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# Diversity of mangrove vegetation and carbon sink estimation of Segara Anakan Mangrove Forest, Cilacap, Central Java, Indonesia

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**Abstract.** *Widyastuti A, Yani E, Nasution EK, Rochmatino. 2018. Diversity of mangrove vegetation and carbon sink estimation of Segara Anakan Mangrove Forest, Cilacap, Central Java, Indonesia. Biodiversitas 19: 246-252.* Mangrove forests are known as standing stores of sequestered atmospheric carbon. The role of mangrove forests in the sequestering substantial amount of atmospheric carbon dioxide ($CO_2$) and storing the carbon in its biomass has been recently underscored. This research aimed to estimate vegetation diversity and carbon sink potential of Segara Anakan Mangrove Forest Cilacap, Central Java from August-December 2012. Vegetations sampling was done by square plots technique. Diversity index was utilized to determine species diversity. Allometric equations were used to estimate biomass and carbon sinks. This study only calculates aboveground biomass and carbon sinks. The research results showed that mangrove in Segara Anakan was composed of 24 species with 19 families, consisting of 16 species of trees, 14 species of saplings and 16 species of herbs. The most dominant tree was *Avicennia marina* with importance value of 43.62% in Kembang Kuning, 60.27% in Ujung Alang and 25.6% in Klaces. The most dominant of sapling was *Avicennia marina*, with an important value of 31.1%. The total biomass of a tree is about 43.06 kg/tree or 0.13 ton/ha. Total biomass of sapling was 27.38 kg/tree or 0.32 ton/ha. The carbon sink of the tree was 49.10 ton/ha and carbon sink of sapling was 79.39 ton/ha. It can be concluded that Segara Anakan Mangrove forest is very important as a carbon sink in South part of Central Java, Indonesia.

**Keywords:** Allometric equations, mangrove forest, diversity, carbon sink

## INTRODUCTION

Indonesia as a country has a very extensive forest, and it is time to be able to see the forest with a new paradigm that is no longer synonymous with wood. Forests can provide services in other forms such as hydrological functions, ecological functions, social and cultural functions as well as forests play a major role in the effort to protect the earth's atmosphere. Benefits like these sometimes are often overlooked because they provide no economic value directly. Currently, the international community has developed a new trend through the trading of carbon dioxide ($CO_2$). Carbon trading began with the signing of the Kyoto Protocol stating that carbon emitters must reduce the level of emissions by applying high technology. The mangrove forest ecosystem has much higher carbon binding ability than terrestrial forests and tropical forests. Particularly in the Indo-Pacific region, carbon stocks stored in mangrove ecosystems are two times higher than that of terrestrial forest (Donato et al. 2011). Despite mangrove accounting for only 0.7% of tropical forest area, it generates emissions up to 10% of total global deforestation. Hence, mangroves are considered as an important component in climate change mitigation and reducing emissions from deforestation and degradation (REDD+) schemes (Sahu et al. 2016). The area of mangrove forest has decreased by 1.4% per year since the last decade (Ardli and Wolff 2008). The Food and Agriculture Organization (FAO) reported that in 2007 that mangrove forest area globally has dropped from 18.8 million ha in 1980 to 15.2 million ha in late 2005, or decreased approximately 20% from 1980 (Abino et al. 2014).

Mangrove forest Segara Anakan Cilacap was the largest mangrove in Java. In terms of floral and faunal regimes, mangrove forests are among the most productive and biologically complex ecosystems. This ecosystem was made up of carbon-based life forms in plant biomass and soil. Mangroves are highly productive ecosystems, next only to tropical forests, with a global primary production of 218 ± 72 tg c/yr. These tidal forests have the potential to act as highly efficient sinks of carbon as they sequester atmospheric carbon in their aboveground and belowground biomass, and in sediments. This carbon sequestration and storage service by mangroves provides global benefits by removing the harmful greenhouse carbon dioxide gas from the atmosphere. Lasco and Pulhin (2004) reported that the estimated mean biomass of mangrove forests in the Philippines is around 409 t/ha with a corresponding stored carbon of 184 t c/ha. Consequently, a huge percentage of the total carbon sequestered and stored in the biomass and sediment of the mangroves. Plant communities sequester carbon during photosynthesis and store it as biomass. Carbon in forest ecosystems is stored in five pools, namely above-ground biomass, below-ground biomass, leaf litter, dead wood, and soils. Forests acted as both sink and source of $CO_2$ when it is conserved and destroyed respectively. However, since 2000, Segara Anakan mangrove forest, Cilacap has experienced a conversion. Nearly 4,000 hectares mangrove forests converted to agricultural land

and ponds, settlements, as well as mangrove woods were felled to be utilized as firewood and charcoal.

