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Soil carbon storage in dominant species of Mangrove Forest of Sarawak, Malaysia

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Carbon storage in forest ecosystems involves inordinate components including plant biomass carbon and soil carbon. Sequestration of carbon along with other aggressive conservation efforts helps to reduce the increasing negative impact of global warming on the environment and mangroves as the coastal forest. The objective of this study was to assess the soil carbon storage of dominant plant species of Awat-Awat Mangrove Forest, Sarawak, Malaysia. A total of 32 soil samples of mangrove forest were collected in nine different plots with different species using a peat auger at a soil depth of 0 to 50 cm. The total C in the soil samples was analyzed using CHNS analyzer (TruSpec Micro Elemental Analyzer (NCHS), LECO, USA). Soil carbon content of mangrove forest was found varies in each plot. The highest soil carbon content in Awat-Awat Mangrove Forest was found for soil under dominance of *Rhizophora mucronata* (6.24%) whereas the lowest (1.73%) was found for soil under dominated by *Sonneratia alba*. The soil carbon content of Awat-Awat Mangrove Forest was found to be influenced by the difference in species dominance.

Key words: Soil carbon storage, soil carbon, species dominance, mangrove forest, Sarawak, Malaysia.

INTRODUCTION

Among all of source of life on the earth, carbon is one of the primary one. It is found in all living organism and obtainable in many forms, mostly as tree biomass, soil organic matter and as gasses (CO_2) in the atmosphere. Carbon is also the major component of soil organic matter, but its content can vary from 48 to 60% or more of the weight of soil organic matter (Tan, 2005). Carbon sequestration is the carbon that is stored in long term which is available in the oceans, soils, vegetation (especially forests), and geologic formation (ESA, 2000). Carbon storage in forest ecosystems involves inordinate components including biomass carbon and soil carbon (Lal, 2005). Along with soil properties such as soil chemical properties, it can indicate the current status and also determine the characteristics of tested mangroves soil. In addition, soil carbon contain approximately 75% of

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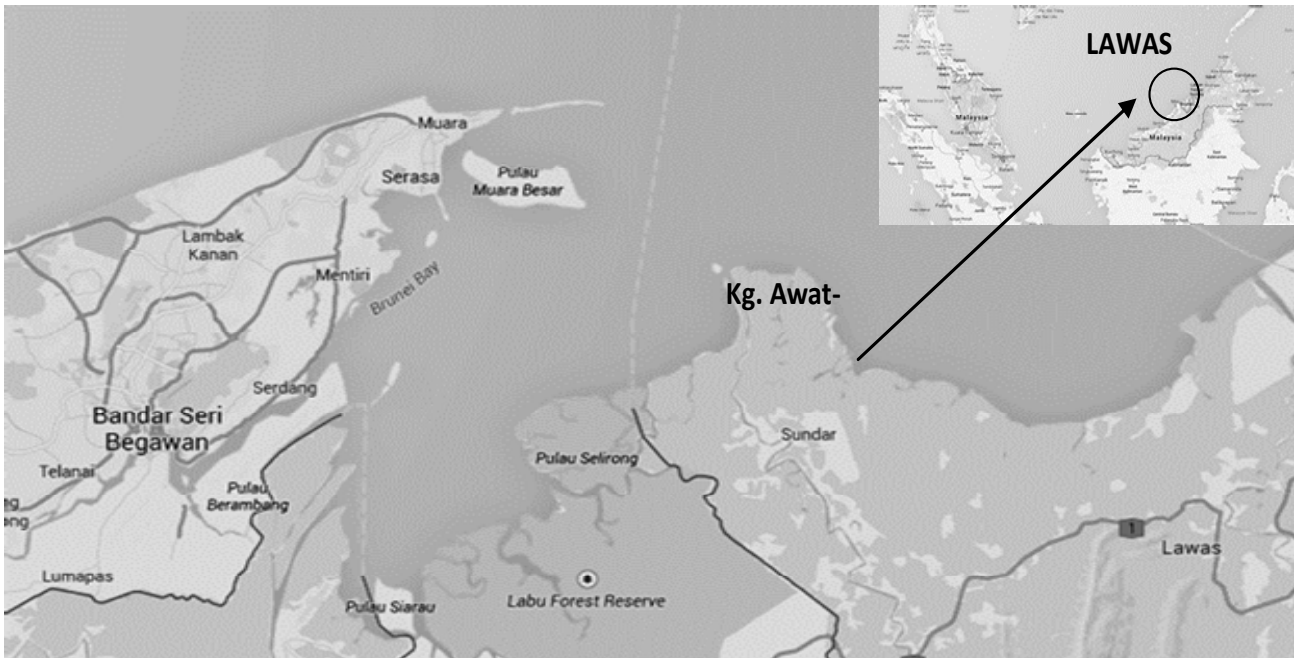

Figure 1. Location of study area at Awat- Awat Mangrove Forest in Lawas, Sarawak, Malaysia.

the carbon pool on land and it is three times more than the number of carbon stored in living plants and animal (ESA, 2000; Lal, 2005).

