 DOI: 10.11598/btb.2019.26.3.1099

CARBON SEQUESTRATION OF MANGROVE ECOSYSTEM IN SEGARA ANAKAN LAGOON, INDONESIA**

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Received 10 July 2018 / Accepted 26 July 2018

ABSTRACT

Carbon conservation programs in mangrove ecosystems focus on the growth of mangrove vegetation that is measured based on the amount of carbon present at different tree stages particularly, the seedlings, saplings and mature mangrove trees. This study was aimed to determine carbon percentage of mangrove ecosystems using the SNI 06 – 3730 – 1995 and TAPPI T 211 om 85 methods, and to analyse the mangrove clustering based on carbon percentage. The results showed that (1) *Avicennia* spp., *Sonneratia* spp., *Bruguiera* spp., *Rhizophora* spp., *Aegiceras* spp., *Lumnitzera* spp., *Ceriops* spp., *Exoecaria agallocha* and *Xylocarpus granatum* had carbon percentages between 45.01% and 55.54%; (2) the carbon percentage of mangroves at different growth stages were as follows; seedlings at 16.3-21.2%, sapling at 19.0-28.1%, trees with diameter at breast height (DBH) of 10-20 cm at 38.1-46.3%, trees with DBH of 20-30 cm at 40.2-51.1% and trees with DBH of 30-40 cm at 49.1-55.2%. The carbon conservation is positively correlated with the carbon sequestration ability and growth of the mangroves.

Keywords: carbon conservation, carbon sequestration, mangrove clustering, mangrove ecosystem, Segara Anakan

INTRODUCTION

Carbon conservation means carbon sequestration (Dutschke 2004; Boer 2004; IPCC 2005; Jennerjahn and Mitchell 2013), and reduction of atmospheric CO_2 (Silva *et al.* 2017) for forest sustainability and social welfare (Murdiyarso 2005; Dutschke 2004). Carbon conservation management in mangrove ecosystems follows the concept of carbon conservation program such as LULUCF (*Land Use, Land Use Change and Forestry*) (Boer 2004) REDD program and Kyoto Protocol (Ajani *et al.* 2013). Carbon conservation also means reduction of the negative impact of carbon emission and climate change in some coastal areas (Nanlohy *et al.* 2015).

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**This paper was presented at the 2nd Scientific Communication in Fisheries and Marine Sciences (SCiFiMaS 2018), 07-09 May 2018, Purwokerto, Central Java, Indonesia

The amount of sequestered carbon can be measured by destructive analysis (Hilmi 2003) or non destructive analysis/remote sensing analysis (Dandois & Ellis 2013). It is positively correlated with carbon absorption (Cathcart 2000) which is defined as carbon percentage of carbon sink in forest ecosystems. The stored carbon is the main parameter to support an economic valuation of carbon stock and carbon payment compensation followed by REDD and the Demonstrative Activities Program (Hilmi *et al.* 2017).

The mangrove ecosystem also receives the pressures, stresses and shocks from climate change and carbon emission (Mandala *et al.* 2012; Jennerjahn & Mitchell 2013). Mangrove as an interface between the terrestrial and aquatic ecosystems (Hilmi *et al.* 2014; Kusmana *et al.* 2000) helps maintain coastal stability (Qiu *et al.* 2014), reduce the effect of seawater inundation (Kathiresan & Bingham 2001; Parvaresh *et al.* 2011), give valuable ecosystem services and absorb carbon emission (Brander *et al.* 2012). The mangrove ecosystem has a productivity of 2500 $mg.C.m^{-2}day^{-1}$categorized as the high carbon ecosystems producer (Mukherjee & Ray 2012).

Carbon conservation in mangrove ecosystem shows the ability of mangrove ecosystem to sequester the emitted carbon which has relation with mangrove growth. The mangrove growth consisting of seedling, sapling and mangrove trees have variation of carbon sequestration (Hilmi 2003; Chheng *et al.* 2016; Cathcart 2000). The carbon sequestration can also be shown as carbon sinker or carbon accumulation. The carbon accumulation of mangrove trees can be developed by carbon percentage. The carbon sinker or carbon accumulation of mangrove growth stages can be expressed as the horizontal distribution of carbon sequestration. Whereas the carbon accumulation of leaves, stems, branches, flowers and roots can be expressed as the vertical distribution of carbon sequestration. The vertical distribution and horizontal distribution of carbon sequestration can be shown by mangrove clustering or zoning based on carbon sinker or carbon accumulation. This paper aimed to develop mangrove clustering based on the carbon percentage and carbon accumulation.

