Gmail ionelclaudiu@yahoo.com

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From: **gavriloaie ionel claudiu** <ionelclaudiu@yahoo.com>
Date: 2017-08-29 14:24 GMT+07:00
Subject: in regard to the paper submitted to AACL Bioflux journal - Carbon Stock Potency of Mangrove Ecosysten
To: "nanakariada@mail.unnes.ac.id" <nanakariada@mail.unnes.ac.id>

Dear Dr. Tri Martuti,

We have analyzed the paper with the title "**Carbon Stock Potency of Mangrove Ecosystem**
and we think it could be published in AACL Bioflux journal, but it is much more suitable for Al
Sciences (http://www.aes.bioflux.com.ro/). So, I strongly recommend to have it is AES journa
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Thank you very much!

Cordially yours,
Claudiu Gavriloaie, PhD
editor-in-chief AACL Biolfux journal

Submission letter

Article title:
Carbon Stock Potency of Mangrove Ecosystem at Tapak Sub-village, Semarang, Indonesia.

Name of the authors:
Nana Kariada Tri Martuti, Dewi Liesnoor Setyowati, Satya Budi Nugraha, Ditha Prasisca Mutiatari

Hereby I would like to submit the manuscript entitled "**Carbon Stock Potency of Mangrove Ecosystem at Tapak Sub-village, Semarang, Indonesia**" to Aquaculture, Aquarium, Conservation & Legislation - International Journal of the Bioflux Society.

This manuscript was not submitted or published to any other journal. The authors declare that the manuscript is an original paper and contain no plagiarized text. All authors declare that they are not currently affiliated or sponsored by any organization with a direct economic interest in subject of the article. My co-authors have all contributed to this manuscript and approve of this submission.

Corresponding author
Nana Kariada Tri Martuti

16/8/2017

Carbon Stock Potency of Mangrove Ecosystem at Tapak Sub-village, Semarang, Indonesia

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Abstract. The mangrove ecosystem is very important in reducing carbon emissions because of its ability to absorb carbon. Nevertheless, contribution of carbon emissions of mangrove forests is also quite large due to the destruction of their ecosystems. Tapak Sub-village of Semarang City has typical variation of coastal ecosystems, consisting of pond ecosystem (artificial), river ecosystem (natural) and coastal ecosystem (natural). Each of these ecosystems has different structure types of plants and mangrove density. This study aims to assess the amount of biomass and carbon stocks in each type of mangrove ecosystem in coastal area of Tapak Sub-village, Semarang. Biomass measurement was conducted by allometric equations. Estimations of carbon stock based on biomass calculation which coverted with carbon fraction. The calculation results showed the biomass content of mangrove at the research location was 1507,91 ton/ha, the number of carbon stock 708,2 ton C/ha, and absorbing ability of CO2 2598,65 ton/ha. The highest biomass value in each plot is from *Avicennia marina* that is 913,94 ton/ha or equal to carbon content of 429,55 ton C/ha.

Key Words: biomass content, carbon stock, mangrove, Tapak Sub-village.

Introduction. Global warming becomes one of mayor environmental issue on the world recently. It begins with the emission of greenhouse gases that form a layer in the atmosphere. As a result, the sun heat that enters the earth can not return to the atmosphere because its energy is not able to pass through the layer.

Antropogenic is the biggest contributor of green house gases. Intergovernmental Panel on Climate Change (IPCC) Report in 2014 recorded that agriculture sector, forestry and land use contributed emission 24%, while transportation and industrial sector contibuted sequently 14% dan 21% of global emission. The escalation of green house gases from antropogenic activity, the biggest contribution was from land use sector, particularly deforestation and land use change of 8-20%(van der Werf et al., 2009). Various strategies for reducing emissions was conducted in order to reduce the global warming rate. One of the strategy is the REDD Policy (Reducing Emissions from Deforestation and Forest Degradation), which isi offering incentives for developing countries to control carbon emissions from forest land.

The REDD Policy was proposed by UNEP, World Bank, GEF and Environmental NGO as a strategy of climate change mitigation which integrate forest management into the scheme of carbon absorption (Beymer-Farris & Bassett, 2012). According to Munawar et al. (2015), the insentive which was gave for the amount of carbon could be used for sustainable livelihood of the community around the forest. However, limited implementation of the REDD Policy was the lack of data on the amount of forest area and carbon stocks contained (Alongi, 2011).

Land mitigation efforts have been well implemented in terrestrial forest area. Even, the attention to coastal degradation not have been mayor priority yet. Though it has been known that coastal area with mangrove forest vegetation has high potential as carbon absorber compared with other type of tropical forest (Donato et al., 2011). Pendleton et al. (2012) also reccomended that coastal ecosystem management policy significantly needed for reducing carbon emissions because during this time still less attention.

The mangrove ecosystem is very important in reducing carbon emissions because of its ability to absorb carbon. Eong (1993) estimated that Mangrove vegetation could absorb carbon from the atmosphere between 75-150 Tg C ha-1y-1. Nevertheless, contribution of carbon emissions of mangrove forests is also quite large due to the destruction of their ecosystems. Some research results indicate that mangrove forest area is a region with quick rate of land use change and deforestation due to aquaculture activities and development center (Primavera, 1997;Donato et al. 2011;Bournazel et al. 2015). Generally, Mangrove waters release the amount of CO2 into the atmosphere more than 2.5 times (-42,8 Tg C y-1) which emitted from another entire subtropical and tropical coastal water area (Alongi & Mukhopadhyay, 2015).

Tapak Sub-village of Semarang City has typical variation of coastal ecosystems, consisting of pond ecosystem (artificial), river ecosystem (natural) and coastal ecosystem (natural). Each of these ecosystems has different structure types of plants and mangrove density. This condition could influence the amount of carbon content in each type of ecosystem. This similar to the research of Liu et al. (2014) about carbon content of mangrove forest in China, which obtained that the mangrove density could affect carbon content.

Based on desk study, until 2015 there is no record about carbon stock database (carbon squestration) of mangrove ecosystem at coastal area of Semarang. This study aims to assess the amount of biomass and carbon stocks in each type of mangrove ecosystem in coastal area of Tapak Sub-village, Semarang. It is important because carbon calculation result could be used as instruments to protect mangrove area. Beside, the carbon emission reduction policy through the REDD Policy should be support with database of carbon stock and stored carbon potential. The entire calculation result of each type of ecosystem could become consideration material for Semarang City government in formulating policy of coastal area management in Tapak particularly, and coastal area of Semarang in general.

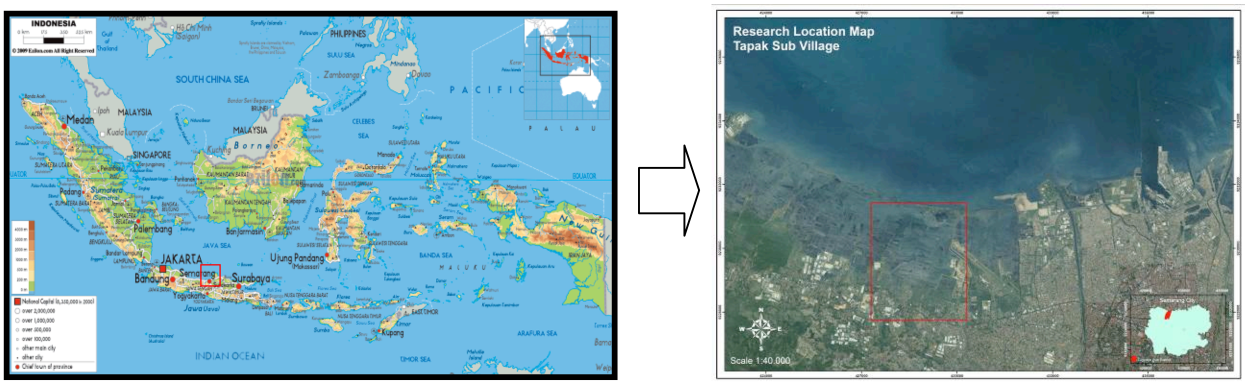
Material and Method

***Description of the study sites*.** This study was conducted at Mangrove ecosystems of Tapak Sub-village, Semarang, which consist of various lansdcape such as mangrove vegetation, fish pond, sandy beach and estuary. Tapak Sub-village located at 110º17’15” BT - 110º22’4” BT dan 6º56’13” LS - 6º59’14” LS (Martuti, et al., 2017). It is one of administration area of Tugurejo Sub-district, Semarang.

***Determination of research station location*.** Research station classified based on ecosystem type and density of mangrove species in Tapak area. Sampling was taken using purposive sampling method, which is based on research objectives and considered to certain principles. In consideration to the research site area, than the sampling emphasized the representation of mangrove species and landscape type (Kauffman & Donato, 2012). So that obtained six (6) research stations, station I were mangrove ecosystem , station II and IV were river ecosystem, station III, V and VI were fishpond ecosystem.

***Preparation of research plots*.** The research plots used a circle shape with diameter sized 20 m, which represented each types of ecosystem (n = 9). Meanwhile, underground biomass data collection was conducted by random sampling method with priority to the area around the research plots (n = 18) (Kauffman & Donato, 2012).

***Data collection*.** Data collected once in July 2016. The soil sample was conducted by destructive method then stored in a plastic bag and stored in a cooler for laboratorium analysis. The soil sample was taken from 0-20 cm depth. The sample collection was depend on standing water level in the mangrove forest. Because the research sites are always inundated by sea water at 20-30 cm high, so the soil sampling only covered from the top layer. While, for the carbon calculation above the water surface, allometric method was used with diameter at breast high (DBH) measurement. The trees diameter and height in all plots were measured, from small to large diameter (example: with the distribution of DBH class 6.4-35.2 cm) (Mitra et al., 2011; Kauffman & Donato, 2012).



source: ezilon.com, 2009

Figure 1. Research Location

Data analysis. In this research, the collected data analyzed based on the type of sampling data, including soil carbon content analysis, biomass amount measurement and carbon stock calculation. Biomass measurement could be conducted by two approach, i.e. alometric equation and destructive method (Prasetyo et al., 2011). According to Hairiah et al (2001) destructive method generally used for underground biomass measurement and stands types which do not have allometric value yet. Here are some allometry models of some mangrove trees species (The Forestry Agency of Research and Development - BALITBANG, 2013)

Table 1. Allometric model of mangrove tree biomass estimation

Type of tree	Allometric Model	DBH	R^2
Avicennia marina	$BBA=0{,}1848\ D^{2{,}3524}$	6,4-35,2	0,98
Bruguiera gymnorrhiza	$\log BBA=-0{,}552+2{,}244\ \log D$	5,0-60,9	0,99
Rhizophora apiculata	$\log BBA=-1{,}315+2{,}641\ \log D$	2,5-67,1	0,96
Xylocarpus granatum	$\log BBA=-0{,}763+2{,}23\ \log D$	5,9-49,4	0,95
information: BBA (Upper Part Biomass), D (Diameter at breast high (DBH))			

source: The Forestry Agency of Research and Development - BALITBANG, 2013

Carbon stock estimation in stands/trees based on biomass calculation result. Then, biomass value converted with carbon fraction to obtained carbon stock value. It should use appropriate value which match to ecosystem type. While, if specific carbon fraction value from some type of ecosystem was not exist, then it could use default IPCC 0.47, with following equation.

$$\text{Carbon Stock} = \text{Carbon Fraction} \times \text{Biomass}$$

In this research will also calculate CO2-equivalent using following equation.

$$CO_2\text{-equivalent} = (44/12) \times \text{carbon stock}$$

After that, in the data analysis of carbon stock calculation of the soil was conducted with bulk density and c-organic measurement. C-Organic analysis was conducted in the BPTP Laboratory of Central Java using Walkley & Black Method (Walkley & Black, 1934).

Results

***Biomass content, carbon stock, CO2 absorption by Mangrove in Tapak Sub-village*.** Based on research results, it was obtained total comparison of biomass value, carbon stock and CO2 absorption of mangrove vegetation in Tapak Sub-village, Tugurejo Sub-district, Semarang in this following table.

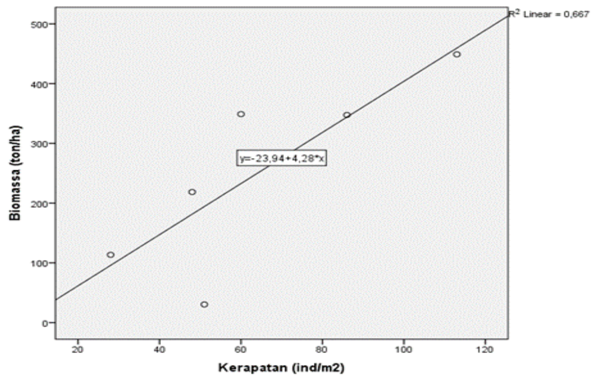
Table 2. Biomass Content, Carbon Stock, and CO2 Absorption in Tapak Sub-village

Station	Mangrove species	Number of species	The Stands Biomass (ton/ha)	Carbon Stock (ton/ha)	CO_2 - Equivalent (ton/ha)
I	AM	113	449	211,03	773,78
II	RM	46	289,44	136,04	498,8
	AM	14	59,51	27,97	102,56
	Σ	60	348,95	164,01	601,36
III	AM	28	113,43	53,31	195,48
IV	RM	64	247,48	116,32	426,49
	RS	13	57,05	26,81	98,32
	AM	9	43,02	20,22	74,14
	Σ	86	347,55	163,35	598,95
V	AM	48	218,58	102,73	376,69
VI	AM	51	30,4	14,29	52,39
Total		386	1507,91	708,2	2598,65

Information: AM: Avicennia marina, RM: Rhizhophora mucronata, RS: Rhizophora stylosa
source: data analysis, 2016

The research result showed that biomass content, carbon stock and CO2 absorption of mangrove vegetation in Tapak Sub-village, the sequence in a row from the biggest were in station I, II, IV, V, III and VI. The carbon deposits which obtained with the research area at each station of 314 m^2 were converted to carbon deposits per hectare so that the yield of mangrove biomass content in the research location was 1507.91 ton/ha, carbon stock was 708,2 ton C/ha, and able to absorb CO2 of 2598.65 ton/ha. The highest biomass value in each plot were come from *Avicennia marina* with number 913.94 ton/ha or equal to carbon content 429.55 ton C/ha, because this mangrove species could be found at all six research stations and the most widely among the others.