Conserving plant diversity and retaining terrestrial carbon stocks are targets for environmental policy (Nathalia 2017). According to Pandey (2012), the ability of mangrove forest to sequester and store carbon depends on plant species diversity, soil condition, climate, and geography. In Indonesia, Most of the studies on carbon storage and sequestration are conducted on terrestrial vegetation like second-growth forests, plantation forests, and agroforestry. There is, however, lack of information on carbon sequestration and storage of Indonesian coastal vegetation in general and mangrove forest in particular. Therefore, this study aims to assess species diversity as well as to estimate above-ground biomass, and C-stocks in Segara Anakan mangrove forest, Cilacap, Central Java.

## MATERIALS AND METHODS

### Study area

The study was carried out in mangrove forest Segara Anakan, Cilacap, Central Java, Indonesia, located at the estimated coordinates 7º 40' 57”,91 - 7º 43',04 16” S and 108º 49' 04”- 108º 57' 24” E from August to December 2012 (Figure 1). Samples were taken at three locations: West Region: Klaces (1) Middle Region: Ujung Alang, and (2) East Region: Kembang Kuning River (3).

### Data collection

Twenty-seven 10m × 10m plots were established through a nondestructive quadrat sampling technique to determine the species composition and structure in the study area. The plots were laid with 20 to 30 m distance in between depending on vegetation characteristics and landscape. Inside each plot, all trees with at least 5 cm in diameter were identified and trunk diameters (cm) and total height (m) were measured.

### Data analysis

The measured parameters included the number of species, the number of individuals with a stem diameter at breast height. Identification used Heekenda et al. (2104) The data were analyzed according to their importance value index (IVI) (Alavaisha and Mangora 2016). The importance value index (IVI) which indicates the structural importance of each species in the community was obtained by adding the percentage values of relative frequency (RF), relative dominance (RDom) and relative density (RD). The explanation is as follows:

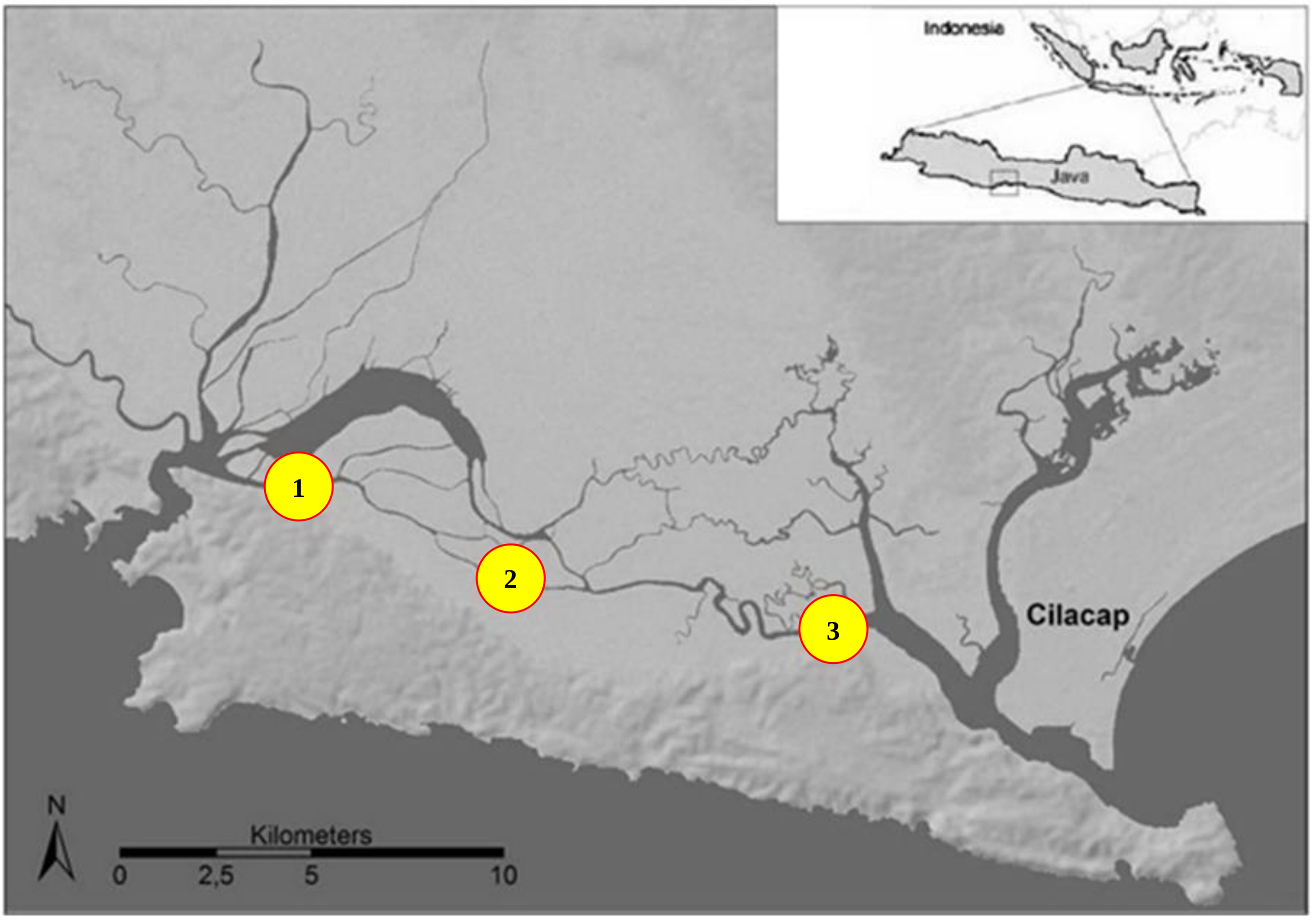



**Figure 1.** Study site in Segara Anakan Mangrove forest, Cilacap, Central Java, Indonesia. 1. Klaces, 2. Ujung Alang 3. Kembang Kuning

RF = Number of occurrence of species /Number of occurrence of all species x 100%

RDom = Total basal area of the species/Total basal area of all species x100%

RD = Number of individuals of the species/Number of individuals of all species x 100%

IVI for tree = RF +RDom+RD
IVI for sapling and herb = RF +RD

Diversity index in this study using the Shannon-Wiener's Index (Margurran 1992).

$$H' = - \Sigma (pi \log pi)$$

Note :
H' = Diversity index
Pi = Comparison of the number of individuals of one type by number of individual of overall sample in plot (n /N)

The stability of a species is also influenced by the level of evenness. The higher the value of H ', then the diversity of species in the community was more stable.

$$E = H'/\ln(S)$$

This study only calculates aboveground biomass and carbon sinks on trees and saplings. To measure the carbon stored in the mangrove ecosystems, two pools of carbon were considered: the carbon present in the biomass (above-ground and roots) and the carbon stored in the sediment. In this study, we only calculated the aboveground biomass and carbon. The estimation of aboveground biomass (*Wtop*) was calculated using the allometric equations for mangroves developed by Komiyama et al. (2005) for Southeast Asian mangroves. The maximum diameter of trees included in the derivation of these equations was 49 cm with a total number of 104 trees. These allometric equations which use diameter and wood density as predictive variables have a coefficient of determination ($R^2$) of 0.979 and 0.954, respectively, and are comparably reliable with allometric equations derived for natural stands (Chave et al. 2005; Hossain et al. 2008; Kauffman and Cole 2010). The following common allometric equations were used:

$$\mathbf{W_{top} = 0.251_p\, D^{2.46}}$$

Where $W_{top}$ is the above-ground biomass (kg), p is the woody density of the species, and D is the tree diameter at breast height. The values of total biomass per plot were summed for all plots and averaged to get the mean stand biomass which was then converted to tons per hectare. Carbon pools of the above-ground were calculated as the product of biomass multiplied by the carbon concentration using formula = 0.46 x biomass (Kauffman and Donato 2012).