MATERIALS AND METHODS

Research Site

This research was conducted at the Segara Anakan Lagoon (SAL), Indonesia (Fig. 1) using the cluster sampling method based on the rivers of East Segara Anakan such as Donan River, Kembang Kuning River and Sapuregel river. Ten sampling plots with geographical coordinates were used in this research (Table 1).

Figure 1 Research site in Segara Anakan Lagoon

Table 1 The geographical coordinates of sampling stations

Stations	Geographical coordinates		Stations	Geographical coordinates	
	Longitude (East)	Latitude (South)		Longitude (East)	Latitude (South)
1	108.8119	7.6703	22	109.0113	7.6747
2	108.8083	7.6789	23	109.0093	7.6724
3	108.8003	7.6756	24	109.0090	7.6717
4	108.7947	7.6961	25	109.0094	7.6781
5	108.7958	7.6869	26	108.9995	7.6761
6	108.7961	7.6939	27	108.9991	7.6733
7	108.8056	7.6731	28	108.9953	7.6876
8	108.8036	7.6633	29	108.9899	7.7028
9	108.8075	7.6514	30	108.9914	7.7128
10	108.8122	7.6467	31	108.9863	7.7300
11	108.8131	7.6831	32	108.9687	7.7225
12	108.8297	7.6847	33	108.9630	7.6981
13	108.8297	7.6761	34	108.9605	7.6967
14	108.8617	7.6828	35	108.9617	7.7151
15	108.8461	7.6900	36	108.9540	7.7202
16	108.8608	7.6956	37	108.9511	7.7188
17	108.8617	7.7000	38	108.9284	7.7104
18	108.8647	7.7017	39	108.9244	7.7070
19	108.8825	7.7083	40	108.9203	7.7086
20	108.8939	7.7089	41	108.9187	7.7091
21	109.0157	7.6728	42	108.9149	7.7072

Research Procedures / Data Collection

Sampling Species

The mangrove species used for sampling at the East Segara Anakan Lagoon were *Avicennia* spp., *Sonneratia* spp., *Bruguiera* spp., *Rhizophora* spp., *Aegiceras* spp., *Lumnitzera* spp., *Ceriops* spp., *Exoecaria agallocha* and *Xylocarpus* spp.

Growth Stage of Mangrove Sampling

Three growth stages were used for sampling, namely: seedling, pole and mature trees with diameter at breast height (DBH) at 10-20 cm, 20-30 cm and 30-40 cm, respectively). Five trees per growth stage per species were measured.

Section of Mangrove Trees Sampling

The sampling carbon of mangrove sections were taken from the leaves, branch, twig and stem with five replications

Carbon Content Analysis

The carbon content expressed in percent was measured by destructive analysis using (1) the Wood dust procedure SNI 06 – 3730 – 1995 (volatile analysis) and TAPPI T 211 om 85 (dust analysis) at the Wood properties Laboratory, Faculty of Forestry of IPB University and Forestry Departement (Hilmi *et al.* 2017). The formula for the dust approach TAPPI T 211 om 85 (gravimetric method) (Hilmi *et al.* 2017) is as follows:

$$\text{Percent of Carbon } (\%) = \left(\frac{C - D}{C - A}\right) : (1.724 \times 100\ \%)$$

Where:

A: empty cup (without sample)

C: cup + heated sample with temperature 105°C for 24 hours.

D: cup + heated sample with temperature 700°C for 2 hours.

Data Analysis

The descriptive analysis to analyze carbon percent from leaves, twig, branch and stem (vertical distribution) and seeding, sapling, trees (horizontal distribution) using data tabulation, graph and figure.

RESULTS AND DISCUSSION

Carbon Distribution of Mangrove Species

The carbon stored in stem, branch, leaves, twig, root and flower were measured per species (Table 2). The percent of carbon indicating carbon accumulation has relation with carbon sequestration (Charoenjit *et al.* 2013; Prasad *et al.* 2013).