Based on Tabel 2, it was obtained biomass potential of mangrove in Tapak Sub-village were different in each station. Station I had the highest biomass potential (449 ton/ha), while Station VI had the lowest potential (30.4 ton/ha). It could possibly thought that station I located near the estuary, had a high density compared to other stations and had older stands. Based on correlation analysis result, relationship pattern of mangrove density and mangrove biomass content had correlation value (R) 0.67 (figure 1).



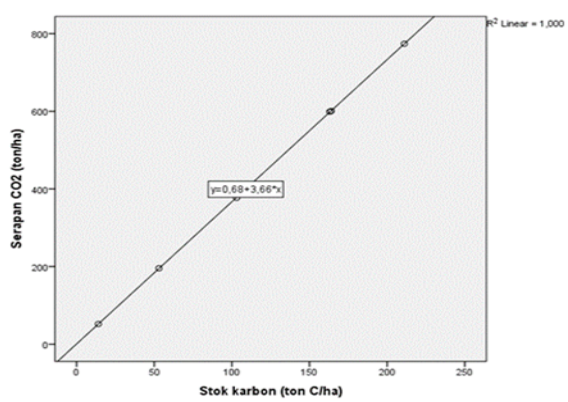
source: data analysis, 2016

Figure 2. Correlation graph of mangrove density and the biomass content

Figure 2 explained that the mangrove density had positive correlation to the biomass content. In other word, the mangrove density directly proportional to the biomass content of mangrove. The higher the mangrove density, the higher the biomass content.

Except be influenced by the tree density, the biomass value also influenced by the diameter size of the tree, because the larger the tree diameter then the higher the biomass value (Mandari et al., 2016). According to Syam'ani et al., (2012), the biomass increased because the vegetation absorb CO2 in the atmosphere and transformed it become organic compound through photosynthesis process. The photosynthesis result used to growth vertically or horizontally which indicated by increased diameter and height. Through photosynthesis process, CO2 were absorbed by the vegetation with the help of sunlight then transform become carbohydrate which distribute to whole body of tree and stored in leaf, stem, branch, fruit and flower (Hairiah et al., 2011).

Chanan (2012) stated, every addition of biomass content will be followed by the addition of carbon stock. This explained that carbon and biomass have positive relation so anything which causes an increase or decrease in biomass will lead to an increase or decrease in carbon stock. High value of biomass at Station I will followed with high carbon stock of mangrove, vice versa low value of biomass at Station VI will followed with low carbon stock of mangrove. In line with Imiliyana et al. (2012) who stated that carbon stock percentage increase in line with the increase of biomass. Relationship pattern of biomass and carbon stock had positive maximum correlation value (R) 1.00 (figure 2).



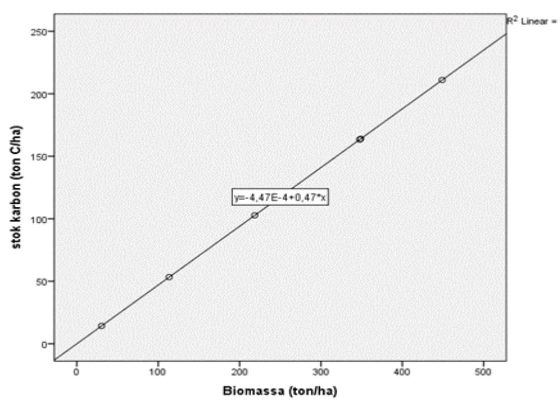
source: data analysis, 2016

Figure 3. Correlation graph of biomass and carbon stock

Figure 3 explained that mangrove biomass had positive correlation to carbon stock content. In other words, biomass value directly proportional to mangrove carbon stock. The higher biomass value then the higher carbon stock of mangrove.

Stem is part of wood that 50% consist of cellulose (Delmer & Haigler, 2002). Cellulose is main part of tough wall which cover vegetation cell and consist of linear sugar molecule in long chain of carbon (Campbell et al., 2008), so the higher the cellulose then the higher carbon content value. The bigger size of tree diameter was estimated that has high potential of cellulose and other wood compound will be larger. The high carbon in the stem is closely related to higher stem biomass when compared to other tree parts. This factor causes the larger diameter grade of the tree then the carbon content will be larger.

Carbon stored process inside the life vegetation body called sequestration process (C-sequestration). The carbon stock number inside the life vegetation body (biomass) in a land could describe the amount of CO2 in the atmosphere absorbed by plants. CO2 absorption related to carbon stock (Heriyanto & Subiandono 2012). It could be seen from research result (Table 2), mangrove ability to absorb CO2 directly proportional to carbon stock stored in the vegetation. The highest ability of mangrove to absorb CO2 were in Station I that equal to 773.78 ton/ha, while the lowest ability were in Station VI that equal to 52.39 ton/ha. Mangrove vegetation in Station I had the highest ability in absorbing CO2 because had high density of mangrove and supported by the number of mangroves that have large stem diameter, while in Station VI had low density of mangrove and small stem diameter mangrove. Referred to the research of Huy & Anh (2008), total accumulation of CO2 in vegetation's stem equal to 62%, branch 26%, bark/shell 10% and leaf 2%. CO2 absorption related positively to total number of biomass and carbon stock. Based on correlation analysis result, relationship pattern between carbon stock content with CO2 absorption had maximum positive correlation value (R) 1.00 (figure 3).



source: data analysis, 2016

Figure 4. Correlation graph of carbon stock and CO_2 absorption

Figure 4 explained that carbon stock content of a mangrove stand had positive correlation to CO2 absorption. Thus it could be interpreted that CO2 absorption will be large if the total stock was large. Vice versa, CO2 absorption will be small if the carbon stock is small. In addition to the measurement of biomass content, carbon stock, and CO2 absorption, environmental parameter measurements were also carried out at the study sites.

The average value of mangrove vegetation biomass in Tapak Sub-village from all of six research station equal to 251.32 ton/ha (equal to 118.03 ton C) which mean higher than mangrove vegetation biomass in Kemujan Island, National Park of Karimunjawa equal to 182.62 ton (equal to 91.31 ton C) (Cahyaningrum et al., 2014). This condition caused by the environment quality where it growth. Tapak Sub-village is a coastal area closed to industrial area that allows the existence of pollutants that can contaminate the

environment. There are fourteen (14) industry exist around Tapak River which ran to Tapak Sub-village (Martuti et al., 2016). Meanwhile Xiao (2015) explained that industrial emission consist of SO2 (32%), NO2 (18%), CO (20%), VOC (22%) and PM (8%).
The existence of CO2 gas in atmosphere as industrial emission result would be absorbed by the vegetation for photosynthesis process (Purba dan Khairunisa, 2012). Mangrove that lived in coastal area, has the high ability in reducing CO2 emission. Nelleman et al. (2009) stated that one of strategy to reduce CO2 emission was used coastal ecosystem as CO2 absorber which known as *blue carbon*. Mangrove had a role in reducing the amount of carbon in the air by absorbing CO2 through the photosynthesis process, otherwise known as the sequestration process. The absorbed carbon would be stored in the form of tree biomass (Ardli, 2012). The results of this study showed that mangrove ecosystem in Tapak Sub-village effective in absorbing CO2 in air, judging from the amount of biomass content and carbon stock stored in the vegetation.

Conclusions. The highest mangrove biomass content was obtained from Station I 449 ton/ha, then in a row were Station II (348.95 ton/ha) and Station III (115.35 ton/ha). Carbon stock stored in each type of ecosystem, the highest one was mangrove forest ecosystem, then river ecosystem and the lowest was fish pond ecosystem.
Acknowledgments. This research was funded by Ministry of Technology Research and Higher Education of Indonesia in 2016.

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Carbon Stock Potency of Mangrove Ecosystem at Tapak Sub-village, Semarang, Indonesia

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Key Words: biomass content, carbon stock, mangrove, Tapak Sub-village.

Introduction. Global warming becomes one of mayor environmental issue on the world recently. It begins with the emission of greenhouse gases that form a layer in the atmosphere. As a result, the sun heat that enters the earth can not return to the atmosphere because its energy is not able to pass through the layer.

Antropogenic is the biggest contributor of green house gases. Intergovernmental Panel on Climate Change (IPCC) Report in 2014 recorded that agriculture sector, forestry and land use contributed emission 24%, while transportation and industrial sector contibuted sequently 14% dan 21% of global emission. The escalation of green house gases from antropogenic activity, the biggest contribution was from land use sector, particularly deforestation and land use change of 8-20%(van der Werf et al., 2009). Various strategies for reducing emissions was conducted in order to reduce the global warming rate. One of the strategy is the REDD Policy (Reducing Emissions from Deforestation and Forest Degradation), which isi offering incentives for developing countries to control carbon emissions from forest land.

The REDD Policy was proposed by UNEP, World Bank, GEF and Environmental NGO as a strategy of climate change mitigation which integrate forest management into the scheme of carbon absorption (Beymer-Farris & Bassett, 2012). According to Munawar et al. (2015), the insentive which was gave for the amount of carbon could be used for sustainable livelihood of the community around the forest. However, limited implementation of the REDD Policy was the lack of data on the amount of forest area and carbon stocks contained (Alongi, 2011).

Land mitigation efforts have been well implemented in terrestrial forest area. Even, the attention to coastal degradation not have been mayor priority yet. Though it has been known that coastal area with mangrove forest vegetation has high potential as carbon absorber compared with other type of tropical forest (Donato et al., 2011). Pendleton et al. (2012) also reccomended that coastal ecosystem management policy significantly needed for reducing carbon emissions because during this time still less attention.

The mangrove ecosystem is very important in reducing carbon emissions because of its ability to absorb carbon. Eong (1993) estimated that Mangrove vegetation could absorb carbon from the atmosphere between 75-150 Tg C ha-1y-1. Nevertheless, contribution of carbon emissions of mangrove forests is also quite large due to the destruction of their ecosystems. Some research results indicate that mangrove forest area is a region with quick rate of land use change and deforestation due to aquaculture activities and development center (Primavera, 1997;Donato et al. 2011;Bournazel et al. 2015). Generally, Mangrove waters release the amount of CO2 into the atmosphere more than 2.5 times (-42,8 Tg C y-1) which emitted from another entire subtropical and tropical coastal water area (Alongi & Mukhopadhyay, 2015).

Tapak Sub-village of Semarang City has typical variation of coastal ecosystems, consisting of pond ecosystem (artificial), river ecosystem (natural) and coastal ecosystem (natural). Each of these ecosystems has different structure types of plants and mangrove density. This condition could influence the amount of carbon content in each type of ecosystem. This similar to the research of Liu et al. (2014) about carbon content of mangrove forest in China, which obtained that the mangrove density could affect carbon content.

Based on desk study, until 2015 there is no record about carbon stock database (carbon squestration) of mangrove ecosystem at coastal area of Semarang. This study aims to assess the amount of biomass and carbon stocks in each type of mangrove ecosystem in coastal area of Tapak Sub-village, Semarang. It is important because carbon calculation result could be used as instruments to protect mangrove area. Beside, the carbon emission reduction policy through the REDD Policy should be support with database of carbon stock and stored carbon potential. The entire calculation result of each type of ecosystem could become consideration material for Semarang City government in formulating policy of coastal area management in Tapak particularly, and coastal area of Semarang in general.

Material and Method

***Description of the study sites*.** This study was conducted at Mangrove ecosystems of Tapak Sub-village, Semarang, which consist of various lansdcape such as mangrove vegetation, fish pond, sandy beach and estuary. Tapak Sub-village located at 110º17’15” BT - 110º22’4” BT dan 6º56’13” LS - 6º59’14” LS (Martuti, et al., 2017). It is one of administration area of Tugurejo Sub-district, Semarang.

***Determination of research station location*.** Research station classified based on ecosystem type and density of mangrove species in Tapak area. Sampling was taken using purposive sampling method, which is based on research objectives and considered to certain principles. In consideration to the research site area, than the sampling emphasized the representation of mangrove species and landscape type (Kauffman & Donato, 2012). So that obtained six (6) research stations, station I were mangrove ecosystem , station II and IV were river ecosystem, station III, V and VI were fishpond ecosystem.

***Preparation of research plots*.** The research plots used a circle shape with diameter sized 20 m, which represented each types of ecosystem (n = 9). Meanwhile, underground biomass data collection was conducted by random sampling method with priority to the area around the research plots (n = 18) (Kauffman & Donato, 2012).

***Data collection*.** Data collected once in July 2016. The soil sample was conducted by destructive method then stored in a plastic bag and stored in a cooler for laboratorium analysis. The soil sample was taken from 0-20 cm depth. The sample collection was depend on standing water level in the mangrove forest. Because the research sites are always inundated by sea water at 20-30 cm high, so the soil sampling only covered from the top layer. While, for the carbon calculation above the water surface, allometric method was used with diameter at breast high (DBH) measurement. The trees diameter and height in all plots were measured, from small to large diameter (example: with the distribution of DBH class 6.4-35.2 cm) (Mitra et al., 2011; Kauffman & Donato, 2012).

