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Mangrove Vegetation Structure and Its Carbon Stock Potency in Bunaken National Park, North Sulawesi

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Abstract: *Aims of this research are to describe structure of mangrove vegetation and its potential of carbon stock in northern area of the Bunaken National Park. Totally, there are about 18 mangrove species growing in coastal area of Bunaken. In Teling areas, R. mucronata and S. alba become two co-dominant species in plot 1, S. alba become important species in plot 2, and R. apiculata is the important species in plot 3. Avicennia marina become the most important species in Rap-rap. In Pungkol, B. sexangula has highest value of important value index in Plot 1, followed by R. mucronata in Plot 2 and B. parviflora in plot 3. In Wawontulap areas, B. parviflora has the highest value of important value index. The highest carbon stock was found at Rap-rap (ca. 1784,68 Mg/ha) and the lowest was found at Wawontulap (390,03 Mg ha^{-1}). The highest necromass was found at Teling (ca 208,79 Mg ha^{-1}) and the lowest was found at Wawontulap (ca. 21,30 Mg ha^{-1}). Mangrove ecosystem in the Bunaken National Park is important for global warming mitigation through their ecosystem ability to absorb CO_2 and store carbon into vegetation biomass and necromass.*

Keywords: *Bunaken National Park, mangrove, Global warming, biodiversity conservation, Carbon stock*

I. Introduction

Recent global industrialization and development program lead to the increase of greenhouse gases. Decrease of forest cover due to rapid deforestation, land uses changes and forest fire triggering increase of green houses in the globe. Scholar point out those problems contributes to the 18% - 20% of total greenhouses gases emissions. Carbon dioxide is the most abundance greenhouse gases which are related to industrialization [1] [2] [3] [4].

In 2009, United Nations report the ecosystems degradation in coastal and marine environments potentially reduces the ability of such ecosystem in greenhouse gases emission reduction. Coastal forest, mangrove, peat and sea grass able to absorb 1.65 billion ton of CO_2. Unfortunately, many of them are disturbed and degraded in significant rates. United nation report that coastal habitat decrease 7% yearly. In 1940, about 90% of mangrove in Asian degraded [3] [5]. Deforestation and forest degradation contributes 17,4% global greenhouses [6]. Coastal degradation has been considered important for human being, especially for human in coastal area [7]. About 50% of world population located at the coastal area or area within 65 miles from coastal line. In such area there are business and industrial area, tourism centre, human settlement, and educational area. The protection of coastal environment is therefore crucial [8].

Vegetation in the earth contributes to the carbon capture and sequestration. The photosynthesis process in plant is the important key in carbon capture. The photosynthesis absorbs CO_2 and biochemically convert to the carbohydrates molecules. Carbohydrates is the basis component of plant biomass. The plant's biomass therefore rich in carbon content. The fundamental plants metabolism lead to the opportunities to uses plants to reduce CO_2 in atmosphere. Forest conservation, therefore becomes important. In man-influenced ecosystem, there is possibility to increase ecosystem ability to absorb CO_2 through sustainable agroforestry practices, comprehensive urban park design and tourism park management [9] [10] [11].

Indonesian national park is the important site for global biodiversity conservation. This protected area is one of the potential sites for the global carbon capture and sequestration strategy implementation. National park contains numerous plants species which are important for global carbon capture and sequestration. Recent condition of Indonesia national park, however, under serious threats [12] [13]. Bunaken National Park in North Sulawesi is home of biodiversity. There are about 351 ha mangrove ecosystem in Bunaken National Park. The existence of mangrove in Bunaken National Park, however, is under serious threat due to human activity. During 1982-1993 mangrove area reported decrease with average rate 17.70% [14] [15]. In Bunaken, especially mangrove in the north part of the island, the potential of mangrove vegetation to absorb CO_2 is rarely discussed. The aims of the research are to describe the recent vegetation structure of mangrove and its potential carbon stock in northern area of Bunaken National Park. Focus will be paid to the mangrove trees species.

II. Methods

Study site

Research was set up at Bunaken Island in North Sulawesi. The island and its adjacent water environment were rich in term of biodiversity. Bunaken is one of the famous nature-based tourism or ecotourism destinations in Indonesia. The terrestrial and marine biodiversity has been reported high. The coral reef with numerous coral fish found in northern area of the park. The park (ca. 89.065 hectare) is important habitat for Macaca nigra nigra, Cervus timorensis russa and Ailurops ursinus ursinus. The northern area dominated by mangrove ecosystem while the south was rich in coral reefs. There are numerous diving sites in such area. In the southern part is the habitat for mangrove biota. The mangrove ecosystem has been identified crucial in Bunaken islands [14] [16] [17].