Table 2 Amount of carbon per species

The mangrove species	Amount of carbon (%)		
	Distribution interval	Average	STDV
Bruguiera spp	50.89 - 55.54	53.22	3.29
Rhizophora spp	50.25 - 55.38	52.82	3.63
Aegiceras spp	49.40 - 51.14	50.27	1.23
Sonneratia spp	49.00 - 50.56	49.78	1.10
Excoecaria aggallocha	48.61 - 49.56	49.09	0.67
Lumnitzera spp	46.02 - 51.03	48.53	3.54
Heritiera sp.	47.01 - 49.95	48.48	2.08
Ceriops spp	47.02 - 49.84	48.43	1.99
Terminalia sp.	46.57 - 49.95	48.26	2.39
Xylocarpus spp	46.50 - 49.77	48.14	2.31
Avicennia spp	45.01 - 49.73	47.37	3.34

The carbon percentage of *Bruguiera* spp. and *Rhizophora* spp. is more than *Aegiceras* spp., *Ceriops* spp. and *Lumnitzera* spp., more than *Avicennia* spp., *Sonneratia* spp., *Terminalia* sp., *Heritiera* sp., *Excoecaria aggallocha* and *Xylocarpus* spp. *Bruguiera* spp. and *Rhizophora* spp., belong to class 1. *Aegiceras* spp., *Ceriops* spp. and *Lumnitzera* spp. to class 2. *Avicennia* spp., *Sonneratia* spp., *Terminalia* sp., *Heritiera* sp., *Excoecaria aggallocha* and *Xylocarpus* spp. to class 3 (Table 2). The carbon percentage in mangrove trees (Table 2) had a range of 46.02-55.54% which was bigger than other ecosystem (Casasola *et al.* 2017; Brown 1997). The carbon percentage of other forests are between 41% and 54% (IPCC 1996). This amount of carbon in the mangrove ecosystem reflects the mangrove sinker which is correlated with carbon sequestration (Hilmi *et al.* 2017; Dutschke 2004; Boer 2004; IPCC 2005; Jennerjahn & Mitchell 2013). These values expressed the ability of mangroves to sequester carbon from the air, soil and water (Prasad *et al.* 2013; Mukherjee & Ray 2012; Charoenjit *et al.* 2013; Ajani *et al.* 2013; Harmon 2001). These also show the ability to absorb atmospheric carbon dioxide that is stored in stem, leaves, branch and other segment of tress (Jennerjahn & Mitchell 2013; Mukherjee & Ray 2012).

The mangrove ecosystem can be categorized as the best carbon pool, because the mangrove species have effective activities of CO_2 flux balancing between photosynthetic uptake, respiratory releasing (Mukherjee & Ray 2012) and carbon reducing (Avelar *et al.* 2017). Basically, the ability to sequester carbon is an essential ecological function (Anneboina & Kumar 2017) to reduce carbon emission and climate impact mitigation (Duncan *et al.* 2016).

Bruguiera spp. and *Rhizophora* spp. had the highest carbon percentage in mangrove ecosystem expressed as the effectiveness of carbon sequestration and absorption (Table 2). The carbon stored in mangrove species is correlated with the potential of cellulose, hemicellulose, lignin and extractive as the wood matter of the trees. The potency of cellulose, hemicellulose and extractive compound had positive correlation with wood density (Hilmi *et al.* 2017; Tsoumis 1991). The wood density from *Bruguiera gymnorrhiza* was 0.94 (0.82-1.03), *Rhizophora apiculata* was 1.05 (0.95-1.12), and *Rhizophora mucronata* was 0.94 (Martawijaya *et al.* 1989; Hilmi *et al.* 2017).

The carbon stock in mangrove species is part of the major process of transporting carbon in carbon cycle process (Prasad *et al.* 2013). This carbon cycle in this ecosystem is influenced by the soil-water interaction (Charoenjit *et al.* 2013), carbon sources, sinks and reservoirs (Ajani *et al.* 2013), decomposition and subsequent remineralization (Roya *et al.* 2012), species abundance (Zanden *et al.* 2017), the biomass (Duncanson *et al.* 2017) litter biomass, dissolved oxygen, primary productivity, community respiration, temperature, pH and air-water exchange of carbon dioxide (Mukherjee & Ray 2012). The carbon percentage also has positive correlation with ecosystem productivity. Mangrove is highly productive ecosystems with productivity carbon 2500 $mgCm^{-2}day^{-1}$ (Mukherjee & Ray 2012). Forest carbon stocks from *Rhizophora* forest is 134.5 $mgha^{-1}$ (Cohen *et al.* 2013). The rate of carbon sequestration of mangrove vegetation is 0.04 $tonsCkm^{-2}year^{-1}$ (Charoenjit *et al.* 2013).