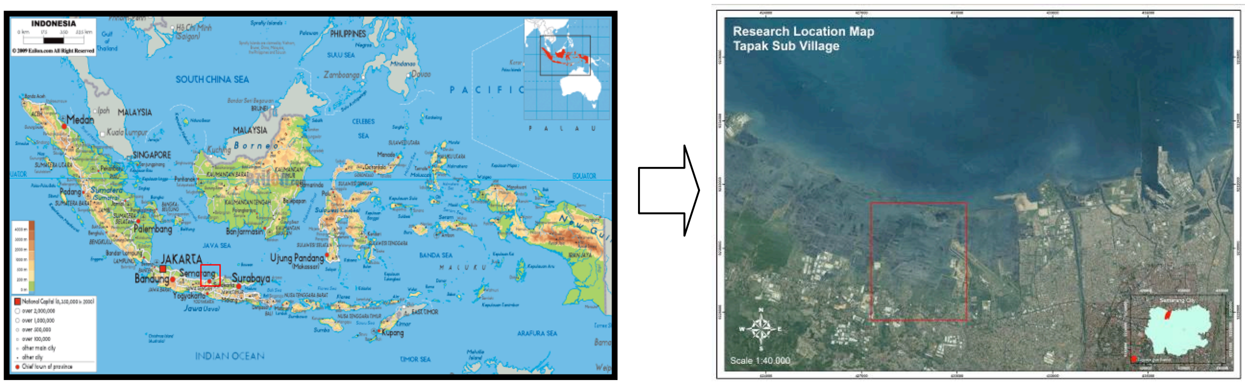

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Figure 1. Research Location

Data analysis. In this research, the collected data analyzed based on the type of sampling data, including soil carbon content analysis, biomass amount measurement and carbon stock calculation. Biomass measurement could be conducted by two approach, i.e. alometric equation and destructive method (Prasetyo et al., 2011). According to Hairiah et al (2001) destructive method generally used for underground biomass measurement and stands types which do not have allometric value yet. Here are some allometry models of some mangrove trees species (The Forestry Agency of Research and Development - BALITBANG, 2013)

Table 1. Allometric model of mangrove tree biomass estimation

Type of tree	Allometric Model	DBH	R^2
Avicennia marina	$BBA=0,1848\ D^{2,3524}$	6,4-35,2	0,98
Bruguiera gymnorrhiza	$\log BBA=-0,552+2,244 \log D$	5,0-60,9	0,99
Rhizophora apiculata	$\log BBA=-1,315+2,641 \log D$	2,5-67,1	0,96
Xylocarpus granatum	$\log BBA=-0,763+2,23 \log D$	5,9-49,4	0,95
information: BBA (Upper Part Biomass), D (Diameter at breast high (DBH))			

source: The Forestry Agency of Research and Development - BALITBANG, 2013

Carbon stock estimation in stands/trees based on biomass calculation result. Then, biomass value converted with carbon fraction to obtained carbon stock value. It should use appropriate value which match to ecosystem type. While, if specific carbon fraction value from some type of ecosystem was not exist, then it could use default IPCC 0.47, with following equation.

$$\text{Carbon Stock} = \text{Carbon Fraction} \times \text{Biomass}$$

In this research will also calculate CO2-equivalent using following equation.

$$CO_2\text{-equivalent} = (44/12) \times \text{carbon stock}$$

After that, in the data analysis of carbon stock calculation of the soil was conducted with bulk density and c-organic measurement. C-Organic analysis was conducted in the BPTP Laboratory of Central Java using Walkley & Black Method (Walkley & Black, 1934).

Results

***Biomass content, carbon stock, CO2 absorption by Mangrove in Tapak Sub-village*.** Based on research results, it was obtained total comparison of biomass value, carbon stock and CO2 absorption of mangrove vegetation in Tapak Sub-village, Tugurejo Sub-district, Semarang in this following table.

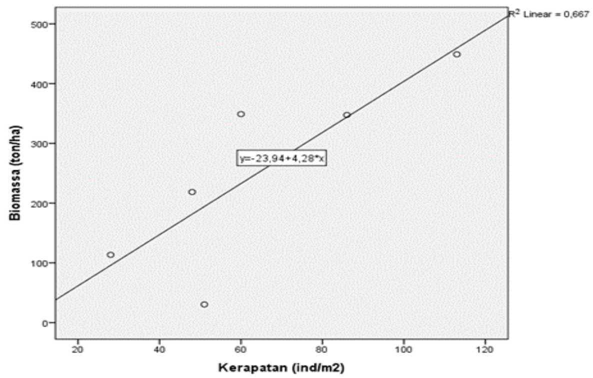
Table 2. Biomass Content, Carbon Stock, and CO2 Absorption in Tapak Sub-village

Station	Mangrove species	Number of species	The Stands Biomass (ton/ha)	Carbon Stock (ton/ha)	CO_2 - Equivalent (ton/ha)
I	AM	113	449	211,03	773,78
II	RM	46	289,44	136,04	498,8
	AM	14	59,51	27,97	102,56
	∑	60	348,95	164,01	601,36
III	AM	28	113,43	53,31	195,48
IV	RM	64	247,48	116,32	426,49
	RS	13	57,05	26,81	98,32
	AM	9	43,02	20,22	74,14
	∑	86	347,55	163,35	598,95
V	AM	48	218,58	102,73	376,69
VI	AM	51	30,4	14,29	52,39
Total		386	1507,91	708,2	2598,65

Information: AM: Avicennia marina, RM: Rhizhophora mucronata, RS: Rhizophora stylosa
source: data analysis, 2016

The research result showed that biomass content, carbon stock and CO2 absorption of mangrove vegetation in Tapak Sub-village, the sequence in a row from the biggest were in station I, II, IV, V, III and VI. The carbon deposits which obtained with the research area at each station of 314 m^2 were converted to carbon deposits per hectare so that the yield of mangrove biomass content in the research location was 1507.91 ton/ha, carbon stock was 708,2 ton C/ha, and able to absorb CO2 of 2598.65 ton/ha. The highest biomass value in each plot were come from *Avicennia marina* with number 913.94 ton/ha or equal to carbon content 429.55 ton C/ha, because this mangrove species could be found at all six research stations and the most widely among the others.

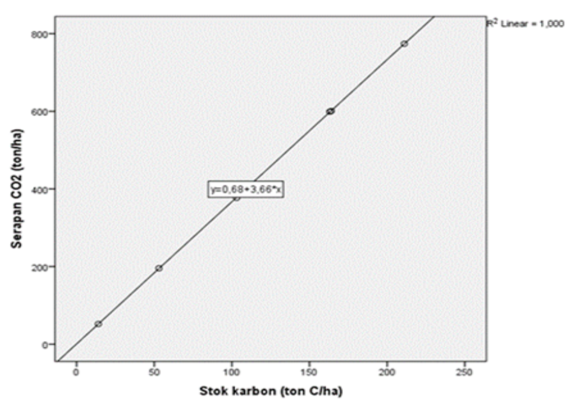
Based on Tabel 2, it was obtained biomass potential of mangrove in Tapak Sub-village were different in each station. Station I had the highest biomass potential (449 ton/ha), while Station VI had the lowest potential (30.4 ton/ha). It could possibly thought that station I located near the estuary, had a high density compared to other stations and had older stands. Based on correlation analysis result, relationship pattern of mangrove density and mangrove biomass content had correlation value (R) 0.67 (figure 1).



source: data analysis, 2016

Figure 2. Correlation graph of mangrove density and the biomass content

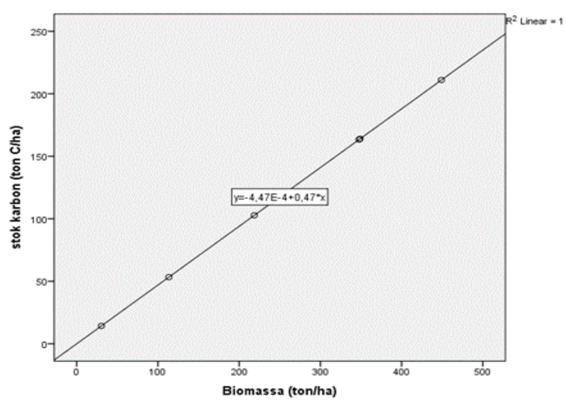
Figure 2 explained that the mangrove density had positive correlation to the biomass content. In other word, the mangrove density directly proportional to the biomass content of mangrove. The higher the mangrove density, the higher the biomass content.
Except be influenced by the tree density, the biomass value also influenced by the diameter size of the tree, because the larger the tree diameter then the higher the biomass value (Mandari et al., 2016). According to Syam'ani et al., (2012), the biomass increased because the vegetation absorb CO2 in the atmosphere and transformed it become organic compound through photosynthesis process. The photosynthesis result used to growth vertically or horizontally which indicated by increased diameter and height. Through photosynthesis process, CO2 were absorbed by the vegetation with the help of sunlight then transform become carbohydrate which distribute to whole body of tree and stored in leaf, stem, branch, fruit and flower (Hairiah et al., 2011).
Chanan (2012) stated, every addition of biomass content will be followed by the addition of carbon stock. This explained that carbon and biomass have positive relation so anything which causes an increase or decrease in biomass will lead to an increase or decrease in carbon stock. High value of biomass at Station I will followed with high carbon stock of mangrove, vice versa low value of biomass at Station VI will followed with low carbon stock of mangrove. In line with Imiliyana et al. (2012) who stated that carbon stock percentage increase in line with the increase of biomass. Relationship pattern of biomass and carbon stock had positive maximum correlation value (R) 1.00 (figure 2).



source: data analysis, 2016

Figure 3. Correlation graph of biomass and carbon stock

Figure 3 explained that mangrove biomass had positive correlation to carbon stock content. In other words, biomass value directly proportional to mangrove carbon stock. The higher biomass value then the higher carbon stock of mangrove.
Stem is part of wood that 50% consist of cellulose (Delmer & Haigler, 2002). Cellulose is main part of tough wall which cover vegetation cell and consist of linear sugar molecule in long chain of carbon (Campbell et al., 2008), so the higher the cellulose then the higher carbon content value. The bigger size of tree diameter was estimated that has high potential of cellulose and other wood compound will be larger. The high carbon in the stem is closely related to higher stem biomass when compared to other tree parts. This factor causes the larger diameter grade of the tree then the carbon content will be larger.
Carbon stored process inside the life vegetation body called sequestration process (C-sequestration). The carbon stock number inside the life vegetation body (biomass) in a land could describe the amount of CO2 in the atmosphere absorbed by plants. CO2 absorption related to carbon stock (Heriyanto & Subiandono 2012). It could be seen from research result (Table 2), mangrove ability to absorb CO2 directly proportional to carbon stock stored in the vegetation. The highest ability of mangrove to absorb CO2 were in Station I that equal to 773.78 ton/ha, while the lowest ability were in Station VI that equal to 52.39 ton/ha. Mangrove vegetation in Station I had the highest ability in absorbing CO2 because had high density of mangrove and supported by the number of mangroves that have large stem diameter, while in Station VI had low density of mangrove and small stem diameter mangrove. Referred to the research of Huy & Anh (2008), total accumulation of CO2 in vegetation's stem equal to 62%, branch 26%, bark/shell 10% and leaf 2%. CO2 absorption related positively to total number of biomass and carbon stock. Based on correlation analysis result, relationship pattern between carbon stock content with CO2 absorption had maximum positive correlation value (R) 1.00 (figure 3).



source: data analysis, 2016

Figure 4. Correlation graph of carbon stock and CO_2 absorption

Figure 4 explained that carbon stock content of a mangrove stand had positive correlation to CO2 absorption. Thus it could be interpreted that CO2 absorption will be large if the total stock was large. Vice versa, CO2 absorption will be small if the carbon stock is small. In addition to the measurement of biomass content, carbon stock, and CO2 absorption, environmental parameter measurements were also carried out at the study sites.
The average value of mangrove vegetation biomass in Tapak Sub-village from all of six research station equal to 251.32 ton/ha (equal to 118.03 ton C) which mean higher than mangrove vegetation biomass in Kemujan Island, National Park of Karimunjawa equal to 182.62 ton (equal to 91.31 ton C) (Cahyaningrum et al., 2014). This condition caused by the environment quality where it growth. Tapak Sub-village is a coastal area closed to industrial area that allows the existence of pollutants that can contaminate the

environment. There are fourteen (14) industry exist around Tapak River which ran to Tapak Sub-village (Martuti et al., 2016). Meanwhile Xiao (2015) explained that industrial emission consist of SO2 (32%), NO2 (18%), CO (20%), VOC (22%) and PM (8%).
The existence of CO2 gas in atmosphere as industrial emission result would be absorbed by the vegetation for photosynthesis process (Purba dan Khairunisa, 2012). Mangrove that lived in coastal area, has the high ability in reducing CO2 emission. Nelleman et al. (2009) stated that one of strategy to reduce CO2 emission was used coastal ecosystem as CO2 absorber which known as *blue carbon*. Mangrove had a role in reducing the amount of carbon in the air by absorbing CO2 through the photosynthesis process, otherwise known as the sequestration process. The absorbed carbon would be stored in the form of tree biomass (Ardli, 2012). The results of this study showed that mangrove ecosystem in Tapak Sub-village effective in absorbing CO2 in air, judging from the amount of biomass content and carbon stock stored in the vegetation.

Conclusions. The highest mangrove biomass content was obtained from Station I 449 ton/ha, then in a row were Station II (348.95 ton/ha) and Station III (115.35 ton/ha). Carbon stock stored in each type of ecosystem, the highest one was mangrove forest ecosystem, then river ecosystem and the lowest was fish pond ecosystem.
Acknowledgments. This research was funded by Ministry of Technology Research and Higher Education of Indonesia in 2016.

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Date: Wed, 6 Sep 2017, 05:39
Subject: Fwd: in regard to the paper submitted to AACL Bioflux journal - Carbon Stock Potency of Mangrove Ecos
To: Satya Budi Nugraha <satyabnugraha@mail.unnes.ac.id>

---------- Forwarded message ----------
From: **gavriloaie ionel claudiu** <ionelclaudiu@yahoo.com>
Date: 2017-09-06 4:09 GMT+07:00
Subject: Re: in regard to the paper submitted to AACL Bioflux journal - Carbon Stock Potency of Mangrove Ecosy
To: Nana Kariada Tri Martuti <nanakariada@mail.unnes.ac.id>

Dear Dr. Tri Martuti,

I will send the paper to two reviewers from AACL editorial board, hoping they will accept the comments I will let you know.
Thank you very much!

Cordially yours,
Claudiu Gavriloaie

On Tuesday, August 29, 2017 11:38 PM, Nana Kariada Tri Martuti <nanakariada@mail.unnes.ac.id> wrote:

Thank you for your suggestion, but SCOPUS coverage is mandatory in my institution. So tha

Carbon stock potency of mangrove ecosystem at Tapak Sub-village, Semarang, Indonesia

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Abstract. The mangrove ecosystem is very important in reducing carbon emissions because of its ability to absorb carbon. Nevertheless, contribution of carbon emissions of mangrove forests is also quite large due to the destruction of their ecosystems. Tapak Sub-village of Semarang City has typical variation of coastal ecosystems, consisting of pond ecosystem (artificial), river ecosystem (natural) and coastal ecosystem (natural). Each of these ecosystems has different structure in terms of types of plants and mangrove density. This study aims to assess the amount of biomass and carbon stocks in each type of mangrove ecosystem in coastal area of Tapak Sub-village, Semarang. Biomass measurement was conducted by allometric equations. Estimations of carbon stock was based on biomass calculation with carbon fraction as coversion factor. The results obtained showed the six research locations contributed 1507.91 ton ha^{-1} in mangrove biomass content, 708.20 ton C ha^{-1} carbon stock, and 2598.65 ton ha^{-1} CO_2 absorption capability. The highest biomass value in each plot is from *Avicennia marina* contributing 913.94 ton ha^{-1} biomass content and 429.55 ton C ha^{-1} carbon content.