## RESULTS AND DISCUSSION

A total of 24 sample trees representing ten true mangrove species, namely: *Avicennia marina, Sonneratia caseolaris Sonneratia alba, Bruguiera gymnorrhiza, Aegiceras corniculatum, Rhizophora mucronata, Rhizophora apiculata, Nypa fruticans, Ceriops tagal, Heritiera littoralis* belonging to 6 families (Acanthaceae, Sonneraticeae, Rhizophoraceae, Myrsinaceae, Arecaceae, and Strecaliaceae) were recorded at the natural mangrove stand of Segara Anakan (Table 1.A). Fourteen species were non-mangrove trees. True mangrove species are those that are exclusively restricted to tropical intertidal habitats and do not extend into terrestrial plant community and are morphological, physiologically and reproductively adapted to saline, waterlogged and anaerobic condition (Polidoro et al. 2010). The Mangrove habitats have relatively lower levels of species richness compared to other high biomass tropical habitats like rainforests because of the distribution restriction of the vegetation (Jayatisa et al. 2002). Species richness and composition in our study site was quite low compared to others locations, Sudarmadji (2004) found eight species of Rhizophoraceae in Baluran Mangrove Forest, East Java, and Satyawan et al. (2005) found 17 species in Tritih and 35 species in northern Java coastal area. On the other hand, those species composition found in our field study was similar to those in the geographic regions, such as Philippine (Abino et al. 2014), Mozambique (Sitoe et al. 2104) and Madagascar (Jones et al. 2104).

On sampling areas, it is showed that the difference in total number of trees, saplings, and herbs species (Table 1.A,B,C). Table 1.A showed that in Kembang Kuning,16 trees species with 132 total individuals were found. The species with the highest IVI was *A. marina* (343.62%). In Ujung Alang, 10 tree species with 111 total individuals were found. The species with the highest IVI was *A. marina*, too (60.27%). In Klaces, 11 tree species with 121 total individuals were found. The species with the highest IVI was *A. marina*, too (57.06%). For sapling (Table 1.B), in Kembang Kuning, 14 saplings species with 129 total individuals were found. The species with the highest IVI was *A. marina* (30.82%). In Ujung Alang, 11 saplings species with 139 total individuals were found. The species with the highest IVI was *A. marina*, too (32.43%). In Klaces, 9 saplings species with total 132 individuals were found. The species with the highest IVI was *A. marina*, too (34.13%). *A. marina* became the most dominant species in 3 locations and for tree and sapling. (Figure 2 A, B). Yunasfri (2013) found *A. marina* was a pioneer plant on sheltered coastal land and has the ability to grow and develop in various tidal habitats. Meanwhile, according to Noor, et al(1999) *A. marina* can grow on the edge of mangrove forests, especially along the riverbanks affected by tides and lows and river estuaries. And according to Duke (2006), *A.marina* was a pioneer of mangrove species, probably the most widely distributed, covering the entire Western Indo-Pacific because *A marina* is a pioneer vegetation type, as well as easy to grow. For herbs (Table 1.C), in Kembang Kuning, 16 herbs species

**Table 1.A.** Species composition, and important value index of tree mangrove vegetation in Segara Anakan, Cilacap, Central Java, Indonesia

| Species | Kembang Kuning | | Ujung Alang | | Klaces | |
|---|---|---|---|---|---|---|
| | ∑ indv | IVI | ∑ indv | IVI | ∑ indv | IVI |
| *Avicenia marina* | 20 | 43.62* | 15 | 60.27* | 15 | 57.06* |
| *Sonneratia caseolaris* | 15 | 45.79 | 16 | 48.90 | 17 | 46.41 |
| *Rhyzophora mucronata* | 10 | 34.44 | 13 | 38.28 | 17 | 36.97 |
| *Sonneratia alba* | 12 | 41.13 | 13 | 43.22 | 10 | 42.00 |
| *Rhyzophora apiculata* | 10 | 22.39 | 12 | 25.24 | 12 | 23.85 |
| *Aegyceras corniculatum* | 9 | 19.14 | 8 | 19.14 | 10 | 18.17 |
| *Bruguiera gymnorrhiza* | 10 | 17.82 | 10 | 18.57 | 11 | 17.43 |
| *Nypa fruticans* | 8 | 17.80 | 11 | 21.67 | 10 | 20.10 |
| *Ceriops tagal* | 9 | 16.09 | 8 | 16.21 | 8 | 14.96 |
| *Heritiera littoralis* | 3 | 6.31 | 5 | 8.50 | 6 | 13.25 |
| *Terminalia cattapa* | 2 | 4.64 | | | 5 | 9.81 |
| *Morinda citrifolia* | 3 | 5.53 | | | | |
| *Leucaena leucocephala* | 7 | 8.46 | | | | |
| *Hibiscus tiliaceus* | 6 | 6.98 | | | | |
| *Ficus annulata* | 5 | 5.89 | | | | |
| *Intsia bijuga* | 3 | 3.96 | | | | |
| ∑ | 132 | 300.00 | 111 | 300.00 | 121 | 300.00 |