The percentage of carbon ecosystem from *Rhizophora apiculata* as major species will give carbon ecosystem between 45.88 and 244.99 $tonsCha^{-1}$ higher than *Aegiceras floridum* (16.16 $tonCha^{-1}$) and *Bruguiera gymnorrhiza* (34.71 $tonsCha^{-1}$), and *Xylocarpus granatum* (37.69

tonsCha^{-1}) (Hilmi *et al.* 2017; Porte *et al.* 2002). The total mangrove carbon of 182.4 tonsha^{-1} which is not different from forest plantation with carbon ecosystem 192.80 mgha^{-1} (Charoenjit *et al.* 2013; Chheng *et al.* 2016; Rahman *et al.* 2015) and in natural forest was 23.5 mgCha^{-1} (Thapa *et al.* 2015; Hartoko *et al.* 2015).

Carbon Distribution in the Mangrove Ecosystem

Carbon distribution in the mangrove ecosystem was measured at the different stages of mangrove growth; as seedling, sapling and trees (horizontal distribution) and mangrove sections (stem, root, flower, branch and leaves) as vertical distribution (Table 3; Fig. 2).

The horizontal distribution represented the carbon accumulation of growth stage of mangrove (seedling, sapling and mangrove trees). The growth stage of mangrove had relation with the ability of mangrove to absorb and accumulate carbon. The growth stage also refers to the diameter of the mangrove species (Porte *et al.* 2002; Rindyastuti & Sancayaningsh 2018; Haripriya 2002; Bismark *et al.* 2008; Johnson *et al.* 2001). The carbon percentage of seedling is less than sapling, less than mangrove trees 10-20 cm, less than mangrove trees 20-30 cm and less than mangrove trees 30-40 cm. The larger the diameter of the species *Rhizophora* spp.*, Bruguiera* spp.*, Sonneratia* spp.*, Avicennia* spp.*, Aegiceras* spp.*, Ceriops* spp.*, Lumnitzera* spp.*, Heritiera* sp., *Terminalia cattapa* and *Excoecaria aggallocha,* the larger is the amount of carbon percentage. Diameter growth positively affects the ability of the species to sequester and accumulate carbon. The increasing carbon sequestration and accumulation rate result in an increased carbon percentage (Ong 1993; Hilmi 2003). The mangrove growth stages have relation with the potential of specific gravity, wood chemical compound (hemicellulose, cellulose, extractive matter), dust degree and volatile degree as the main variables to analyze carbon percentage (Ahmadi 1990; Haygreen & Bowyer 1993; Hilmi *et al.* 2005, 2017), volatile degree, volatile matter (aliphatic, terpena and phenolic compound) (Pettersen 1984), dust degree (calcium, potassium and magnesium). The potential of chemical compound, volatile degree, volatile matter and dust degree has relation with the potential of carbon percent.

The vertical distribution of carbon percentage showed the mangrove percentage of stem was more than branch, more than twig and root, more than leaves, because leaves had bigger volatile compounds and dust than stem, branch and twig (Hilmi *et al.* 2015). The mangrove stem has the biggest chemical compound (cellulose, hemicellulose, and lignin) has relation with the potential of carbon accumulation. **(**Hilmi 2003; Hilmi *et al.* 2015; Tsoumis 1991).

The carbon percentage and carbon accumulation also had relation with the potential of heart wood and juvenile wood which was represented by its specific gravity and water content (Hilmi *et al.* 2015; Hilmi 2003). Stem, twigs and branches had heart wood and juvenile wood bigger than leaves and fruit. Whereas fruit and leaves had water content bigger than stem, twig and branches, because leaves were arranged by chlorophyl, water, mineral and nutrient compound to support photosynthesis process. Fruit had relation with mineral, organic, water content and organic matter to supply food for cotyledon (Hilmi 2003; Hilmi *et al.* 2015).