Key Words: biomass content, carbon stock, mangrove, Tapak Sub-village.

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Introduction. Global warming becomes one of the major environmental issues in the world recently. It begins with the emission of greenhouse gases that form a layer in the atmosphere. As a result, the sun heat that enters the earth can not return to the atmosphere because its energy is not able to pass through the layer.

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Antropogenic activities is the biggest contributor of green house gases. Intergovernmental Panel on Climate Change (IPCC) Report in 2014 recorded that agriculture sector, forestry and land use contributed 24% emission, while transportation and industrial sectors contibuted 14% and 21%, respectively, of global emissions. The biggest contribution to the escalation of green house gases from anthropogenic activity, was from land use sector, particularly, deforestation and land use change, contributing 8-20% (van der Werf et al 2009). Various strategies for reducing emissions were conducted in order to reduce the global warming rate. One of the strategy is the REDD Policy (Reducing Emissions from Deforestation and Forest Degradation), which offers incentives for developing countries to control carbon emissions from forest land.

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The REDD Policy was proposed by UNEP, World Bank, GEF and Environmental NGO as a strategy of climate change mitigation which integrates forest management into the scheme of carbon absorption (Beymer-Farris & Bassett 2012). According to Munawar et al (2015), the incentive suggested the amount of carbon which could be used for sustainable livelihood of the community around the forest. However, the lack of data on the amount of forest area and carbon stocks contained limited implementation of the REDD Policy (Alongi 2011).

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Land mitigation efforts have been well implemented in terrestrial forest area; while coastal degradation is yet to be given a major priority. However, coastal area with mangrove forest vegetation are known to have high potentials as carbon absorber compared to other types of tropical forest (Donato et al 2011). Pendleton et al (2012) also recommended that coastal ecosystem management policy be given significant attention in reducing carbon emissions though it is currently given less attention.

The mangrove ecosystem is very important in reducing carbon emissions because of its ability to absorb carbon. Eong (1993) estimated that mangrove vegetation could absorb carbon from the atmosphere between 75-150 Tg C ha^{-1} y^{-1}. Nevertheless, contribution of carbon emissions of mangrove forests is also quite large due to the destruction of their ecosystems. Some research results indicate that mangrove forest area is a region with quick rate of land use change and deforestation due to aquaculture activities and development center (Primavera 1997; Donato et al 2011; Bournazel et al 2015). Generally, mangrove waters release more than 2.5 times the amount of CO_2 into the atmosphere (-42.8 Tg C y^{-1}) which emitted from another entire subtropical and tropical coastal water area (Alongi & Mukhopadhyay 2015).

Tapak Sub-village of Semarang City has typical variation of coastal ecosystems, consisting of pond ecosystem (artificial), river ecosystem (natural) and coastal ecosystem (natural). Each of these ecosystems has different structures: types of plants and mangrove density which could influence the amount of carbon content in each type of ecosystem. This is strengthened by evidence obtained in China that mangrove density could affect carbon content of mangrove forest (Liu et al 2013).

Based on desk study, until 2015, there was no record of carbon stock database (carbon squestration) of mangrove ecosystem at coastal area of Semarang. This study aims to assess the amount of biomass and carbon stocks in each type of mangrove ecosystem in coastal area of Tapak Sub-village, Semarang. It is important because the carbon calculation obtained in this study could be used as instrument to protect mangrove area. Besides, database of carbon stock and stored carbon potential generated in this study will support the carbon emission reduction policy through the REDD Policy. In addition, the entire calculation result of each type of ecosystem could become consideration material for Semarang City government in formulating policy of coastal area management in Tapak particularly, and coastal area of Semarang in general.

Material and Method

Description of the study sites. This study was conducted at mangrove ecosystems of Tapak Sub-village, Semarang, Indonesia which consist of various lansdcape such as mangrove vegetation, fish pond, sandy beach and estuary. Tapak Sub-village is located at 110º17'15" BT - 110º22'4" BT dan 6º56'13" LS - 6º59'14" LS (Martuti et al 2017). It is one of administration area of Tugurejo Sub-district, Semarang.

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Determination of research station location. The research stations were classified based on ecosystem type and density of mangrove species in Tapak area. Purposive sampling method was adopted emphasizing mangrove species and landscape type represented (Kauffman & Donato 2012); resulting in six (6) research stations marked out as: station I - mangrove ecosystem; stations II and IV - river ecosystems; and stations III, V and VI - fishpond ecosystems.

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Preparation of research plots. The research plots were 20 m in diameter representing each type of ecosystem (n = 9). Underground biomass data were also collected by random sampling method with priority given to the areas around the research plots (n = 18) (Kauffman & Donato 2012).

Data collection. Data were collected once in July 2016. The research sites are always inundated by sea water at 20-30 cm high, so the soil samples was taken from 0-20 cm depth, depending on level of standing water in the mangrove forest. The soil samples were then placed in a labelled plastic bag and stored in a cooler for laboratory analysis. Allometric method of measurement of tree diameter at breast high (DBH) was employed in carbon calculation above the water surface. The tree diameter and height in all plots were measured, from small to large diameter, e.g., DBH class 6.4-35.2 cm (Mitra et al 2011; Kauffman & Donato 2012).

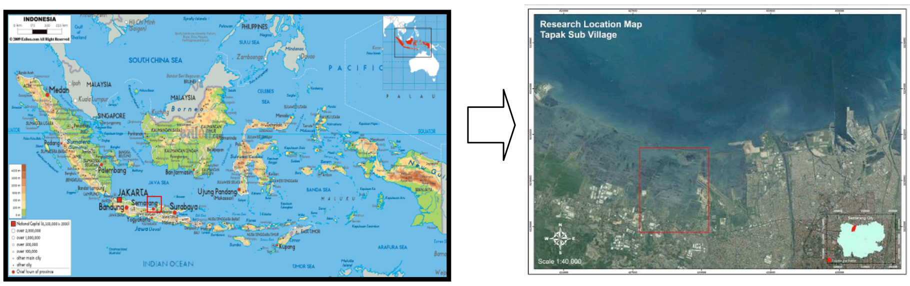

Figure 1. Research location (source: ezilon.com 2009).

Data analysis. The data collected in this study were analyzed based on data type, including soil carbon content analysis, biomass amount measurement and carbon stock calculation. Biomass measurements were analyzed by two approaches, i.e. allometric equation and destructive method (Prasetyo et al 2011). According to Hairiah et al (2001) destructive method was generally used for underground biomass measurement and stand types which do not yet have allometric values. Here are some allometry models of some mangrove trees species (The Forestry Agency of Research and Development - BALITBANG 2013).

Table 1

Allometric models used in mangrove tree biomass estimation

Type of tree	*Allometric model*	*DBH*	*R^2*
Avicennia marina	$BBA = 0.1848\ D^{2.3524}$	6.4-35.2	0.98
Bruguiera gymnorrhiza	logBBA = -0.552+2.244 log D	5.0-60.9	0.99
Rhizophora apiculata	logBBA = -1.315+2.641 log D	2.5-67.1	0.96
Xylocarpus granatum	logBBA = -0.763+2.23 log D	5.9-49.4	0.95

BBA = Upper Part Biomass; D = Diameter at breast high (DBH) (Source: The Forestry Agency of Research and Development - BALITBANG (2013)).

Carbon stock estimation in stands/trees were calculated by first deriving the biomass value, and then multiplying by carbon fraction (appropriate value for the ecosystem type) to convert to carbon stock value. Where the specific carbon fraction value from an ecosystem type does not exist, the default IPCC value of 0.47 was used:

Carbon stock = Carbon fraction x biomass

In this research we also calculated CO_2-equivalent using following equation:

CO_2-equivalent = (44/12) x carbon stock

In addition, the bulk density and organic carbon measurement of the soil was analysed in the BPTP Laboratory of Central Java using Walkley & Black Method (Walkley & Black 1934).

Results and Discussion

Biomass content, carbon stock, CO_2 absorption by mangrove in Tapak Sub-village. The research results indicate total biomass value, carbon stock and CO_2 absorption of mangrove vegetation in Tapak Sub-village, Tugurejo Sub-district, Semarang in Table 2.

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Table 2
Biomass content, carbon stock, and CO_2 absorption in Tapak Sub-village

Station	*Mangrove species*	*Number of species*	*The stands biomass (ton ha^{-1})*	*Carbon stock (ton ha^{-1})*	*CO_2 - equivalent (ton ha^{-1})*
I	AM	113	449	211.03	773.78
II	RM	46	289.44	136.04	498.80
	AM	14	59.51	27.97	102.56
	Σ	60	348.95	164.01	601.36
III	AM	28	113.43	53.31	195.48
IV	RM	64	247.48	116.32	426.49
	RS	13	57.05	26.81	98.32
	AM	9	43.02	20.22	74.14
	Σ	86	347.55	163.35	598.95
V	AM	48	218.58	102.73	376.69
VI	AM	51	30.4	14.29	52.39
Total		386	1507.91	708.20	2598.65

AM = *Avicennia marina*; RM = *Rhizhophora mucronata*; RS = *Rhizhophora stylosa* (Source: Data analysis 2016).

The research result showed that biomass content, carbon stock and CO_2 absorption of mangrove vegetation in Tapak Sub-village, in order of descending magnitude were in stations I, II, IV, V, III and VI. The carbon deposits per hectare obtained from each research station covering 314 m^2 yielded mangrove biomass content of 1507.91 ton ha^{-1} carbon stock was 708.2 ton C ha^{-1}, and able to absorb CO_2 of 2598.65 ton ha^{-1}. The highest biomass value (913.94 ton ha^{-1},) per plot came from *Avicennia marina* which is equal to a carbon content of 429.55 ton C ha^{-1}; because this mangrove species was distributed across all six research stations and covered the widest area, among the others.

Table 2 also indicates the biomass potential of the mangrove in Tapak Sub-village at each different station. Station I had the highest biomass potential (449 ton ha^{-1}), while Station VI had the lowest potential (30.4 ton ha^{-1}). This could be attributed to the fact that station I was located near the estuary, had a high density compared to other stations and had older stands. Correlation analysis reveal a strong relationship (r = 0.67) between mangrove density and mangrove biomass content (Figure 2).

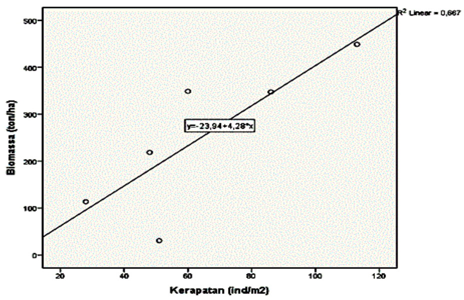

Figure 2. Correlation graph of mangrove density and the biomass content (Source: Data analysis, 2016).

Figure 2 explained that the mangrove density had positive correlation to the biomass content. In other words, the mangrove density is directly proportional to the biomass content of mangrove; the higher the mangrove density, the higher the biomass content.

Apart from tree density, the biomass value was also influenced by the diameter size of the tree, because the larger the tree diameter, the higher the biomass value (Mandari et al 2016). According to Syam'ani & Susilawati (2012), the biomass increased because the vegetation absorbs CO_2 in the atmosphere and transforms it to organic

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compound through photosynthesis process; resulting in vertical or horizontal growth, indicated by increased diameter and height. Through the photosynthesis process, CO_2 were absorbed by the vegetation with the help of sunlight. Thereafter, it was transformed into carbohydrate which was then distributed to the whole body of tree and stored in leaf, stem, branch, fruit and flower (Hairiah et al 2001).

Chanan (2012) stated that every addition of biomass content will be followed by the addition of carbon stock. This explains why carbon and biomass have positive relations; so anything which causes an increase or decrease in biomass will lead to an increase or decrease in carbon stock. High value of biomass at station I will be associatory with high carbon stock of mangrove, vice versa, low value of biomass at station VI will be accompanied with low carbon stock of mangrove. This is in line with Imiliyana et al's (2012) assertion that carbon stock percentage increases in line with the increase of biomass. This assertion is upheld in this study revealing positive maximum correlation value (r = 1.00) between biomass and carbon stock (Figure 3).

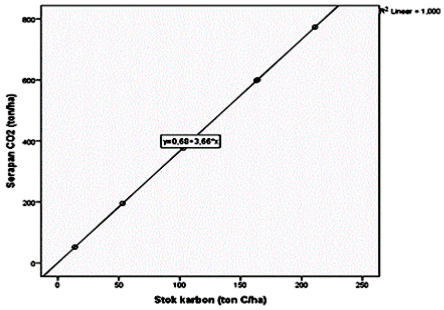

Figure 3. Correlation graph of biomass and carbon stock (Source: Data analysis, 2016)

Figure 3 elucidates the positive correlation between mangrove biomass and carbon stock content. In other words, biomass value is directly proportional to mangrove carbon stock. The higher the biomass value then the higher the carbon stock of mangrove.

Stem is part of wood and consists 50% of cellulose (Delmer & Haigler 2002). Cellulose is the main part of tough wall which covers vegetation cell and consists of linear sugar molecule in a long chain of carbon (Campbell et al 2008), so the higher the cellulose then the higher the carbon content value. It was estimated that the bigger the size of tree diameter the higher the potential that cellulose and other wood compounds will be larger. The high carbon in the stem is closely related to higher stem biomass when compared to other tree parts. This factor causes the larger diameter grade of the tree hence the carbon content will be larger.

