower than secondary species, for examples, *Macaranga triloba* (14.32 Mg/ha) and *Dipterocarpus acutangulus* (12.20 Mg/ha) in the secondary forest (Leduning 2014). However, carbon stock of *M. cajuputi* could be underestimated as our calculation only based on stem biomass only. In a wetland ecosystem, more carbon stock is accumulated in below ground parts of the trees, in roots and soil itself (Adame *et al.* 2013).

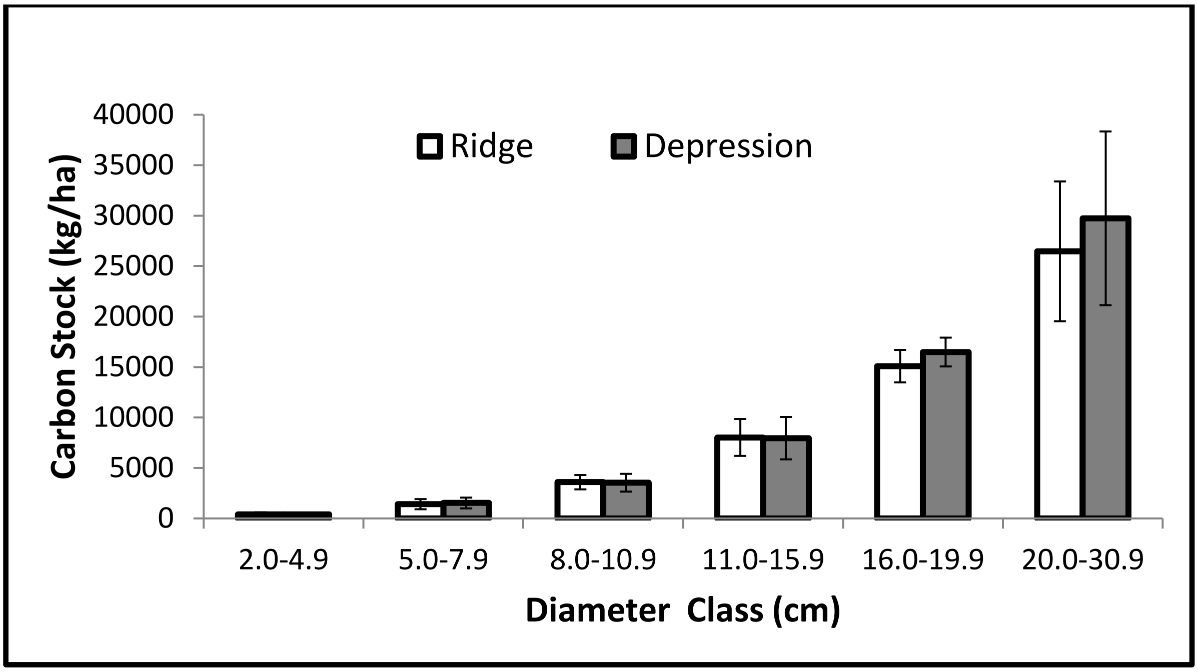

Figure 4 Carbon stock in the stem biomass of *M. cajuputi* trees in two contrasting microhabitat of depression (waterlogged) and ridge (dry) on BRIS soil of Terengganu. Bar represents standard error of mean.

In terms of above ground biomass of *M. cajuputi* across microhabitats of depression and ridge, result from this study is in accordance with previous works in Southeast Asia region (Kagowara *et al*. 2006, Van *et al*. 2000, Suzuki 1999). However, high variation of biomass between both microhabitats is observed based on standard error values. It is recommended that for a future work, more trees should be included to reduce the variation and to obtain more accurate biomass value. This result should also be treated with care as one of limitations of this study is that the age of the trees in each microhabitat, where it is assumed to be similar in both microhabitats.

CONCLUSION

Melaleuca cajuputi trees carbon stock accumulation based on stem biomass is much lower than other trees and typical lowland forest of Malaysia. However, this does not mean that *Melaleuca* is less important its natural ecosystem. In fact, this forest should be conserved for other vital ecosystem services, for example, for its roles as a wetland. Natural stand of *M. cajuputi* can potentially be used as renewable natural resources and managed sustainably due to its abundance in the East Coast of Peninsular Malaysia. Based on the above ground biomass of *M. cajuputi*, it is recommended that *M. cajuputi* trees are conserved in *Melaleuca* swamp microhabitat as it has higher biomass in such condition. Managing *Melaleuca* forest for its ecosystem services and ecotourism activity may be the best way to avoid degradation and conversion. More scientific and technical information needed to contribute to the management plan and policy development for *Melaleuca* forest in Terengganu.

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