Meanwhile, the mangrove root showed low carbon content because the mangrove root is dominated by cork cell, pneumatophora, which has low cellulose, hemicellulose and lignin (Haygreen & Bowyer 1993; Ahmadi 1990; Tsoumis 1991). This condition is related with the pneumatophore to absorb nutrient, water and air during the photosynthesis and respiration activities.

Table 3 The carbon percentage of mangrove vegetation based on growth stage and trees section

The Mangrove Species	Carbon Percentage (%)																
	Seedling	Sapling	Mature trees														
			(10-20 cm)					(20 – 30 cm)					(30 – 40 cm)				
			Leaves	Twig	Branch	Stem	Root	Leaves	Twig	Branch	Stem	Root	Leaves	Twig	Branch	Stem	Root
Aegiceras spp	15.1-19.0	19.1-21.0	19.6-22.1	20.2-23.2	24.2-28.8	40.4-43.1	21.2-25.1	19.7-22.3	20.4-23.2	24.4-28.9	45.4-48.1	22.2-25.3					
Avicennia spp	15.3-19.2	19.0-20.3	19.8-22.0	20.1-23.4	24.1-28.5	40.0-43.7	16.1-18.0	19.9-22.2	20.3-23.4	24.2-28.6	43.0-47.7	16.3-18.2					
Bruguiera spp	16.2-20.2	20.1-22.2	20.2-23.5	20.2-25.3	25.1-30.2	40.1-45.1	21.2-25.2	20.3-23.8	20.3-35.4	25.1-30.3	48.2-51.1	22.2-28.3	20.2-23.6	20.2-34.6	25.2-30.4	49.2-55.6	22.1-28.2
Ceriops spp	14.2-19.2	19.3-20.5	20.2-23.0	21.0-24.3	24.6-29.1	40.0-43.8	20.0-24.1	20.3-23.4	21.2-24.4	24.8-29.3	43.0-48.2	20.4-23.4					
Excoecaria aggallocha	15.6-19.2	18.9-20.3	20.2-23.0	21.3-24.2	24.6-28.8	40.6-43.6	20.2-23.0	20.2-23.0	21.4-24.3	24.8-28.9	43.0-47.6	20.3-23.2					
Heritiera sp.	16.0-19.0	18.8-19.8	19.8-22.0	20.2-23.4	24.1-27.6	40.0-43.9	20.1-23.1	19.9-22.1	20.4-23.6	24.3-27.8	42.0-46.9	19.9-22.3					
Lumnitzera spp	15.6-19.0	18.8-20.5	20.0-22.8	21.4-24.0	24.2-27.9	40.0-43.0	20.2-23.3	20.3-22.9	21.6-24.1	24.4-28.1	43.0-48.0	20.2-22.9					
Rhizophora spp	16.7-21.1	19.2-23.1	23.7-25.7	21.0-24.5	29.1-31.4	40.1-46.3	20.3-25.1	23.7-25.5	21.9-26.7	25.9-30.5	46.1-50.2	20.8-25.1	20.4-25.1	23.1-26.2	28.1-31.3	49.1-55.2	21.6-25.0
Sonneratia spp	16.5-19.4	18.8-20.4	22.9-24.0	20.5-23.0	24.2-28.1	39.0-43.6	16.1-18.2	22,8-24.1	20.6-23.1	24.3-28.3	43.0-48.6	16.3-18.3					
Terminalia sp.	16.1-19.0	19.0-20.4	22.0-24.0	20.0-23.2	23.8-28.9	39.6-43.9	20.0-22.0	22.3-24.0	20.1-23.3	23.8-28.9	43.6-47.9	20.2-22.3					
Xylocarpus spp	15.9-19.2	19.5-20.7	21.4-23.0	20.4-23.4	23.6-29.0	39.5-43.8	20.2-22.0	21.5-23.1	20.1-23.4	23.7-29.1	44.5-47.8	20.2-22.1					