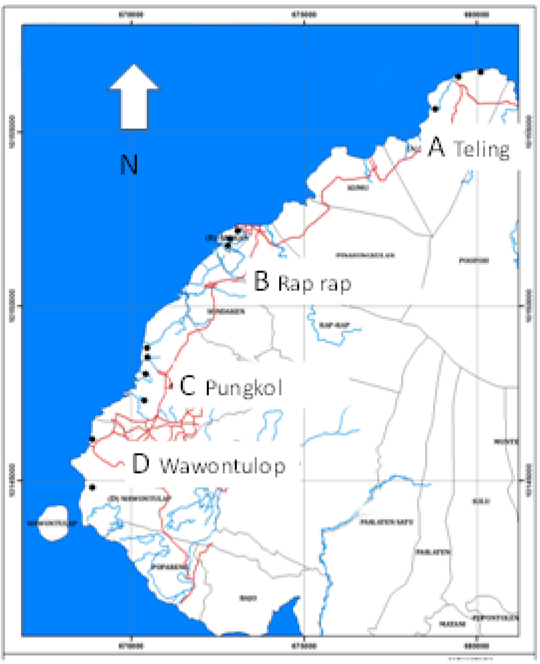

Fig. 1. Study site (A) Teling, (B) Rap-rap, (3) Pungkol and (4) Wawontulap

Methods

Vegetation structure

The survey of vegetation structure in mangrove ecosystem was carried in four villages, namely Teling, Rap-rap, Pungkol dan Wawontulap. In each villages, three observation plot by 10 x10 m was established. The first plot was set up at the adjacent to the local settlement, river and villages roads. The second plot was established at the middle distance of first and thirds plots. The thirds plot was established far from the local settlement, river and villages roads. Totally there are 12 observation plot (Fig.1). Vegetation analysis was focused to the tree species. Mangrove shrubs and herbs were excluded. In each plot, mangrove tree species was identified and calculated systematically. Data were stored in field data sheets for further analysis. The plants species biomass was measured and necromass assessed using standard methods [18] [19].

Plants biomass assessment

All of the trees species was identified and the diameter at breast height of each plants were measured through the non destructive techniques. Plant biomass was estimated by measuring diameter at breast height at 1.3 m height. The biomass is expressed in dry weight. It was calculated using allometric equations:

$$DW = 0{,}11\ \rho\ D^{2,62}$$

With:

DW = dry weight

D = steam diameter (cm)

H = plant height (cm)

ρ = Specific weight of wood (g cm^{-3}).

Woody necromass

Necromass consist of woody dead plant, dead branch and plant debris. Necromass analysis was conducted by collected woody dead plant and dead branch with diameter 5 cm and 50 cm in length. Necromass sample was collected through non destructive sampling. Necromass biomass calculation was done by measuring woody dead plant and dead branch with diameter 5 cm and 50 cm in length. Sample was collected and transferred to laboratory for dried at 80^{o}C during 48 hours, and the specific weight was measured. The woody mangrove necromass was calculated followed formula:

Biomass = π r^2 (cm^2) x length (cm) x Wood specific weight (g cm^{-3})

Carbon content analysis

Carbon content analysis was calculated using formula:

Basal area (m^2) = ¼ π x D^2 x 10^{-4}

With:
D = Plant diameter, measured at 1,3 m from land surface

III. Result and Discussion

Mangrove vegetation structure

In Teling *Rhizophora mucronata* and *Soneratia alba* become two co-dominant species in plot 1, shows that these two species play important role in mangrove ecosystem. In Plot 2, *Soneratia alba* become important species while in plot 3 *Rhizophora apiculata* is the important species. *Sonneratia alba* found in three plots with high value of important value index (Table 1). This data shows that *S. alba* contributes to the characteristic of mangrove ecosystem in Teling. *Sonneratia alba* has been identified tolerate wide fluctuations in water salinity. The species often grow on exposed mud-flats in coastal environment [20].

Avicennia marina become the most important species to characterized mangrove ecosystem in Rap-rap. Among the woody mangrove plant species, *Avicennia marina* has highest value of important value index (Table 2). *Avicennia marina* commonly found in South East Asia, but recent status of the population in many mangrove ecosystem has been reported decreased [21]. Human exploitation to *Avicennia marina* population has been caused population decrease in the wild. The existence of *Avicennia marina* population in Bunaken National Park, therefore should be protected in integrative strategy.