Carbon is stored and incorporated into the forest vegetation in a process called sequestration process (C-sequestration). The carbon stock value incorporated in the life vegetation body (biomass) in a land describes the amount of CO_2 in the atmosphere absorbed by plants. CO_2 absorption is related to carbon stock (Heriyanto & Subiandono 2012). Research result of this study (Table 2), illustrates that mangrove ability to absorb CO_2 is directly proportional to carbon stock stored in the vegetation. The highest ability of mangrove to absorb CO_2 was recorded in station I (773.78 ton ha^{-1}), while the lowest ability was in station VI (52.39 ton ha^{-1}). Mangrove vegetation in station I recorded the highest CO_2 absorption capability owing to its high mangrove density supported by a large number of mangroves that had large stem diameters, while station VI recorded low mangrove density with incidence of mangroves with small stem diameters. In connection with this observation, Huy & Anh (2008) assert that vegetation's stem accounts for 62% of total accumulation of CO_2, branch 26%, bark/shell 10% and leaf 2%. Hence, CO_2 absorption is positively related to total number of mangrove biomass and carbon stock. This is further confirmed by the correlation analysis in this study which reveal maximum positive correlation value (r = 1.00), between carbon stock content with CO_2 absorption (Figure 4).

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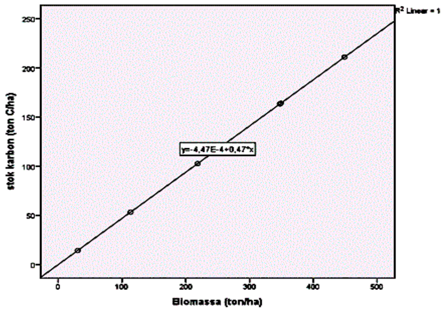

Figure 4. Correlation graph of carbon stock and CO_2 absorption (Source: Data analysis, 2016)

Figure 4 illustrates positive correlation between carbon stock content and CO_2 absorption of a mangrove stand. Thus it could be interpreted that CO_2 absorption will be large if the total stock was large. Vice versa, CO_2 absorption will be small if the carbon stock is small. In addition to the measurement of biomass content, carbon stock, and CO_2 absorption, environmental parameter measurements were also carried out at the study sites.

The average mangrove vegetation biomass in Tapak Sub-village from all of six research stations was 251.32 ton ha^{-1} contributing 118.03 ton C indicating that Kemujan Island, National Park of Karimunjawa with the highest mangrove vegetation biomass of 182.62 ton contributes about 91.31 ton C (Cahyaningrum et al 2014). The high output from the Kemujan Island could be linked to the environment quality of the area which favours its growth. Tapak Sub-village is a coastal area closed to industrial area that allows the existence of pollutants that can contaminate the environment. There are fourteen (14) industries around Tapak River which drain into Tapak Sub-village (Martuti et al 2016). Meanwhile, Xiao (2015) explained that industrial emissions consist of SO_2 (32%), NO_2 (18%), CO (20%), VOC (22%) and PM (8%).

The CO_2 gas in atmosphere from industrial emission would be absorbed by the vegetation by photosynthesis process (Purba & Khairunisa 2012). Mangroves in coastal areas have high ability in reducing CO_2 emission. Hence, Nellemann et al (2009) stated that one of strategy to reduce CO_2 emission was the use of coastal ecosystem as CO_2 absorber which is known as *blue carbon*. Mangroves also play a role in reducing the amount of carbon in the air by absorbing CO_2 through the photosynthesis process, otherwise known as the sequestration process. The absorbed carbon is stored as tree biomass (Ardli 2012). The results of this study showed that the mangrove ecosystem in Tapak Sub-village is effective in absorbing CO_2 in air, judging from the amount of biomass content and carbon stock stored in the vegetation.

Conclusions. In terms of ecosystem type, the highest mangrove biomass content was obtained from station I (449 ton ha^{-1}; mangrove forest), then station II (348.95 ton ha^{-1}; river ecosystem) and station III (115.35 ton ha^{-1}; fish pond ecosystem). Similarly, mangrove forest ecosystem recorded the highest carbon stock, then river ecosystem and the lowest was from fish pond ecosystem.

Acknowledgements. This research was funded by Ministry of Technology Research and Higher Education of Indonesia in 2016.

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Nellemann C., Corcoran E., Duarte C. M., Valdés L., De Young C., Fonseca L., Grimsditch G. (eds), 2009 Blue carbon. A rapid response assessment. United Nations Environment Programme, GRID-Arendal, 80 pp.
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Carbon stock potency of mangrove ecosystem at Tapak Sub-village, Semarang, Indonesia

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Abstract. The mangrove ecosystem is very important in reducing carbon emissions because of its ability to absorb carbon. Nevertheless, contribution of carbon emissions of mangrove forests is also quite large due to the destruction of their ecosystems. Tapak Sub-village of Semarang City has typical variation of coastal ecosystems, consisting of pond ecosystem (artificial), river ecosystem (natural) and coastal ecosystem (natural). Each of these ecosystems has different structure in terms of types of plants and mangrove density. This study aims to assess the amount of biomass and carbon stocks in each type of mangrove ecosystem in coastal area of Tapak Sub-village, Semarang. Biomass measurement was conducted by allometric equations. Estimations of carbon stock was based on biomass calculation with carbon fraction as coversion factor. The results obtained showed the six research locations contributed 1507.91 ton ha^{-1} in mangrove biomass content, 708.20 ton C ha^{-1} carbon stock, and 2598.65 ton ha^{-1} CO_2 absorption capability. The highest biomass value in each plot is from *Avicennia marina* contributing 913.94 ton ha^{-1} biomass content and 429.55 ton C ha^{-1} carbon content.

Key Words: biomass content, carbon stock, mangrove, Tapak Sub-village, carbon emission, coastal ecosystem.

Introduction. Global warming becomes one of the major environmental issues in the world recently. It begins with the emission of greenhouse gases that form a layer in the atmosphere. As a result, the sun heat that enters the earth can not return to the atmosphere because its energy is not able to pass through the layer (Andrew 2011).

Antropogenic activities is the biggest contributor of green house gases. Intergovernmental Panel on Climate Change (IPCC) Report in 2014 recorded that agriculture sector, forestry and land use contributed 24% emission, while transportation and industrial sectors contibuted 14% and 21%, respectively, of global emissions. The biggest contribution to the escalation of green house gases from anthropogenic activity, was from land use sector, particularly, deforestation and land use change, contributing 8-20% (van der Werf et al 2009). Various strategies for reducing emissions were conducted in order to reduce the global warming rate. One of the strategy is the REDD Policy (Reducing Emissions from Deforestation and Forest Degradation), which offers incentives for developing countries to control carbon emissions from forest land.

The REDD Policy was proposed by United Nations Environment Programme (UNEP), World Bank, Global Environment Facility (GEF) and Environmental NGO as a strategy of climate change mitigation which integrates forest management into the scheme of carbon absorption (Beymer-Farris & Bassett 2012). According to Munawar et al (2015), the incentive suggested the amount of carbon which could be used for sustainable livelihood of the community around the forest. However, the lack of data on the amount of forest area and carbon stocks contained limited implementation of the REDD Policy (Alongi 2011).

Land mitigation efforts have been well implemented in terrestrial forest area; while coastal degradation is yet to be given a major priority. However, coastal area with mangrove forest vegetation are known to have high potentials as carbon absorber compared to other types of tropical forest (Donato et al 2011). Pendleton et al (2012) also recommended that coastal ecosystem management policy be given significant attention in reducing carbon emissions though it is currently given less attention.

The mangrove ecosystem is very important in reducing carbon emissions because of its ability to absorb carbon. Eong (1993) estimated that mangrove vegetation could absorb carbon from the atmosphere between 75-150 Tg C ha^{-1} y^{-1}. Nevertheless, contribution of carbon emissions of mangrove forests is also quite large due to the destruction of their ecosystems. Some research results indicate that mangrove forest area is a region with quick rate of land use change and deforestation due to aquaculture activities and development center (Primavera 1997; Donato et al 2011; Bournazel et al 2015). Generally, mangrove waters release more than 2.5 times the amount of CO_2 into the atmosphere (-42.8 Tg C y^{-1}) which emitted from another entire subtropical and tropical coastal water area (Alongi & Mukhopadhyay 2015).

Tapak Sub-village of Semarang City has typical variation of coastal ecosystems, consisting of pond ecosystem (artificial), river ecosystem (natural) and coastal ecosystem (natural). Each of these ecosystems has different structures: types of plants and mangrove density which could influence the amount of carbon content in each type of ecosystem. This is strengthened by evidence obtained in China that mangrove density could affect carbon content of mangrove forest (Liu et al 2013).

Based on desk study, until 2015, there was no record of carbon stock database (carbon squestration) of mangrove ecosystem at coastal area of Semarang. This study aims to assess the amount of biomass and carbon stocks in each type of mangrove ecosystem in coastal area of Tapak Sub-village, Semarang. It is important because the carbon calculation obtained in this study could be used as instrument to protect mangrove area. Besides, database of carbon stock and stored carbon potential generated in this study will support the carbon emission reduction policy through the REDD Policy. In addition, the entire calculation result of each type of ecosystem could become consideration material for Semarang City government in formulating policy of coastal area management in Tapak particularly, and coastal area of Semarang in general.

Material and Method

Description of the study sites. This study was conducted May to October 2016 at mangrove ecosystems of Tapak Sub-village, Semarang, Indonesia (Figure 1), which consist of various lansdcape such as mangrove vegetation, fish pond, sandy beach and estuary. Tapak Sub-village is located at 110º17’15”-110º22’4”E and 6º56’13”-6º59’14”S (Martuti et al 2017). It is one of administration area of Tugurejo Sub-district, Semarang.

Determination of research station location. The research stations were classified based on ecosystem type and density of mangrove species in Tapak area. The mangrove species included *Avicennia marina* (station I, II, III, IV, V and VI), *Rhizhophora mucronata* (station II and IV), and *Rhizophora stylosa* (station IV). Purposive sampling method was adopted emphasizing mangrove species and landscape type represented (Kauffman & Donato 2012); resulting in six (6) research stations marked out as: station I - mangrove ecosystem; stations II and IV - river ecosystems; and stations III, V and VI - fishpond ecosystems.

Preparation of research plots. The research plots were 20 m in diameter representing each type of ecosystem (n = 9). Underground biomass data were also collected by random sampling method with priority given to the areas around the research plots (n = 18) (Kauffman & Donato 2012).

Data collection. Data were collected once in July 2016. The research sites are always inundated by sea water at 20-30 cm high, so the soil samples was taken from 0-20 cm depth, depending on level of standing water in the mangrove forest. The soil samples were then placed in a labelled plastic bag and stored in a cooler for laboratory analysis.

Allometric method of measurement of tree diameter at breast high (DBH) was employed in carbon calculation above the water surface. The tree diameter and height in all plots were measured, from small to large diameter, e.g., DBH class 6.4-35.2 cm (Mitra et al 2011; Kauffman & Donato 2012).

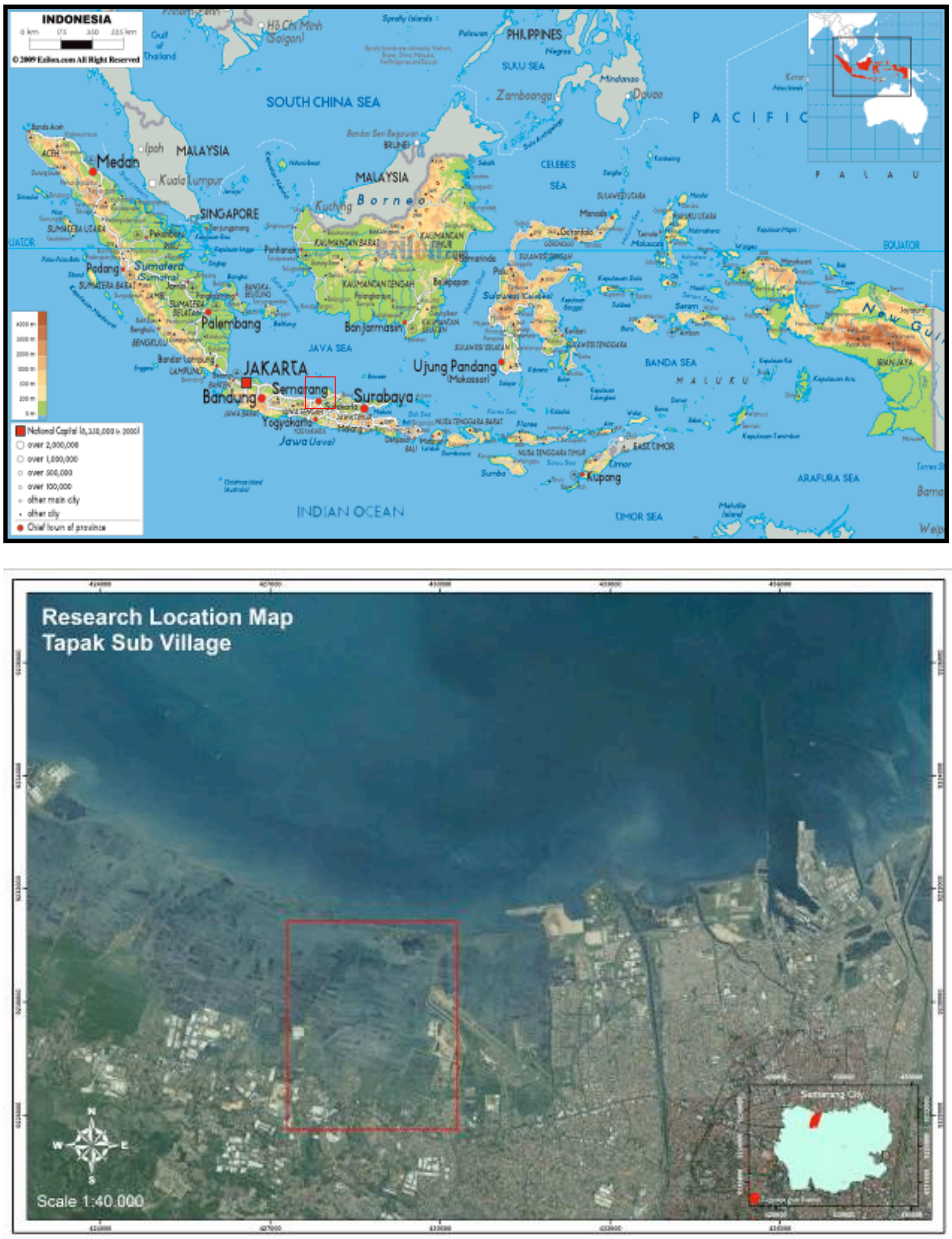

Figure 1. Research location (source: ezilon.com 2009 and google earth maps 2016).