Clustering of Mangrove Species into Zones

Clustering of the mangrove ecosystem was done by carbon zoning of the mangrove species (Hilmi 2018; Hilmi *et al.* 2019) based on the carbon accumulation (potential of sequestration) of the species at different growth stages (seedlings, saplings and trees) (Fig. 2). The clustering of carbon mangrove is following the mangrove dynamics to reach mangrove climax. The mangrove dynamics is an adaptive complex system (Karl & Church 2017) of trees species to grow and life following the stages of trees growth (seedling, sapling and trees) as a model of ecological dynamics process (Hagstrom & Levin 2017). The mangrove ecosystem at zone 1 was dominated by *Avicennia* spp. having carbon percentage of 15.3-19.2% (seedling), 19.0-20.3% (sapling), 40.0-43.7% (mangrove trees with diameter 10-20 cm) and 43.0-47.7% (mangrove trees with diameter 20-30 cm) (Table 3). Then, *Sonneratia* spp. had carbon percentage of 16.5-19.4% (seedling), 18.8-20.4% (sapling), 39.0-43.9% (mangrove trees with diameter of 10-20 cm) and 43.0-48.6% (mangrove trees with diameter of 20-30 cm). Next, *Ceriops* spp. had carbon percentage of 14.2-19.2% (seedling), 19.3-20.5% (sapling), 40.0-43.8% (mangrove trees with diameter of 10-20 cm) and 43.0-48.2% (mangrove trees with diameter of 20-30 cm). *Aegiceras* spp. had carbon percentage of 15.1-19.0% (seedling), 19.1-21.0% (sapling), 40.0-43.1% (mangrove trees with diameter of 10-20 cm) and 45.4-48.1% (mangrove trees with diameter of 20-30 cm).

Zone 2 is dominated by *Rhizophora* spp. which had carbon percentage of 16.7-21.1% for seedling, 19.2-23.2% for sapling, 40.1-46.3% for trees with diameter of 10-20 cm, 46.1-50.2% for trees with diameter of 20-30 cm and 49.1-55.2% for trees with diameter of 30-40 cm. *Bruguiera* spp. had carbon percentage of 16.2-20.2% for seedling, 20.1-22.2% for sapling, 40.1-45.1% for trees with diameter of 10-20 cm, 48.2-51.1% for trees with diameter of 20-30 cm and 49.2-55.6% for trees with diameter of 30-40 cm. *Lumnitzera* spp. had carbon percentage of 15.6-19.0% for seedlings, 18.8-20.5% for saplings, 40.0-43.0% for trees with diameter of 10-20 cm and 46.1-50.2% trees with diameter of 20-30 cm.

The last zone was dominated by *Excoecaria agallocha* having carbon percentage of 15.6-19.2% for seedlings, 18.9-20.2% for saplings, 40.6-43.6% for trees with diameter of 10-20 cm and 43.0-47.6% for trees with diameter of 20-30 cm. *Xylocarpus* spp. had carbon percentage of 15.9-19.2% for seedlings, 19.8-20.7% for saplings, 39.5-43.8% for trees with diameter of 10-20 cm and 44.5-47.8% for trees with diameter of 20-30 cm. Then, *Heritiera* sp. had carbon percentage of 16.0-19.0% for seedlings, 18.8-19.8% for saplings, 40.0-43.9% for trees with diameter of 10-20 cm and 42.0-45% for trees with diameter of 20-30 cm. *Terminalia cattapa* had carbon percentage of 16.1-19.0% for seedlings, 19.0-20.4% for saplings, 39.6-43.9% for trees with diameter of 10-20 cm and 43.6-47.9% for trees with diameter of 20-30 cm. These results showed that seedlings and saplings had carbon percentages less than the mangrove trees. Expectedly, mangrove trees with large diameter have carbon sequestration potential bigger than those with smaller diameter. In the ecosystem, the carbon sequestration potential has relation with the carbon accumaltion rates (D'Amore *et al.* 2015).

Carbon sequestration potential has relation with the carbon accumulation potential of cellulose, hemicellulose, lignin and extractive substances, water degree, volatile degree, dust degree and specific gravity. The data also expressed that the horizontal distribution of carbon based on growth stage (seedling, sapaling and trees) and diameter stratification of mangrove vegetation (Table 3; Fig. 2) showed that the dynamic of carbon accumulation in mangrove ecosystem as representative of sequester carbon. The carbon sequestration potential of mangrove based on growth stages also show the ability of mangrove species to support mangrove life (Hagstrom & Levin 2017). The carbon sequestration can be defined by carbon sink that show as carbon accumulation on an essential life-support mechanism in the ecosystems. This carbon accumulation in ecosystem is important ability to determine the potential of the net ecosystem carbon balance (NECB) from seedling, sapling and trees (White & Plaskett 1981).