Sequestration of carbon along with other aggressive conservation efforts helps to mitigate the increasing negative impact of global warming on the environment and mangroves as the coastal forest. Sequestration of carbon also plays significant role in the global carbon cycling because they store a large stock of carbon as well as potential carbon sinks and sources to the atmosphere (Muukonen and Heiskanen, 2007). Moreover, in the last decade, strong evidence about significant differences among mangrove soils due to the presence of different mangrove species has been reported (Lacerda et al., 1995). The different among those mangrove soils might be determined from mangrove species composition which is different in each zone of mangrove forest. Furthermore, the main objective of this study was to assess the soil carbon storage of dominant plant species of Awat-Awat Mangrove Forest, Sarawak, Malaysia (Figure 1).

MATERIALS AND METHODS

This study was carried out in Awat-Awat Mangrove Forest, Lawas Sarawak, Malaysia, 4°56'N, 115°14'E. Nine plots were established in each area with different dominant species. Moreover, *Rhizophora apiculata* Blume is the main species of Awat-Awat Mangrove Forest, Lawas, Sarawak, Malaysia (Chandra et al., 2011). Soil sampling was done in November 2012. Soil samples were collected randomly in every plot using a peat auger at a depth of 0 to 20 cm and 20 to 40 cm depth and a total of 42 samples were collected during this study period. The soil samples were placed into closed labeled plastic bag and transported to UPMKB soil laboratory for processing. Samples were air dried at room temperature, ground and sieved pass to 0.05 mm for further analysis. Soil pH from each plot was determined use the potentiometric method of Tan (2005). The total C content of soil samples was analyzed using CHNS analyzer (TruSpec Micro Elemental Analyzer (NCHS), LECO, USA). The soil organic matter was determined using the conversion factor 1.724 that has been used to convert organic matter to organic carbon based on assumption that organic matters contain 58% of organic carbon (Schumacher, 2002). Analysis of variance (ANOVA) test at $P \leq 0.05$ using SAS version 9.1 software was used to check the variance of pH and carbon content among the plots and Duncan's multiple range test (DMRT) were used to show and specify the difference among them (Table 1).

RESULTS

The soils of Awat-Awat Mangrove Forest were acidic with an average pH of 4.63. Furthermore, the lowest pH in this mangrove forest was 3.93 in Plot 6 (soil under dominance of *Rhizophora mucronata*) whereas the highest was 5.41 in Plot 8 (soil under dominance of*S. alba*). From ANOVA at $P \leq 0.05$, pH was found significantly different between plots. Soil carbon content of Awat-Awat Mangrove Forest was different among the plots. The average of soil carbon content in mangrove forest was 3.29%. The highest carbon content was found in Plot 6 (soil under dominance of *R. mucronata*) whereas the lowest carbon content was found in Plot 8 (soil under dominance of *S. alba*). According to ANOVA test at $P \leq 0.05$, soil carbon content in 9 plot of this mangrove forest was significantly different and from Duncan's multiple range test (DMRT) it was clearly seen there were significant difference among them (Table 2).

Table 1. Dominant species of each plot in Awat-Awat mangrove forest, Lawas, Sarawak, Malaysia.

Plot	Dominant species	Local name
1	*Rhizophora apiculata*	Bakau minyak
2	*Lumnitzera racemosa*	Nggeriting putih
3	*Nypa fruticans*	Nipah/Apung
4	*L. littorea*	Nggeriting merah
5	*Xylocarpus granatum*	Nyireh bunga
6	*R. mucronata*	Bakau kurap
7	*Bruguiera parviflora*	Lenggadai
8	*Sonneratia alba*	Perepat
9	*S. caseolaris*	Pedada

Table 2. Mean of soil carbon content and pH of Awat-Awat mangrove forest at Lawas, Sarawak.

Plot	Species dominance	pH	C Content (%)
1	*Rhizophora apiculata*	4.20^{cd}	2.72^{cde}
2	*Lumnitzera racemosa*	4.65^{c}	3.62^{bcd}
3	*Nypa fruticans*	4.61^{c}	4.08^{bc}
4	*L. littorea*	4.68^{c}	2.22^{de}
5	*Xylocarpus granatum*	4.19^{cd}	2.30^{de}
6	*R. mucronata*	3.93^{d}	6.24^{a}
7	*Bruguiera parviflora*	4.76^{bc}	4.60^{b}
8	*Sonneratia alba*	5.41^{a}	1.73^{e}
9	*S. caseolaris*	5.24^{ab}	2.08^{de}

*Mean with same letter for each variable are not significantly different at P≤0.05 using ANOVA, Duncan's multiple range test was used to check the differences among the station.

DISCUSSION

Soil pH of in every plot of this mangrove forest were acidic with range of 3.93 to 5.41. The most acidic one was found in Plot 6 soil under *R. mucronata* dominance. Average pH value in this mangrove forest were lower compared to other research areas that were done by other researchers but still in the comparable values (Table 3). Generally, soils of mangrove are neutral to slightly acidic due the sulphur-reducing bacteria and the presence of acidic clays, but in Malaysia there are mangroves with very acidic brackish waters due to the aeration of soil sulphates, forming sulphuric acid (Peter and Sivasothi, 2001).