Data analysis. The data collected in this study were analyzed based on data type, including soil carbon content analysis, biomass amount measurement and carbon stock calculation. Biomass measurements were analyzed by two approaches, i.e. allometric equation and destructive method (Prasetyo et al 2011). According to Hairiah et al (2001) destructive method was generally used for underground biomass measurement and stand types which do not yet have allometric values. Some allometry models of some mangrove trees species are showed in Table 1 (Research and Development Agency of Forestry Department 2013).

Table 1

Allometric models used in mangrove tree biomass estimation

Type of tree	*Allometric model*	*DBH*	*R^2*
Avicennia marina	$BBA = 0.1848\ D^{2.3524}$	6.4-35.2	0.98
Bruguiera gymnorrhiza	logBBA = -0.552+2.244 log D	5.0-60.9	0.99
Rhizophora apiculata	logBBA = -1.315+2.641 log D	2.5-67.1	0.96
Xylocarpus granatum	logBBA = -0.763+2.23 log D	5.9-49.4	0.95

Biomassa Bagian Atas (BBA) = Upper Part Biomass; D = Diameter at breast high (DBH) (Source: The Forestry Agency of Research and Development - BALITBANG (2013)).

Carbon stock estimation in stands/trees were calculated by first deriving the biomass value, and then multiplying by carbon fraction (appropriate value for the ecosystem type) to convert to carbon stock value (Smith et al 2006; Schöngart et al 2011). Where the specific carbon fraction value from an ecosystem type does not exist, the default IPCC value of 0.47 was used:

$$\text{Carbon stock} = \text{Carbon fraction} \times \text{biomass}$$

In this research we also calculated CO_2-equivalent using following equation:

$$CO_2\text{-equivalent} = (44/12) \times \text{carbon stock}$$

In addition, the bulk density and organic carbon measurement of the soil was analysed in the Balai Pengkajian Teknologi Pertanian (BPTP) (Center for Assessment and Study of Agricultural Technology) Laboratory of Central Java using Walkley & Black Method (Walkley & Black 1934).

Results and Discussion

Biomass content, carbon stock, CO_2 absorption by mangrove in Tapak Sub-village. The research results indicate total biomass value, carbon stock and CO_2 absorption of mangrove vegetation in Tapak Sub-village, Tugurejo Sub-district, Semarang in Table 2.

The research result showed that biomass content, carbon stock and CO_2 absorption of mangrove vegetation in Tapak Sub-village, in order of descending magnitude were in stations I, II, IV, V, III and VI. The carbon deposits per hectare obtained from each research station covering 314 m^2 yielded mangrove biomass content of 1507.91 ton ha^{-1} carbon stock was 708.2 ton C ha^{-1}, and able to absorb CO_2 of 2598.65 ton ha^{-1}. The highest biomass value (913.94 ton ha^{-1},) per plot came from *Avicennia marina* which is equal to a carbon content of 429.55 ton C ha^{-1}; because this mangrove species was distributed across all six research stations and covered the widest area, among the others.

Table 2 also indicates the biomass potential of the mangrove in Tapak Sub-village at each different station. Station I had the highest biomass potential (449 ton ha^{-1}), while Station VI had the lowest potential (30.4 ton ha^{-1}). This could be attributed to the fact that station I was located near the estuary, had a high density compared to other stations and had older stands. Correlation analysis reveal a strong relationship (r = 0.67) between mangrove density and mangrove biomass content (Figure 2).

Table 2

Biomass content, carbon stock, and CO_2 absorption in Tapak Sub-village

Station	*Mangrove species*	*Number of species*	*The stands biomass (ton ha^{-1})*	*Carbon stock (ton ha^{-1})*	*CO_2 - equivalent (ton ha^{-1})*
I (mangrove ecosystem	AM	113	449	211.03	773.78
II (river ecosystem)	RM	46	289.44	136.04	498.80
	AM	14	59.51	27.97	102.56
	∑	60	348.95	164.01	601.36
III (fishpond ecosystem)	AM	28	113.43	53.31	195.48
IV (river ecosystem)	RM	64	247.48	116.32	426.49
	RS	13	57.05	26.81	98.32
	AM	9	43.02	20.22	74.14
	∑	86	347.55	163.35	598.95
V (fishpond ecosystem)	AM	48	218.58	102.73	376.69
VI (fishpond ecosystem)	AM	51	30.4	14.29	52.39
Total		386	1507.91	708.20	2598.65

AM = *Avicennia marina*; RM = *Rhizhophora mucronata*; RS = *Rhizophora stylosa* (Source: Data analysis 2016).

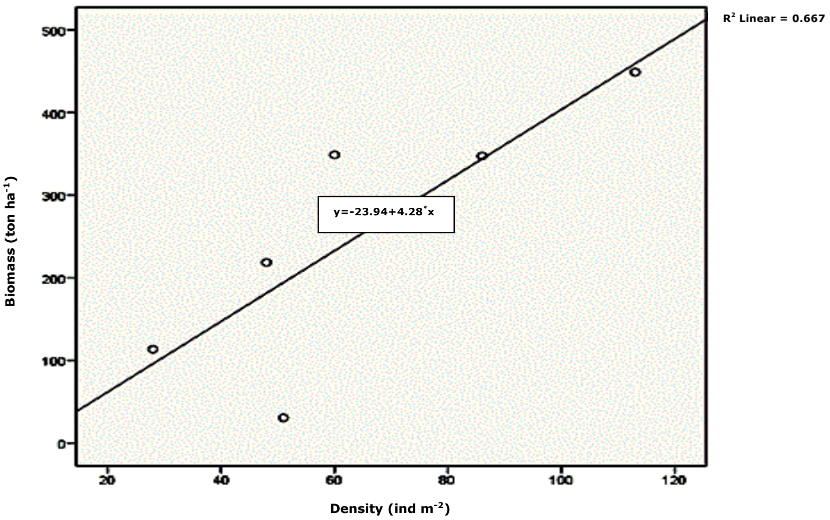

Figure 2. Correlation graph of mangrove density and the biomass content

(Source: Data analysis, 2016).

Figure 2 explained that the mangrove density had positive correlation to the biomass content. In other words, the mangrove density is directly proportional to the biomass content of mangrove; the higher the mangrove density, the higher the biomass content.

Apart from tree density, the biomass value was also influenced by the diameter size of the tree, because the larger the tree diameter, the higher the biomass value (Mandari et al 2016). According to Syam'ani & Susilawati (2012), the biomass increased because the vegetation absorbs CO_2 in the atmosphere and transforms it to organic compound through photosynthesis process; resulting in vertical or horizontal growth, indicated by increased diameter and height. Through the photosynthesis process, CO_2 were absorbed by the vegetation with the help of sunlight. Thereafter, it was transformed into carbohydrate which was then distributed to the whole body of tree and stored in leaf, stem, branch, fruit and flower (Hairiah et al 2001).

Chanan (2012) stated that every addition of biomass content will be followed by the addition of carbon stock. This explains why carbon and biomass have positive relations; so anything which causes an increase or decrease in biomass will lead to an increase or decrease in carbon stock. High value of biomass at station I will be associatory with high carbon stock of mangrove, vice versa, low value of biomass at station VI will be accompanied with low carbon stock of mangrove. This is in line with Imiliyana et al's (2012) assertion that carbon stock percentage increases in line with the increase of biomass. This assertion is upheld in this study revealing positive maximum correlation value (r = 1.00) between biomass and carbon stock (Figure 3).

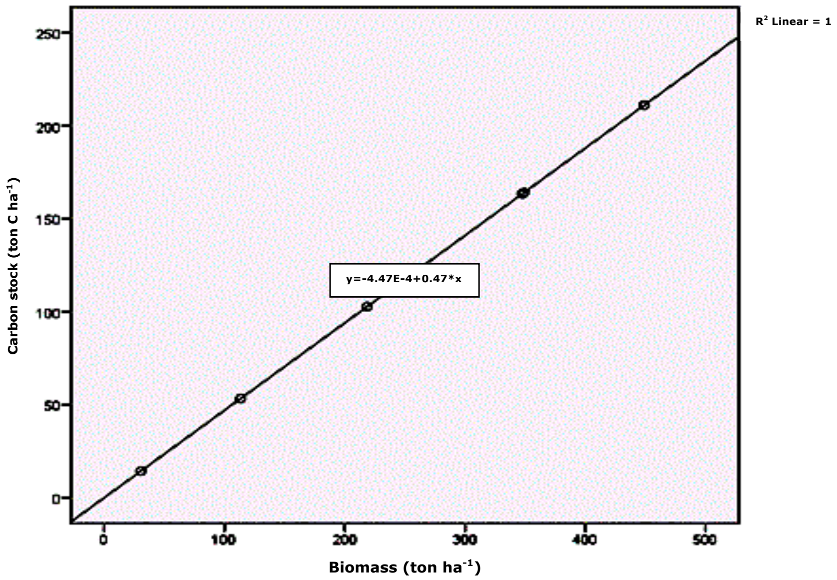

Figure 3. Correlation graph of biomass and carbon stock (Source: Data analysis, 2016).

Figure 3 elucidates the positive correlation between mangrove biomass and carbon stock content. In other words, biomass value is directly proportional to mangrove carbon stock. The higher the biomass value then the higher the carbon stock of mangrove.

Stem is part of wood and consists 50% of cellulose (Delmer & Haigler 2002). Cellulose is the main part of tough wall which covers vegetation cell and consists of linear sugar molecule in a long chain of carbon (Campbell et al 2008), so the higher the cellulose then the higher the carbon content value. It was estimated that the bigger the size of tree diameter the higher the potential that cellulose and other wood compounds will be larger. The high carbon in the stem is closely related to higher stem biomass when compared to other tree parts. This factor causes the larger diameter grade of the tree hence the carbon content will be larger.

Carbon is stored and incorporated into the forest vegetation in a process called sequestration process (C-sequestration). The carbon stock value incorporated in the life vegetation body (biomass) in a land describes the amount of CO_2 in the atmosphere absorbed by plants. CO_2 absorption is related to carbon stock (Heriyanto & Subiandono 2012). Research result of this study (Table 2), illustrates that mangrove ability to absorb CO_2 is directly proportional to carbon stock stored in the vegetation. The highest ability of mangrove to absorb CO_2 was recorded in station I (773.78 ton ha^{-1}), while the lowest ability was in station VI (52.39 ton ha^{-1}). Mangrove vegetation in station I recorded the highest CO_2 absorption capability owing to its high mangrove density supported by a large number of mangroves that had large stem diameters, while station VI recorded low mangrove density with incidence of mangroves with small stem diameters. In connection with this observation, Huy & Anh (2008) assert that vegetation's stem accounts for 62% of total accumulation of CO_2, branch 26%, bark/shell 10% and leaf 2%. Hence, CO_2 absorption is positively related to total number of mangrove biomass and carbon stock. This is further confirmed by the correlation analysis in this study which reveal maximum positive correlation value (r = 1.00), between carbon stock content with CO_2 absorption (Figure 4).

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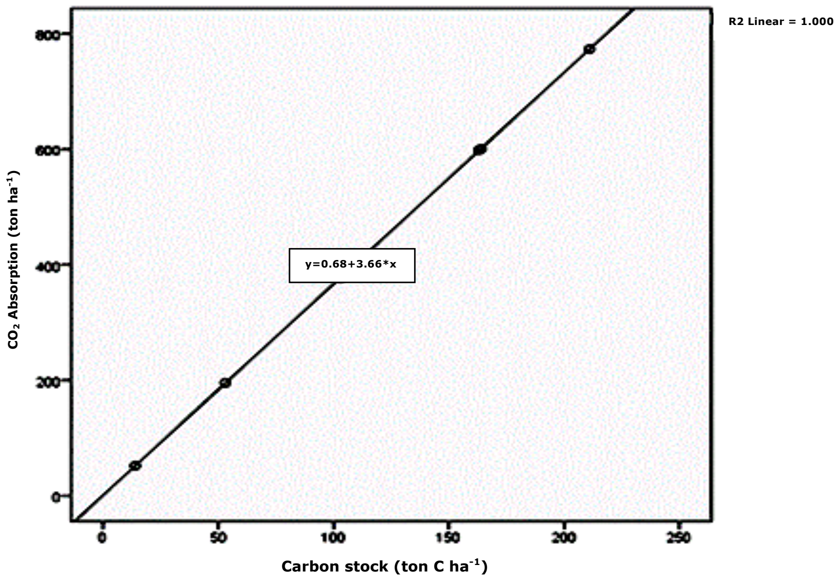

Figure 4. Correlation graph of carbon stock and CO_2 absorption (Source: Data analysis, 2016)

Figure 4 illustrates positive correlation between carbon stock content and CO_2 absorption of a mangrove stand. Thus it could be interpreted that CO_2 absorption will be large if the total stock was large. Vice versa, CO_2 absorption will be small if the carbon stock is small.

The average mangrove vegetation biomass in Tapak Sub-village from all of six research stations was 251.32 ton ha^{-1} contributing 118.03 ton C indicating that Kemujan Island, National Park of Karimunjawa with the highest mangrove vegetation biomass of 182.62 ton contributes about 91.31 ton C (Cahyaningrum et al 2014). The high output from the Kemujan Island could be linked to the environment quality of the area which favours its growth. Tapak Sub-village is a coastal area closed to industrial area that allows the existence of pollutants that can contaminate the environment. There are fourteen (14) industries around Tapak River which drain into Tapak Sub-village (Martuti et al 2016). Meanwhile, Xiao (2015) explained that industrial emissions consist of SO_2 (32%), NO_2 (18%), CO (20%), volatile organic compounds (VOC) (22%) and particulate matter (PM) (8%).

The CO_2 gas in atmosphere from industrial emission would be absorbed by the vegetation by photosynthesis process (Purba & Khairunisa 2012). Mangroves in coastal areas have high ability in reducing CO_2 emission. Hence, Nellemann et al (2009) stated that one of strategy to reduce CO_2 emission was the use of coastal ecosystem as CO_2 absorber which is known as *blue carbon*. Mangroves also play a role in reducing the amount of carbon in the air by absorbing CO_2 through the photosynthesis process, otherwise known as the sequestration process. The absorbed carbon is stored as tree biomass (Ardli 2012). The results of this study showed that the mangrove ecosystem in

Tapak Sub-village is effective in absorbing CO_2 in air, judging from the amount of biomass content and carbon stock stored in the vegetation.