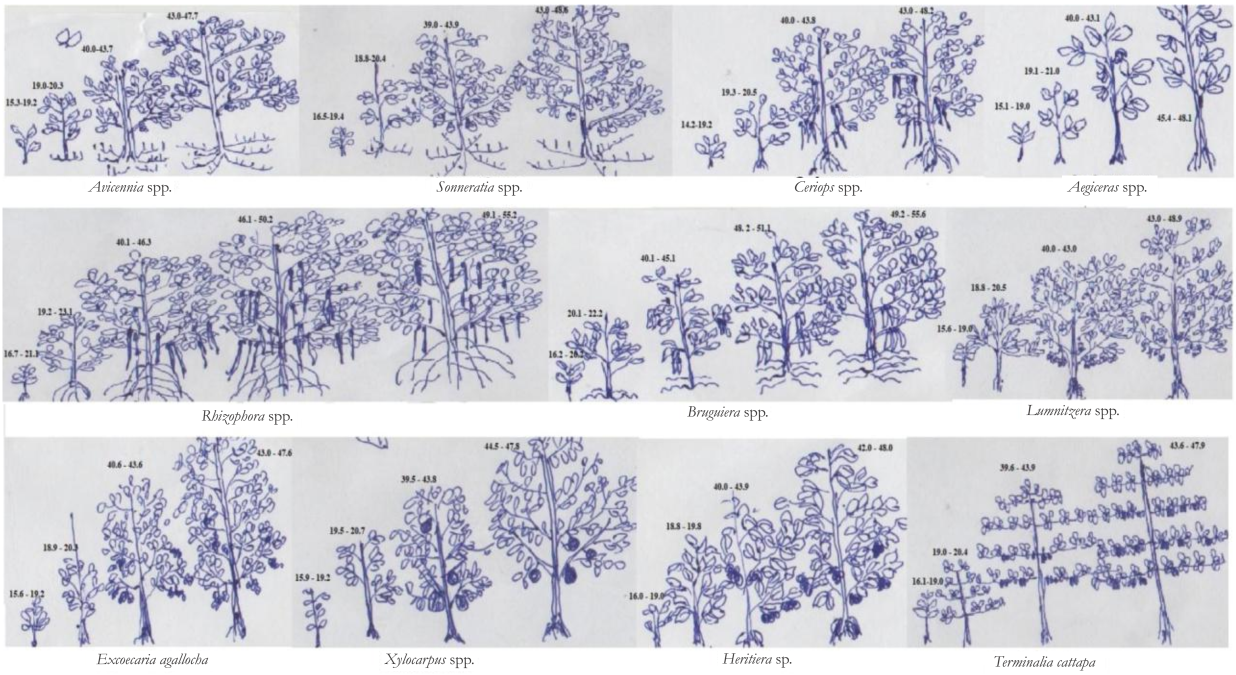

Figure 2 Mangrove clustering based on carbon percentage

CONCLUSION

The mangrove clustering based on carbon accumulation in the mangrove area of the Segara Anakan Lagoon showed that the cluster 1 was dominated by *Bruguiera* spp. and *Rhizophora* spp. Cluster 2 was dominated by *Aegiceras* spp., *Ceriops* spp. and *Lumnitzera* spp. Cluster 3 was dominated by *Avicennia* spp., *Sonneratia* spp., *Terminalia* sp., *Heritiera* sp., *Excoecaria aggallocha* and *Xylocarpus* spp. The carbon percentage of mangrove trees ranged between 46.02% and 55.54%.

The carbon dynamic (horizontal distribution) of mangrove showed that the carbon percentage of seedling and sapling is less than carbon percentage of mangrove trees. The carbon percentage based mangrove sections (fruits, leaves, roots, branches and stem) showed that the carbon percentage of stem was higher than other sections of mangrove trees.

ACKNOWLEDGEMENTS

The authors would like to give their heartiest thanks to the National Ministry of Education of Indonesia (DIKTI) for the grants-in-aid through the Hibah Competence and unggulan research grant (Unsoed Grant). Their gratitude also goes to the Dean of Fisheries and Marine Science Faculty of Universitas Jenderal Soedirman and the researcher colleagues for the valuable advice. Moreover, they would also like to thank the anonymous reviewers for their help and constructive comments which greatly improved the manuscript.

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