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Research Article

Tree carbon stock analysis in education forest KHDTK Wanadipa UNDIP, Semarang

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Abstract. Global warming occurs due to increased gases from human activity. Efforts that can be made to minimize global warming are through the forestry sector. Trees play an ecological role, namely as carbon sinks and biomass storage throughout the plant body. The purpose of this study was to analyze the estimated value of carbon stocks in tree biomass in the Special Purposes Forest Area (SPFA) Wanadipa UNDIP Semarang Regency. The sampling method used for measuring tree biomass is the non-destructive method. The non-destructive method is a method that is carried out without destroying or taking all parts of the plant. Data analysis used was the calculation of tree biomass and carbon stocks, and statistical tests of the effect of tree diameter and tree height on carbon stocks in tree biomass. The research station that has the highest carbon stock value is the conservation block of 213,621.25 kg/ha or 213.62 tons/ha. The species that have the highest carbon stock value are *Tectona grandis* (Jati) and *Swietenia mahagoni* (Mahoni) in the research block. The amount of carbon that is increasing in the atmosphere at this time must be balanced with the amount of absorption, one of which is by conserving forests, namely through regular tree planting and paying attention to their regeneration, so that trees in carrying out their ecological role can be maintained.

Keywords: Tree, Biomass, Carbon Stocks, Global Warming, Special Purposes Forest Area (SPFA) Wanadipa UNDIP

1. Introduction

Global warming occurs due to increased exhaust gases from several human activities. According to Ainurrohman (2022), these gases are in the form of carbon dioxide (CO2), water vapor (H2O), Chloro Fluoro Carbon (CFC), nitrous oxide (N2O), methane (CH4), ozone (O3) and others that called greenhouse gases. It caused the temperature conditions in the atmosphere to increase drastically. Ananda et al (2021) argues that this can affect the amount and pattern of rainfall, rising sea water and other ecological events that can harm organisms on earth.

Big cities in Indonesia contribute to greenhouse gas emissions. The amount of greenhouse gas emissions is inventoried from 4 main sectors, namely the Agriculture, Forestry and Other Land Use (AFOLU) sectors; Energy Sector; Waste Sector; and the Industrial Process and Product Usage (IPPU) sector. One of the city in Indonesia is Semarang also contributes to greenhouse gas emissions. According to DLH Semarang City (2019), the amount of emissions in Semarang City in 2018 was 4,127,286.89 tons of CO2e. The highest greenhouse gas producers were the energy sector (82.07%), the waste sector (16.64%), AFOLU (1.28%), and the IPPU sector with the lowest contribution (0.01%).

Efforts that can be made to reduce global warming are through the forestry sector. According to Hairiah et al (2011), things that can be done to control global warming events are to maintain the amount of natural forest and increase the density of trees in the forest. Ananda et al (2021) also added that there are ways to reduce carbon emissions, namely by maintaining carbon stocks in trees and increasing carbon absorption through forest conservation programs.

Forest is a land ecosystem dominated by trees that have an ecological and economic role. According to Draupadi et al. (2021), forests play an important ecological role, namely in the process of absorbing carbon dioxide (CO2) and storing it in the form of biomass. This is done by the tree during the process of photosynthesis that occurs in the leaves, where CO2 is absorbed and converted in the form of organic carbon which is stored in all parts of the tree in the form of biomass. Rifandi (2021) explained that the results of CO2 absorption are stored in leaves, roots, and organic matter found in the soil. Lukito et al (2013) argues that the greater the leaf surface area of a tree, the greater the CO2 content absorbed by the tree.

Trees have the ability to absorb and store carbon. According to Putri et al (2015), this ability can be known from the presence of biomass in trees. Biomass is the total amount of organic material contained in organisms. The parameters used to determine the value of tree biomass are stem diameter, stem height, and tree specific gravity. Komul et al (2016) stated that trees have a higher biomass value than other habitus, because they have a trunk diameter of more than 20 cm. Sribianti et al (2022) proved in their research that the tree stage has the largest average amount of biomass of 103.68 tonnes per ha, because the tree stage has the largest diameter compared to the other levels. In addition, Rahim et al (2018) also explained that the tree trunk has the greatest biomass compared to the root part of the tree. This is because the stem is a storage place for food reserves obtained from the process of photosynthesis. Ristiara et al (2017) also added that carbon stocks absorbed at the tree level were higher, namely 85.68 tons/ha compared to other levels. This is also caused by the age of the tree, the older the tree, the larger the diameter and height of the tree.