Conclusions. In terms of ecosystem type, the highest mangrove biomass content was obtained from station I (449 ton ha^{-1}; mangrove forest), then station II (348.95 ton ha^{-1}; river ecosystem) and station III (115.35 ton ha^{-1}; fish pond ecosystem). Similarly, mangrove forest ecosystem recorded the highest carbon stock, then river ecosystem and the lowest was from fish pond ecosystem.

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Carbon stock potency of mangrove ecosystem at Tapak Sub-village, Semarang, Indonesia

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Abstract. The mangrove ecosystem is very important in reducing carbon emissions because of its ability to absorb carbon. Nevertheless, contribution of carbon emissions of mangrove forests is also quite large due to the destruction of their ecosystems. Tapak Sub-village of Semarang City has typical variation of coastal ecosystems, consisting of pond ecosystem (artificial), river ecosystem (natural) and coastal ecosystem (natural). Each of these ecosystems has different structure in terms of types of plants and mangrove density. This study aims to assess the amount of biomass and carbon stocks in each type of mangrove ecosystem in coastal area of Tapak Sub-village, Semarang. Biomass measurement was conducted by allometric equations. Estimations of carbon stock was based on biomass calculation with carbon fraction as coversion factor. The results obtained showed the six research locations contributed 1507.91 ton ha^{-1} in mangrove biomass content, 708.20 ton C ha^{-1} carbon stock, and 2598.65 ton ha^{-1} CO_2 absorption capability. The highest biomass value in each plot is from *Avicennia marina* contributing 913.94 ton ha^{-1} biomass content and 429.55 ton C ha^{-1} carbon content.
Key Words: biomass content, carbon stock, mangrove, Tapak Sub-village, carbon emission, coastal ecosystem.

Introduction. Global warming becomes one of the major environmental issues in the world recently. It begins with the emission of greenhouse gases that form a layer in the atmosphere. As a result, the sun heat that enters the earth can not return to the atmosphere because its energy is not able to pass through the layer (Andrew 2011).

Antropogenic activities is the biggest contributor of green house gases. Intergovernmental Panel on Climate Change (IPCC) Report in 2014 recorded that agriculture sector, forestry and land use contributed 24% emission, while transportation and industrial sectors contibuted 14% and 21%, respectively, of global emissions. The biggest contribution to the escalation of green house gases from anthropogenic activity, was from land use sector, particularly, deforestation and land use change, contributing 8-20% (van der Werf et al 2009). Various strategies for reducing emissions were conducted in order to reduce the global warming rate. One of the strategy is the REDD Policy (Reducing Emissions from Deforestation and Forest Degradation), which offers incentives for developing countries to control carbon emissions from forest land.

The REDD Policy was proposed by United Nations Environment Programme (UNEP), World Bank, Global Environment Facility (GEF) and Environmental NGO as a strategy of climate change mitigation which integrates forest management into the scheme of carbon absorption (Beymer-Farris & Bassett 2012). According to Munawar et al (2015), the incentive suggested the amount of carbon which could be used for sustainable livelihood of the community around the forest. However, the lack of data on the amount of forest area and carbon stocks contained limited implementation of the REDD Policy (Alongi 2011).

Land mitigation efforts have been well implemented in terrestrial forest area; while coastal degradation is yet to be given a major priority. However, coastal area with mangrove forest vegetation are known to have high potentials as carbon absorber compared to other types of tropical forest (Donato et al 2011). Pendleton et al (2012) also recommended that coastal ecosystem management policy be given significant attention in reducing carbon emissions though it is currently given less attention.

The mangrove ecosystem is very important in reducing carbon emissions because of its ability to absorb carbon. Eong (1993) estimated that mangrove vegetation could absorb carbon from the atmosphere between 75-150 Tg C ha^{-1} y^{-1}. Nevertheless, contribution of carbon emissions of mangrove forests is also quite large due to the destruction of their ecosystems. Some research results indicate that mangrove forest area is a region with quick rate of land use change and deforestation due to aquaculture activities and development center (Primavera 1997; Donato et al 2011; Bournazel et al 2015). Generally, mangrove waters release more than 2.5 times the amount of CO_2 into the atmosphere (-42.8 Tg C y^{-1}) which emitted from another entire subtropical and tropical coastal water area (Alongi & Mukhopadhyay 2015).

Tapak Sub-village of Semarang City has typical variation of coastal ecosystems, consisting of pond ecosystem (artificial), river ecosystem (natural) and coastal ecosystem (natural). Each of these ecosystems has different structures: types of plants and mangrove density which could influence the amount of carbon content in each type of ecosystem. This is strengthened by evidence obtained in China that mangrove density could affect carbon content of mangrove forest (Liu et al 2013).

Based on desk study, until 2015, there was no record of carbon stock database (carbon squestration) of mangrove ecosystem at coastal area of Semarang. This study aims to assess the amount of biomass and carbon stocks in each type of mangrove ecosystem in coastal area of Tapak Sub-village, Semarang. It is important because the carbon calculation obtained in this study could be used as instrument to protect mangrove area. Besides, database of carbon stock and stored carbon potential generated in this study will support the carbon emission reduction policy through the REDD Policy. In addition, the entire calculation result of each type of ecosystem could become consideration material for Semarang City government in formulating policy of coastal area management in Tapak particularly, and coastal area of Semarang in general.

Material and Method

Description of the study sites. This study was conducted May to October 2016 at mangrove ecosystems of Tapak Sub-village, Semarang, Indonesia (Figure 1), which consist of various lansdcape such as mangrove vegetation, fish pond, sandy beach and estuary. Tapak Sub-village is located at 110º17’15”-110º22’4”E and 6º56’13”-6º59’14”S (Martuti et al 2017). It is one of administration area of Tugurejo Sub-district, Semarang.

Determination of research station location. The research stations were classified based on ecosystem type and density of mangrove species in Tapak area. The mangrove species included *Avicennia marina* (station I, II, III, IV, V and VI), *Rhizhophora mucronata* (station II and IV), and *Rhizophora stylosa* (station IV). Purposive sampling method was adopted emphasizing mangrove species and landscape type represented (Kauffman & Donato 2012); resulting in six (6) research stations marked out as: station I - mangrove ecosystem; stations II and IV - river ecosystems; and stations III, V and VI - fishpond ecosystems.

Preparation of research plots. The research plots were 20 m in diameter representing each type of ecosystem (n = 9). Underground biomass data were also collected by random sampling method with priority given to the areas around the research plots (n = 18) (Kauffman & Donato 2012).

Data collection. Data were collected once in July 2016. The research sites are always inundated by sea water at 20-30 cm high, so the soil samples was taken from 0-20 cm depth, depending on level of standing water in the mangrove forest. The soil samples were then placed in a labelled plastic bag and stored in a cooler for laboratory analysis.

Allometric method of measurement of tree diameter at breast high (DBH) was employed in carbon calculation above the water surface. The tree diameter and height in all plots were measured, from small to large diameter, e.g., DBH class 6.4-35.2 cm (Mitra et al 2011; Kauffman & Donato 2012).

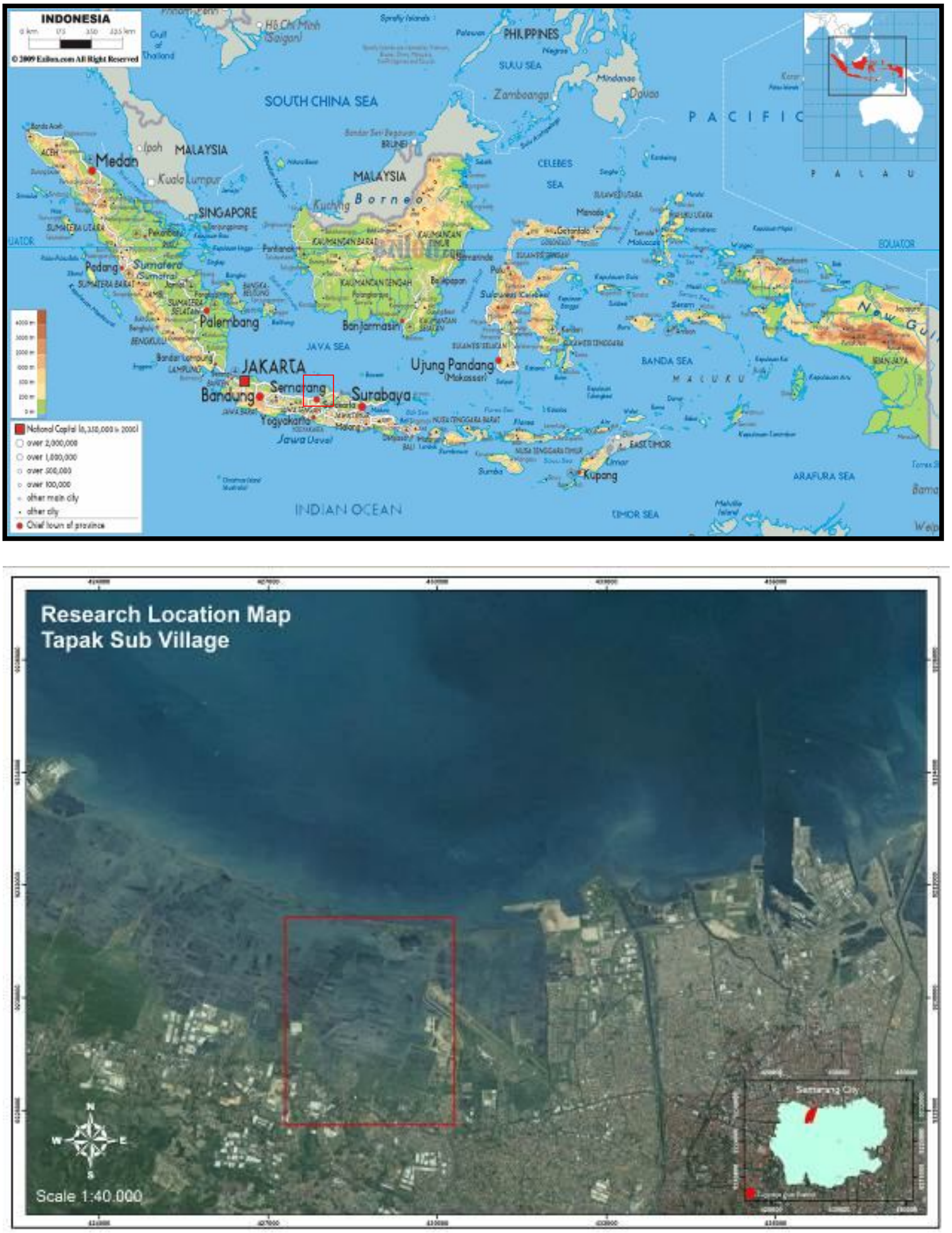

Figure 1. Research location (source: ezilon.com 2009 and google earth maps 2016).

Data analysis. The data collected in this study were analyzed based on data type, including soil carbon content analysis, biomass amount measurement and carbon stock calculation. Biomass measurements were analyzed by two approaches, i.e. allometric equation and destructive method (Prasetyo et al 2011). According to Hairiah et al (2001) destructive method was generally used for underground biomass measurement and stand types which do not yet have allometric values. Some allometry models of some mangrove trees species are showed in Table 1 (Research and Development Agency of Forestry Department 2013).

Table 1

Allometric models used in mangrove tree biomass estimation

Type of tree	*Allometric model*	*DBH*	*R^2*
Avicennia marina	$BBA = 0.1848 D^{2.3524}$	6.4-35.2	0.98
Bruguiera gymnorrhiza	$logBBA = -0.552+2.244 \log D$	5.0-60.9	0.99
Rhizophora apiculata	$logBBA = -1.315+2.641 \log D$	2.5-67.1	0.96
Xylocarpus granatum	$logBBA = -0.763+2.23 \log D$	5.9-49.4	0.95

Biomassa Bagian Atas (BBA) = Upper Part Biomass; D = Diameter at breast high (DBH) (Source: The Forestry Agency of Research and Development - BALITBANG (2013)).

Carbon stock estimation in stands/trees were calculated by first deriving the biomass value, and then multiplying by carbon fraction (appropriate value for the ecosystem type) to convert to carbon stock value (Smith et al 2006; Schöngart et al 2011). Where the specific carbon fraction value from an ecosystem type does not exist, the default IPCC value of 0.47 was used:

$$\text{Carbon stock} = \text{Carbon fraction} \times \text{biomass}$$

In this research we also calculated CO_2-equivalent using following equation:

$$CO_2\text{-equivalent} = (44/12) \times \text{carbon stock}$$

In addition, the bulk density and organic carbon measurement of the soil was analysed in the Balai Pengkajian Teknologi Pertanian (BPTP) (Center for Assessment and Study of Agricultural Technology) Laboratory of Central Java using Walkley & Black Method (Walkley & Black 1934).

Results and Discussion

Biomass content, carbon stock, CO_2 absorption by mangrove in Tapak Sub-village. The research results indicate total biomass value, carbon stock and CO_2 absorption of mangrove vegetation in Tapak Sub-village, Tugurejo Sub-district, Semarang in Table 2.

The research result showed that biomass content, carbon stock and CO_2 absorption of mangrove vegetation in Tapak Sub-village, in order of descending magnitude were in stations I, II, IV, V, III and VI. The carbon deposits per hectare obtained from each research station covering 314 m^2 yielded mangrove biomass content of 1507.91 ton ha^{-1} carbon stock was 708.2 ton C ha^{-1}, and able to absorb CO_2 of 2598.65 ton ha^{-1}. The highest biomass value (913.94 ton ha^{-1},) per plot came from *Avicennia marina* which is equal to a carbon content of 429.55 ton C ha^{-1}; because this mangrove species was distributed across all six research stations and covered the widest area, among the others.

Table 2 also indicates the biomass potential of the mangrove in Tapak Sub-village at each different station. Station I had the highest biomass potential (449 ton ha^{-1}), while Station VI had the lowest potential (30.4 ton ha^{-1}). This could be attributed to the fact that station I was located near the estuary, had a high density compared to other stations and had older stands. Correlation analysis reveal a strong relationship (r = 0.67) between mangrove density and mangrove biomass content (Figure 2).