In Pungkol, *Bruguiera sexangula* has highest value of important value index in Plot 1, followed by *R. mucronata* in Plot 2 and *B. parviflora* in plot 3. *R. mucronata* however, consistent to found in Pungkol. This species considered as one of the most wide spread species in Southeast Asia.

In Wawontulap, *B. parviflora* has the highest value of important value index in Plot 1, 2 and 3, indicated that the species plays important role to construct mangrove characters in Wawontulap. *B. parviflora* widely distributes in South Asia and Malesia phytoregion, including Indonesia archipelago.

The existence of mangrove ecosystem in Bunaken national park is one of the key for sustainable development in Bunaken Island. Mangrove is important habitat to support marine-based industry. It is because mangrove is habitat for numerous marine living creature which are important for local economic development [22]. Therefore, there is integrative development strategy needed. It will be necessary to obtain comprehensive support. It is encompasses evolving local community and stakeholder into conservation effort [23] [24] [25]. Native forest ecosystem structure and composition is a main factor to be taken into account when degraded native ecosystem is repaired [13]. In mangrove conservation effort in Bunaken National Park, however, this research data can be crucial as a complementary data. No restoration program is likely to be successful unless it arises from complete basis data.

Table 1. Important value index of woody mangrove species in Teling, Rap-rap, Pungkol and Wawontulap

Species	Teling			Rap-rap			Pungkol			Wawontulap		
	plot 1	plot 2	plot 3	plot 1	plot 2	plot 3	plot 1	plot 2	plot 3	plot 1	plot 2	plot 3
A. marina			67.72	178.9	86.13	70.18	48.71					
A. lanata				60.21			45.90					
A. officinalis	52.57	95.19				27.50	50.99					
B.cylindrica					20.76							
Ae. floridum				60.90								
B. gymnorrhiza					21.13							
B. parviflora					31.88			96.95	124.91	96.25	95.21	106.50
B. sexangula							129.44					
C. tagal					20.63	54.44					40.99	
C. decandra								47.45				
N. fruticans					81.28							

R. mucronata	127.2	-	-				75.99	118.38	112.29			
R. stylosa								37.22	62.80	56.60		42.36
R. apiculata	0.42	69.00	145.85				84.44			84.15	82.06	60.55
S. alba	120.3	135.8	86.43									
X. mekongensis						47.88				63.00	81.75	41.59
X. moluccensis					38.19							49.00

Carbon stock in mangrove vegetation

The major mangrove species found in Teling were encompasses *Rhizophora mucronata*, *Avicennia officinalis*, *Soneratia alba*, *Rhizophora apiculata* and *Avicennia marina*. In Rap-rap observation station, mangrove species encompasses *Aegiceras floridum*, *Avicennia marina*, *Avicennia lanata*, *Rhizophora apiculata*, *Xylocarpus mekongensis*, *Avicennia officinalis*, *Ceriops tagal*, *Nipah fruticans*, *Xylocarpus moluccensis*, *Bruguiera gymnorrhiza*, *Bruguiera cylindrica*, and *Bruguiera parviflora*. In Pungkol, mangrove species encompasses *Rhizophora mucronata*, *Bruguiera parviflora*, *Rhizophora stylosa*, *Ceriops decandra*, *Avicennia officinalis*, *Bruguiera sexangula*, *Rhizophora apiculata*, *Avicennia lanata* and *Avicennia marina*. In Wawontulap station, mangrove encompasses *Xylocarpus mekongensis*, *Bruguiera parviflora*, *Rhizophora apiculata*, *Ceriops tagal*, *Xylocarpus moluccensis*, *Rhizophora stylosa*, *Rhizopora mucronata* and *Bruguiera sexangula*.

Totally, there are about 18 mangrove plants species grows in coastal area of Bunaken. This data shows that mangrove species diversity as abundance, and mangrove composed from multi species. These will become the ideal habitat for birds and aquatic species which area depend on mangrove ecosystem. The conservation of mangrove in Bunaken coastal area therefore contributes to the integral strategy of biodiversity conservation in Bunakan national Park. The existence of mangrove contributes to the protection of coastal ecosystem which is important for human [26]. It is particularly important due to Bunaken is one of the spot of tourism activities in North Sulawesi [16] [17]. The biomass of mangroves plant tree species was presented at Table 2.