According to Duncan's multiple range test (DMRT), there were 4 groups of soil pH among 9 plots which were significantly different among each other. They were Plots 8 and 9; Plots 7 and 9; Plots 1, 2, 3, 4, 5 and 7; Plots 1, 5 and 6. Soil pH in plots with same group was not significantly different among each other (Table 2).

Soil carbon content of this mangrove forest varied. It ranged from 1.73 to 6.24% with average mean of 3.29%. The highest soil carbon content in this mangrove forest was 6.24% and the area was dominated by *R. mucronata* (Plot 6) whereas the lowest soil carbon content was 1.73% under dominance of *S. alba*. According to DMRT test, there were 5 groups of soil carbon content which were significantly different whereas soil carbon content with same group was not significantly different (Table 2).

Soil carbon studies of mangrove have been carried out in many places with many different site characteristics. In the present study, carbon content of soil under dominance of *R. apiculata* in Awat-Awat Mangrove Forest was comparatively similar to carbon content in soil under *R. mangle* in Sepetiba Bay, Brazil (Lacerda et al., 1995). Furthermore, the soil carbon content of Awat-Awat mangrove forest was comparable with the values recorded in elsewhere (Table 4). Studies revealed that the soil carbon content is different and varies from one different place to another. Different species dominance gave different results to the content of soil carbon.

Moreover, Lacerda et al. (1995) also noted an accumulation of strong evidence for significant differences among mangrove soils due to the presence of different mangrove species.

Conclusion

Soils of this mangrove forest were acidic and the acidity

Table 3. Soil pH of several mangrove forest.

Author	Site characteristics	Average pH value
Sukardjo (1994)	Mangrove forest of the Apar Nature Reserve, East Kalimantan, Indonesia. With species of *Avicennia* and *Ceriops*.	4.35 to 5.29 (Avicennia), 3.70 to 4.20(Ceriops)
Wakushima et al. (1994a)	Mangrove forest of Amphur Laemngop, Thailand. With species of *R. apiculata R. mucronata. C. tagal, Excoecaria agallocha,* and *Lumnitzera racemosa*.	4.27±0.05 to 7.32±0.09
Wakushima et al. (1994b)	Mangrove forest of southern Japan. With species of *R. stylosa.*	3.31 to 8.16
Ukpong (1995)	Mangrove swamp of southeastern Nigeria. With species of *Rhizophora spp* and *Nypa fruticans.*	2.9 to 3.8
Mahmood et al. (2005)	Mangrove forest of Kuala Selangor, Malaysia. With species of *Bruguiera parviflora*	6.77±0.05 to 7.07±0.04
Muhibbullah et al. (2005)	Sundarband mangrove forest, Bangladesh. With various species.	6.3 to 7.13
Shazra et al. (2008)	Mangrove forest of HA. Baarah, Maldives. With species *R. mucronata* and *Hibiscus tiliacius*	6.0 (*R. mucronata*), 6.5 (*H. tiliacius)*
Rambok et al. (2010)	Wildlife sanctuary mangrove forest, Sibuti, Malaysia. With species of *R. apiculata*.	3.34
Present study	Awat-Awat Mangrove Forest, Lawas, Sarawak, Malaysia. With species of *R. apiculata*	3.93 to 5.41

Table 4. Soil total carbon of several mangrove area.

Author	Site characteristics	Carbon content (%)
Sukardjo (1994)	Mangrove forest of the Apar Nature Reserve, East Kalimantan, Indonesia	3.96% (*Avicennia* forest) 11.40% (*Ceriops* forest)
Lacerda et al. (1995)	Itacuruca Experimental Forest, Sepetiba Bay, Brazil	2.70 to 2.80% (under *Rhizophora mangle)* and 3.80 to 6.10% (under *Avicennia schaueriana)*
Chmura et al. (2003)	World mangrove and salt marshes (western and eastern Atlantic and Pacific coasts)	11.1%
Shazra et al. (2008)	Mangrove forest of Maldives	0.196 and 0.017%
Rambok et al. (2010)	Sibuti, Malaysia (Wildlife sanctuary mangrove forest)	12.18%
Ray et al. (2011)	Sundarbands, India (natural mangrove forest)	0.51 to 0.65%
Chandra et. al. (present study)	Awat-Awat mangrove forest, Malaysia	1.73 to 6.24%

varied according to plant species dominance. The soil under dominance of *R. mucronata* was most acidic (pH 3.93). Soil carbon content of this mangrove forest varied according plant species dominance. The highest soil carbon content was 6.24% and the area was dominated by *R. mucronata* whereas the lowest soil carbon content was 1.73% under dominance of *S. alba*. Soil carbon storage and pH at this mangrove forest varied according to plant dominance.

Conflict of Interest

The authors have not declared any conflict of interest.

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