**Table 1.B.** Species composition, and important value index of saplings mangrove vegetation in Segara Anakan, Cilacap, Central Java, Indonesia

| Species | Kembang Kuning | | Ujung Alang | | Klaces | |
|---|---|---|---|---|---|---|
| | ∑ indv | IVI | ∑ indv | IVI | ∑ indv | IVI |
| *Avicenia marina* | 20 | 30.82* | 21 | 32.43* | 23 | 34.13* |
| *Sonneratia caseolaris* | 17 | 27.14 | 20 | 32.39 | 25 | 34.12 |
| *Sonneratia alba* | 12 | 22.37 | 15 | 24.30 | 15 | 25.44 |
| *Bruguiera gymnorrhiza* | 15 | 21.54 | 12 | 20.27 | 13 | 20.67 |
| *Aegyceras corniculatum* | 10 | 15.41 | 13 | 19.93 | 17 | 21.41 |
| *Rhyzophora mucronata* | 8 | 14.76 | 12 | 17.93 | 12 | 18.44 |
| *Rhyzophora apiculata* | 9 | 14.18 | 16 | 14.25 | 10 | 15.45 |
| *Nypa fruticans* | 10 | 14.06 | 11 | 11.34 | 6 | 11.55 |
| *Ceriops tagal* | 5 | 10.18 | 7 | 10.69 | 8 | 12.85 |
| *Heritiera littoralis* | 3 | 5.93 | 5 | 8.09 | | |
| *Morinda citrifolia* | 2 | 4.70 | 7 | 8.38 | | |
| *Leucaena leucocephala* | 7 | 7.68 | | | | |
| *Gliricidia* | 9 | 7.88 | | | | |
| *Terminalia cattapa* | 2 | 3.35 | | | 3 | 5.97 |
| ∑ | 129 | 200.01 | 139 | 200.00 | 132 | 200.00 |

**Table 1.C.** Species composition, and important value index of herbs mangrove vegetation in Segara Anakan, Cilacap, Central Java, Indonesia

| Species | Kembang Kuning | | Ujung Alang | | Klaces | |
|---|---|---|---|---|---|---|
| | ∑ indv | IVI | ∑ indv | IVI | ∑ indv | IVI |
| *Acanthus ilicifolius* | 18 | 25.53* | 15 | 26.20* | 15 | 25.53* |
| *Deris trifoliata* | 17 | 23.86 | 16 | 26.04 | 17 | 23.86 |
| *Acanthus ebracteatus* | 19 | 25.03 | 13 | 25.08 | 17 | 25.03 |
| *Sonneratia caseolaris* | 9 | 15.29 | 13 | 15.,25 | 10 | 15.29 |
| *Avicenia marina* | 10 | 13.76 | 12 | 14.32 | 12 | 13.76 |
| *Rhyzophora mucronata* | 10 | 13.39 | 8 | 14,09 | 10 | 13.39 |
| *Sonneratia alba* | 9 | 12.58 | 10 | 13.20 | 11 | 12.58 |
| *Bruguiera gymnorrhiza* | 9 | 14.16 | 11 | 11.41 | 10 | 14.16 |
| *Rhyzophora apiculata* | 10 | 9.92 | 8 | 10.80 | 8 | 9.92 |
| *Aegyceras corniculatum* | 8 | 9.82 | 5 | 9.74 | 3 | 9.82 |
| *Nypa fruticans* | 7 | 8.04 | 3 | 9.46 | 6 | 8.04 |
| *Zoysia matrella* | 9 | 8.44 | 2 | 8.53 | 5 | 8.44 |
| *Ceriops tagal* | 5 | 9.23 | 3 | 7.33 | 3 | 9.23 |
| *Cyperus malacanencies* | 5 | 5.99 | 3 | 5.34 | 2 | 5.99 |
| *Acrosticum aureum* | 1 | 3.40 | 3 | 2.12 | 2 | 3.40 |
| *Merope angulata* | 0 | 0 | 1 | 1.06 | 1 | 1.54 |
| ∑ | 146 | 200,01 | 111 | 200 | 121 | 200,01 |