Table 2

Biomass content, carbon stock, and CO_2 absorption in Tapak Sub-village

Station	Mangrove species	Number of species	The stands biomass (ton ha^{-1})	Carbon stock (ton ha^{-1})	CO_2 - equivalent (ton ha^{-1})
I (mangrove ecosystem	AM	113	449	211.03	773.78
II (river ecosystem)	RM	46	289.44	136.04	498.80
	AM	14	59.51	27.97	102.56
	Σ	60	348.95	164.01	601.36
III (fishpond ecosystem)	AM	28	113.43	53.31	195.48
IV (river ecosystem)	RM	64	247.48	116.32	426.49
	RS	13	57.05	26.81	98.32
	AM	9	43.02	20.22	74.14
	Σ	86	347.55	163.35	598.95
V (fishpond ecosystem)	AM	48	218.58	102.73	376.69
VI (fishpond ecosystem)	AM	51	30.4	14.29	52.39
Total		386	1507.91	708.20	2598.65

AM = *Avicennia marina*; RM = *Rhizhophora mucronata*; RS = *Rhizophora stylosa* (Source: Data analysis 2016).

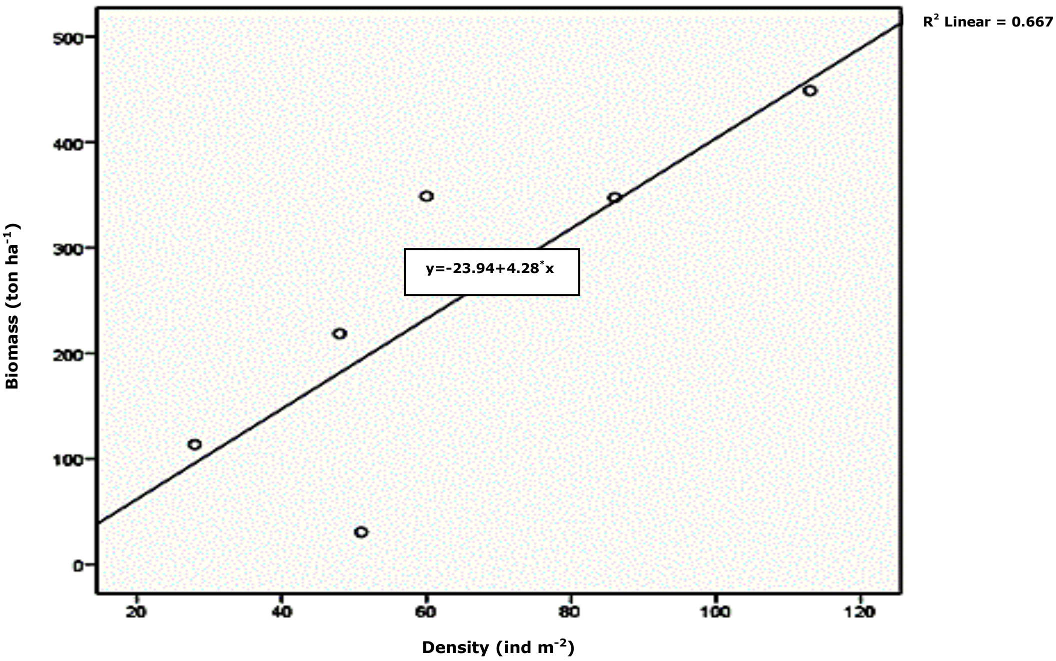

Figure 2. Correlation graph of mangrove density and the biomass content (Source: Data analysis, 2016).

Figure 2 explained that the mangrove density had positive correlation to the biomass content. In other words, the mangrove density is directly proportional to the biomass content of mangrove; the higher the mangrove density, the higher the biomass content.

Apart from tree density, the biomass value was also influenced by the diameter size of the tree, because the larger the tree diameter, the higher the biomass value (Mandari et al 2016). According to Syam'ani & Susilawati (2012), the biomass increased because the vegetation absorbs CO_2 in the atmosphere and transforms it to organic compound through photosynthesis process; resulting in vertical or horizontal growth, indicated by increased diameter and height. Through the photosynthesis process, CO_2 were absorbed by the vegetation with the help of sunlight. Thereafter, it was transformed into carbohydrate which was then distributed to the whole body of tree and stored in leaf, stem, branch, fruit and flower (Hairiah et al 2001).

Chanan (2012) stated that every addition of biomass content will be followed by the addition of carbon stock. This explains why carbon and biomass have positive relations; so anything which causes an increase or decrease in biomass will lead to an increase or decrease in carbon stock. High value of biomass at station I will be associatory with high carbon stock of mangrove, vice versa, low value of biomass at station VI will be accompanied with low carbon stock of mangrove. This is in line with Imiliyana et al's (2012) assertion that carbon stock percentage increases in line with the increase of biomass. This assertion is upheld in this study revealing positive maximum correlation value (r = 1.00) between biomass and carbon stock (Figure 3).

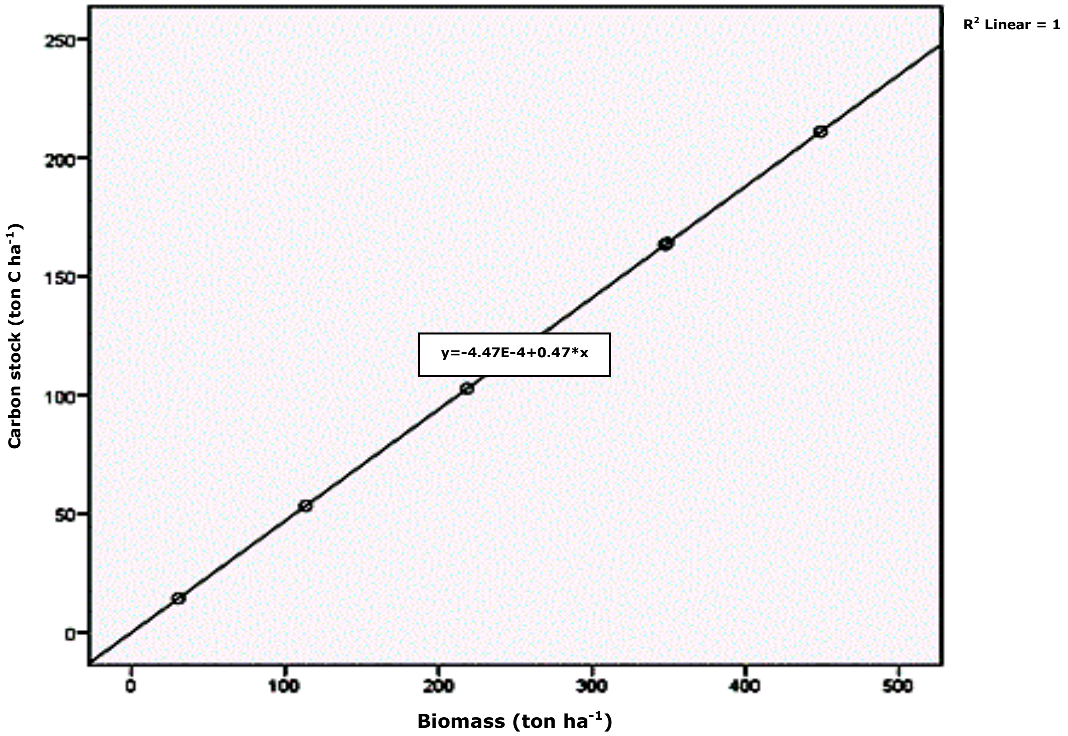

Figure 3. Correlation graph of biomass and carbon stock (Source: Data analysis, 2016).

Figure 3 elucidates the positive correlation between mangrove biomass and carbon stock content. In other words, biomass value is directly proportional to mangrove carbon stock. The higher the biomass value then the higher the carbon stock of mangrove.

Stem is part of wood and consists 50% of cellulose (Delmer & Haigler 2002). Cellulose is the main part of tough wall which covers vegetation cell and consists of linear sugar molecule in a long chain of carbon (Campbell et al 2008), so the higher the cellulose then the higher the carbon content value. It was estimated that the bigger the size of tree diameter the higher the potential that cellulose and other wood compounds will be larger. The high carbon in the stem is closely related to higher stem biomass when compared to other tree parts. This factor causes the larger diameter grade of the tree hence the carbon content will be larger.

Carbon is stored and incorporated into the forest vegetation in a process called sequestration process (C-sequestration). The carbon stock value incorporated in the life vegetation body (biomass) in a land describes the amount of CO_2 in the atmosphere absorbed by plants. CO_2 absorption is related to carbon stock (Heriyanto & Subiandono 2012). Research result of this study (Table 2), illustrates that mangrove ability to absorb CO_2 is directly proportional to carbon stock stored in the vegetation. The highest ability of mangrove to absorb CO_2 was recorded in station I (773.78 ton ha^{-1}), while the lowest ability was in station VI (52.39 ton ha^{-1}). Mangrove vegetation in station I recorded the highest CO_2 absorption capability owing to its high mangrove density supported by a large number of mangroves that had large stem diameters, while station VI recorded low mangrove density with incidence of mangroves with small stem diameters. In connection with this observation, Huy & Anh (2008) assert that vegetation's stem accounts for 62% of total accumulation of CO_2, branch 26%, bark/shell 10% and leaf 2%. Hence, CO_2 absorption is positively related to total number of mangrove biomass and carbon stock. This is further confirmed by the correlation analysis in this study which reveal maximum positive correlation value (r = 1.00), between carbon stock content with CO_2 absorption (Figure 4).

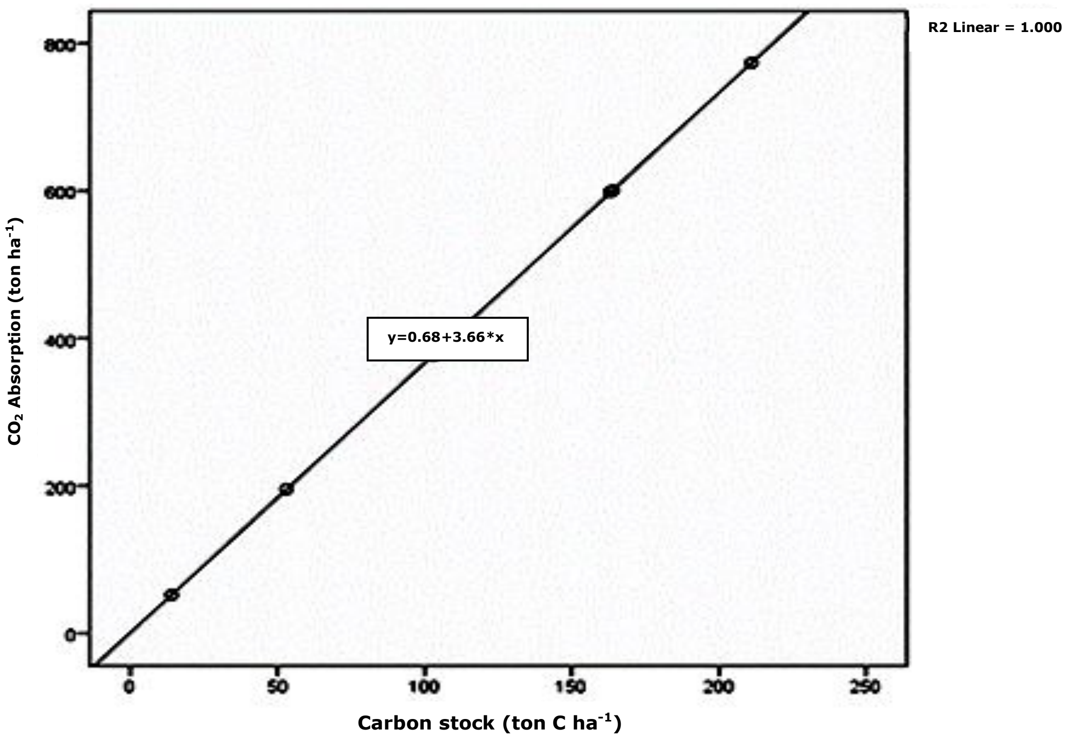

Figure 4. Correlation graph of carbon stock and CO_2 absorption (Source: Data analysis, 2016)

Figure 4 illustrates positive correlation between carbon stock content and CO_2 absorption of a mangrove stand. Thus it could be interpreted that CO_2 absorption will be large if the total stock was large. Vice versa, CO_2 absorption will be small if the carbon stock is small.

The average mangrove vegetation biomass in Tapak Sub-village from all of six research stations was 251.32 ton ha^{-1} contributing 118.03 ton C indicating that Kemujan Island, National Park of Karimunjawa with the highest mangrove vegetation biomass of 182.62 ton contributes about 91.31 ton C (Cahyaningrum et al 2014). The high output from the Kemujan Island could be linked to the environment quality of the area which favours its growth. Tapak Sub-village is a coastal area closed to industrial area that allows the existence of pollutants that can contaminate the environment. There are fourteen (14) industries around Tapak River which drain into Tapak Sub-village (Martuti et al 2016). Meanwhile, Xiao (2015) explained that industrial emissions consist of SO_2 (32%), NO_2 (18%), CO (20%), volatile organic compounds (VOC) (22%) and particulate matter (PM) (8%).

The CO_2 gas in atmosphere from industrial emission would be absorbed by the vegetation by photosynthesis process (Purba & Khairunisa 2012). Mangroves in coastal areas have high ability in reducing CO_2 emission. Hence, Nellemann et al (2009) stated that one of strategy to reduce CO_2 emission was the use of coastal ecosystem as CO_2 absorber which is known as *blue carbon*. Mangroves also play a role in reducing the amount of carbon in the air by absorbing CO_2 through the photosynthesis process, otherwise known as the sequestration process. The absorbed carbon is stored as tree biomass (Ardli 2012). The results of this study showed that the mangrove ecosystem in

Tapak Sub-village is effective in absorbing CO_2 in air, judging from the amount of biomass content and carbon stock stored in the vegetation.

Conclusions. In terms of ecosystem type, the highest mangrove biomass content was obtained from station I (449 ton ha^{-1}; mangrove forest), then station II (348.95 ton ha^{-1}; river ecosystem) and station III (115.35 ton ha^{-1}; fish pond ecosystem). Similarly, mangrove forest ecosystem recorded the highest carbon stock, then river ecosystem and the lowest was from fish pond ecosystem.

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