Table 2. Mangrove plants biomass in observation plots (Mg ha^{-1})

Species	Teling			Rap-rap			Pungkol			Wawontulap		
	plot 1	plot 2	plot 3	plot 1	plot 2	plot 3	plot 1	plot 2	plot 3	plot 1	plot 2	plot 3
A. marina			49.99	799.36	32.26	265.46			6.05			
A. lanata				15.80					3.10			
A. officinalis	4.93	60.68			197.43				9.92			
A.cylindrica						4.27						
Ae. floridum				22.58						5.91		
B. gymnorrhiza						60.5						
B. parviflora						7.53	50.27	137.11	1.42	154.15	184.1	237.46
B. sexangula									41.87	0.64		
C. tagal					20.84	5.18						
C. decandra								18.18	0.26			
N. fruticans												
R. mucronata	68.73	-	-				33.91	40.72	15.46		0.75	1.12
R. stylosa							125.3	120.4			330.0	368.8
R. apiculata	0.42	15.77	48.07	0.16		1.02			20.09	34.3	46.12	51.93
S. alba	466.39	449.73	30.05									
X. mekongensis					36.55					193.15	31.39	62.00
X. moluccensis						42.90				0.4	61.6	
A. cylin drica												

The total carbon stock from biomass and necromass in Teling, Rap-rap, Pungkol and Wawontulap was given in table 3. The carbon stock in biomass was highest than carbon stock in necromass. This data indicated that conserving mangrove plant species is crucial in CO_2 mitigation.

Table 3. Carbon stock from biomass and necromass of mangrove plant trees

Sites	Plots	Biomass (Mg ha^{-1})	Necromass (Mg ha^{-1})	Total (Mg ha^{-1})
Teling	I	540.47	141.00	681.47
	II	526.20	59.80	586.00
	III	128.10	7.99	136.09
	Total	1194.77	208.79	1403.56
Rap-rap	I	837.90	12.46	850.36
	II	287.08	9.28	296.36
	III	659.70	16.70	676.40
	Total	1784.68	38.44	1823.12
Pungkol	I	96.71	4.21	100.92
	II	208.05	16.75	224.80
	III	98.17	56.55	154.72
	Total	402.93	77.51	480.44

Wawontulap	I	387.51	23.10	410.61
	II	356.96	111.55	468.51
	III	390.03	21.30	411.33
	Total	1134.50	155.95	1290.45

The content of carbon stock were influenced by biomass and necromas [19] [27]. Scholar point out that the ability of plant to absorb CO2 in atmosphere and stored into wood and plant biomass is important in global warming mitigation strategy [28]. The evaluation of carbon stock in mangrove ecosystems were varies. The highest carbon stock found at Rap-rap (ca. 1823,12 Mg ha^{-1}) and the lowest was found at Wawontulap (ca. 411,33 Mg ha^{-1}). The carbon stock variety among sites and observed station were the result of the difference vegetation structure and composition. These data shows that mangrove is the important ecosystem in the earth in global carbon storage [28] [29] [30] [31].

Table 4. The total carbon stock of mangrove forest at Teling, Rap-rap, Pungkol and Wawontulap

No	Sites	Biomass (Mg ha^{-1})	Necromass (Mg ha^{-1})	Total (Mg ha^{-1})
1.	Teling	1194.77	208.79	1403.56
2.	Rap-rap	1784.68	38.44	1823.12
3.	Pungkol	402.93	77.51	480.44
4.	Wawontulap	390.03	21.30	411.33
	Total	1134.50	155.95	1290.45

IV. Conclusion

Mangrove ecosystem in the Bunaken National Park, North Sulawesi, is the important sites for carbon captured and stored in biosphere system. There are about 18 mangrove species growing in coastal area of Bunaken, namely *A. marina*, *A. lanata*, *A. cylindrica*, *A. officinalis*, *A.cylindrica*, *Ae. floridum*, *B. gymnorrhiza*, *B. parviflora*, *B. sexangula*, *C. tagal*, *C. decandra*, *N. fruticans*, *R. mucronata*, *R. stylosa*, *R. apiculata*, *S. alba*, *X. mekongensis*, and *X. moluccensis*. In Teling areas, *Rhizophora mucronata* and *Soneratia alba* become two co-dominant species in plot 1, *Soneratia alba* become important species in plot 2, and *Rhizophora apiculata* is the important species in plot 3. *Avicennia marina* become the most important species to characterized mangrove ecosystem in Rap-rap. In Pungkol areas, *Bruguiera sexangula* has highest value of important value index in Plot 1, followed by *R. mucronata* in Plot 2 and B. *parviflora* in plot 3. In Wawontulap areas, *B. parviflora* has the highest value of important value index in Plot 1, 2 and 3. The highest carbon stock was found at Rap-rap (ca. 1784,68 Mg/ha) and the lowest was found at Wawontulap (390,03 Mg ha^{-1}). The highest necromass was found at Teling (ca 208,79 Mg ha^{-1}) and the lowest was found at Wawontulap (ca. 21,30 Mg ha^{-1}).

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