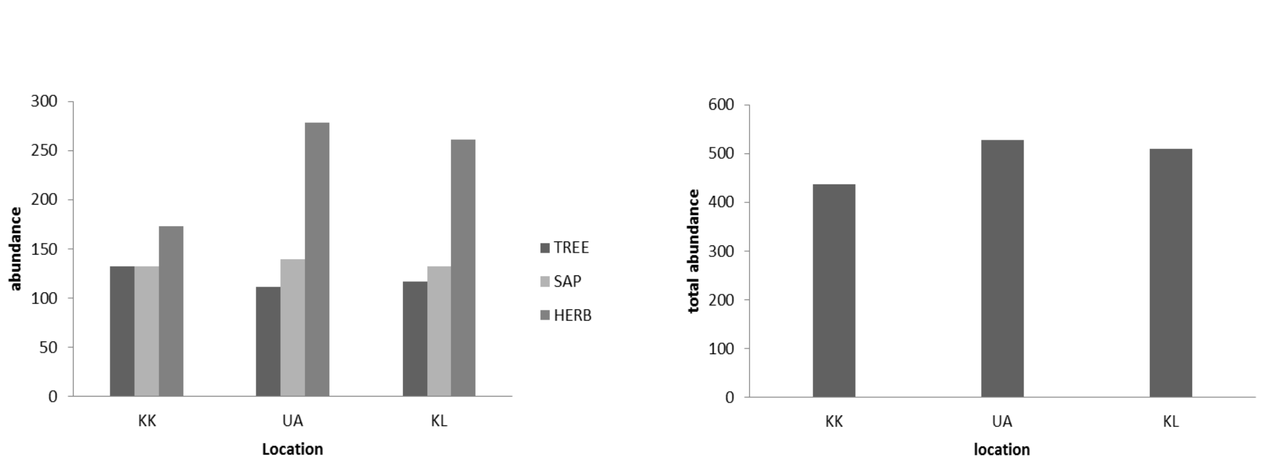
Note: IVI = Important Value Index, * = The Species with the biggest IVI with total individuals 146 were found. The species with the highest IVI was *A. illicifolius* (25.53%). In Ujung Alang, 10 sapling species with total individuals 111 were found. The species with the highest IVI was *A. illicifolius*, too (32.43%). In Klaces, 11 tree species with total individuals 121 were found. The species with the highest IVI was *A. illicifolius*, too (45.53%). *A. illicifolius* became the most dominant species in 3 locations for herbs. According to Noor, et al. (1999), *A. illififolius* has a characteristic as a herb that grows low and strong. It has the ability to spread vegetatively due to its rooting from a horizontal rod, thus forming a large and strong body.

Ten mangrove species were found in the three sites with *A. marina* and *R. mucronata* having high relative frequency compared to others species. According to Ksawani et al. (2007) the mixture of different species influenced the health of forest and enhancement of carbon storage. High frequency of *A. marina* and *R. mucronata* might be attributed to their high regeneration capacity despite these species having high use preferences, particularly. *R. mucronata* species with the high importance values belonged to the true mangrove species. The importance value of a species was determined based on the total contribution to the community in relation to the number of plants within the quadrats (relative abundance), its influence on the other species through its competition, shading, or aggressiveness (relative dominance), and its contribution to the community by means of distribution (relative frequency) in a study plot (Faridah-Hanum et al. 2012).

Table 2 showed the diversity index and evenness index of mangrove in mangrove forest Segara Anakan Cilacap. Kembang Kuning has the highest diversity (H' = 2.615, E = 0.854) followed by Klaces (H' =2.336, E = 0.9398) and the lowest is found at Ujung Alang (H' = 2.257 , E = 0.9556). For saplings, it showed that Kembang Kuning has the highest diversity (H' = 2.521, E = 0.829) followed by Ujung Alang (H' = 2.35 , E = 0.87) and the lowest is found at Klaces (H' =2.169, E = 0.874), and for herb, it showed that Kembang Kuning has the highest diversity (H = 2.719, E = 0.89) followed by Klaces (H' =2.607, E = 0.79) and the lowest is found at Ujung Alang (H' = 2.37 , E = 0.66). From the result, it is showed that Kembang Kuning totally has highest diversity index compared to two other locations. It means that this location has better conditions. These may be because of minimum forest destruction and anthropogenic stress compared to two locations. According to Lee et al. (2014), forest mangrove conditions locally depends on the anthropogenic pressure that comes from the local community. The mangrove forest in Segara Anakan provides benefits for local communities, such as supporting live of the community by producing items of food, fuel wood, charcoal, and construction materials as well as by generating income. The most anthropogenic pressure found in this area was forest conversion to the rice field and ponds and also cutting down the forest trees for household and firewood (Setyawan et al. 2005). Mangrove forest in Java Island is decreasing as the impact of conversion to mariculture, human settlement and other uses worsens. This impact is due to limited understanding and awareness of surrounding communities about the ecological importance of mangrove and uncertainty about land status (Gunawan et al. 2017).

**Table 2.** Diversity index and evenness index in Mangrove Forest Segara Anakan, Cilacap, Central Java, Indonesia

| Habitus | Kembang Kuning | | Ujung Alang | | Klaces | |
|---|---|---|---|---|---|---|
| | H' | E | H' | E | H' | E |
| Tree | 2.615 | 0.854 | 2.257 | 0.956 | 2.336 | 0.94 |
| Sapling | 2.521 | 0.829 | 2.521 | 0.829 | 2.169 | 0.874 |
| Herbs | 2.078 | 0.89 | 2.078 | 0.66 | 2.067 | 0.79 |




A B

**Figure 2.A.** Species abundance of tree, sapling and herbs; B. Total abundance of three location. Note: KK = Kembang Kuning, UA = Ujung Alang,KL = Klaces

Carbon sink for trees category in Kembang Kuning ranges from the lowest 1.63 ton/ha for *A. corniculatum* to the highest 24.15 ton/ha for *A. marina*. In Ujung Alang, it ranges from the lowest 2.57 ton/ha for *Heritiera littolaris* to the highest 22.03 ton/ha for *A. marina*. In Kembang Kuning, compared to saplings, the mean of carbon sink per ha of the trees was quite lower with 140.43 ton/ha (Table 3.A) while in saplings, it was 171.72 ton/ha (Table 3.B). This result indicates that all study site was dominated by saplings and the older vegetation has been destructed by anthropogenic pressure. Between those three sites, for trees category, it was showed that Kembang Kuning has the highest carbon sink (140.43 ton/ha) followed by Klaces (132.07 ton/ha) and the lowest was Ujung Alang (115.09 ton/ha). Carbon sink in this study was higher than carbon pools of the above-ground biomass estimated by Kauffman et al. (2011) in the Micronesian mangrove forests which was 104.4 ton/ha. The mean above-ground biomass in this study was much higher than that of North Sulawesi (61.4 t ton/ha, Murdiyarso et al. 2009), Okinawa, Japan (80.5 ton/ha, Khan et al. 2009), and Sarawak Mangrove Forest in Malaysia (116.8 ton/ha, Chandra et al.2011). Moreover, it was higher than the above-ground C-stocks estimated in Southern China (55.0 ton/ha, Chen et al. 2012). However our result quite lower if it was compared to the result of a study done in Thailand (140.5 4 ton/ha)(Kridiborworn et al. 2012).

Based on the result and discussion, it can be concluded that Segara Anakan Mangrove forest has relative high in carbon sink compared to the Micronesian mangrove forest, mangrove forest in North Sulawesi, Okinawa, and Sarawak Mangrove Forest in Malaysia. However our result is quite lower if it is compared to the result of study done in Thailand. However, our data can be used as a baseline for further conservation program of this area.

**Table 3.A.** Biomass and carbon sink estimation of **trees** in three locations of Segara Anakan Mangrove Fores, Cilacap, Central Java, Indonesia

| Species | Kembang Kuning | | Ujung Alang | | Klaces | |
|---|---|---|---|---|---|---|
| | **Biomass** | **Carbon** | **Biomass** | **Carbon** | **Biomass** | **Carbon** |
| *Avicenia marina* | 52.50 | 24.15 | 47.89 | 22.03 | 40.41 | 18.59 |
| *Sonneratia caseolaris* | 23.02 | 10.59 | 36.35 | 16.72 | 37.69 | 17.34 |
| *Rhizophora mucronata* | 15.63 | 7.19 | 24.68 | 11.35 | 21.2 | 9.75 |
| *Sonneratia alba* | 23.46 | 10.79 | 26.15 | 12.03 | 24.4 | 11.22 |
| *Rhizophora apiculata* | 27.63 | 12.71 | 29.02 | 13.35 | 25.26 | 11.62 |
| *Aegiceras corniculatum* | 8.67 | 3.99 | 26.84 | 12.35 | 24.76 | 11.39 |
| *Bruguiera gymnorrhiza* | 17.00 | 7.82 | 14.05 | 6.46 | 29.57 | 13.60 |
| *Nypa fruticans* | 20.59 | 9.47 | 26.14 | 12.02 | 14.76 | 6.79 |
| *Ceriops tagal* | 34.76 | 15.99 | 13.49 | 6.21 | 22.35 | 10.28 |
| *Heritiera littoralis* | 3.54 | 1.63 | 5.59 | 2.57 | 18.76 | 8.63 |
| *Terminalia cattapa* | 12.41 | 5.71 | | | 27.94 | 12.85 |
| *Morinda citrifolia* | 18.26 | 8.40 | | | | |
| *Leucaena leucocephala* | 17.20 | 7.91 | | | | |
| *Hibiscus tiliaceus* | 16.98 | 7.81 | | | | |
| *Ficus annulata* | 7.76 | 3.57 | | | | |
| *Intsia bijuga* | 5.87 | 2.70 | | | | |
| Total ton/ha | 305.28 | 140.43 | 250.20 | 115.09 | 287.10 | 132.07 |

**Table 4.B.** Biomass and carbon sink estimation of sapling in three locations of Segara Anakan Mangrove Forest, Cilacap, Central Java, Indonesia

| Species | Kembang Kuning | | Ujung Alang | | Klaces | |
|---|---|---|---|---|---|---|
| | **Biomass** | **Carbon** | **Biomass** | **Carbon** | **Biomass** | **Carbon** |
| *Avicenia marina* | 49.07 | 22.57 | 163.4 | 75.16 | 48.42 | 22.27 |
| *Sonneratia caseolaris* | 40.98 | 18.85 | 95.24 | 43.81 | 16.16 | 7.43 |
| *Sonneratia alba* | 24.43 | 11.24 | 70.03 | 32.21 | 36.8 | 16.93 |
| *Bruguiera gymnorrhiza* | 26.70 | 12.28 | 70.03 | 32.21 | 53.89 | 24.79 |
| *Aegyceras corniculatum* | 24.53 | 11.28 | 50.57 | 23.26 | 60.7 | 27.92 |
| *Rhyzophora mucronata* | 22.17 | 10.20 | 26.89 | 12.37 | 25.76 | 11.85 |
| *Rhyzophora apiculata* | 24.81 | 11.41 | 40.34 | 18.56 | 26.46 | 12.17 |
| *Nypa fruticans* | 52.22 | 24.02 | 57.18 | 26.30 | 31.73 | 14.60 |
| *Ceriops tagal* | 31.11 | 14.31 | 18.19 | 8.37 | 38.98 | 17.93 |
| *Heritiera littoralis* | 19.35 | 8.90 | 5.84 | 2.69 | 19.36 | 8.91 |
| *Morinda citrifolia* | 12.59 | 5.79 | 13.73 | 6.32 | | |
| *Leucaena leucocephala* | 15.17 | 6.98 | | | | |
| *Gliricidia* | 18.19 | 8.37 | | | | |
| *Terminalia catappa* | 11.99 | 5.52 | | | | |
| Total ton/ha | 373.31 | 171.72 | 545.03 | 281.26 | 358.26 | 164.80 |

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