The amount of carbon stock stored in trees needs to be measured. This is because it can be used as a way to find out the amount of carbon stock if there is an activity that can increase or decrease the amount of carbon stock. In addition, it can be used as a basis for buying and selling carbon stocks (Komul et al., 2016). According to Biadgligne (2022), the increasing interest in carbon trading today can provide opportunities for better forest management. This can be used as a solution for mitigating climate change and providing livelihoods for forest-based communities. Yonatan (2021) also stated that research related to estimating the amount of carbon stored in trees is currently an area that is still an area for science to show its role and function for the environment. Therefore, it is necessary to carry out periodic research related to the estimation of carbon stocks in trees, in order to know the ecological role of trees for the surrounding environment.

Special Purposes Forest Area (SPFA) Wanadipa UNDIP is one of the forests which is located in part of the Penggaron Forest Area which is located in East Ungaran District, Semarang Regency with an area of 99.65 ha. The Penggaron Forest Area is part of the Semarang Forest Management Unit with a function as a Limited Production Forest covering an area of 500 ha. The Special Purposes Forest Area (SPFA) UNDIP Wanadipa is divided into 5 blocks, namely the Research-Education Block, the Research-Partnership Block, the Rehabilitation-Agroforestry Block, the Utilization and Eco-edutourism Block, and the Conservation-Special Block. The distribution of these blocks is based on considerations of the biophysical conditions and Special Purposes Forest Area (SPFA) activities to be developed. Each block has different characteristics based on the aspects of area, shape and landscape, land cover, and social, cultural, and economic aspects.

Based on the high amount of CO2 gas emissions in Semarang City and the gas will move with the direction of the wind, one of which is to the south of Semarang City, this will be a potential for trees in the Special Purposes Forest Area (SPFA) Wanadipa UNDIP to help the environment in the process of carbon sequestration and storage in the form of biomass.

2. Method

2.1. Materials

The materials used in this study were all of tree growth stages (tree, pole, sapling, and seedling) found in the Special Purposes Forest Area (SPFA) Wanadipa, UNDIP, Semarang Regency.

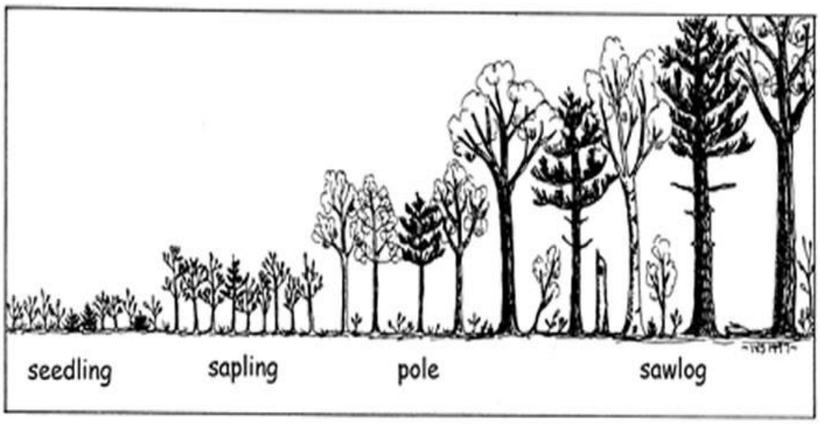


Figure. 1. Tree Growth Stages

2.2. Methods

The research was conducted in the Special Purpose Forest Area (SPFA) Wanadipa UNDIP, Semarang Regency in January 2023 - June 2023.

2.1.1. Pre-survey

The pre-survey activity aims to determine the location in the Special Purposes Forest Area (SPFA) Wanadipa UNDIP, Semarang Regency, the conditions of the sampling site, and determine the sampling stations. The pre-survey was conducted from October to November 2022.

2.2.2. Determination of Research Stations

Determination of the research station was carried out using the purposive sampling method, namely the method carried out by selecting samples based on certain considerations and the intended research objectives. Based on the pre-survey in the Special Purposes Forest Area (SPFA) Wanadipa UNDIP, determined 3 observation station locations that could represent the Special Purposes Forest Area (SPFA) Wanadipa UNDIP, namely the Conservation Block, the Partnership Block, and the Research Block. The three research station locations were determined based on visual observations by looking at the components in each research station

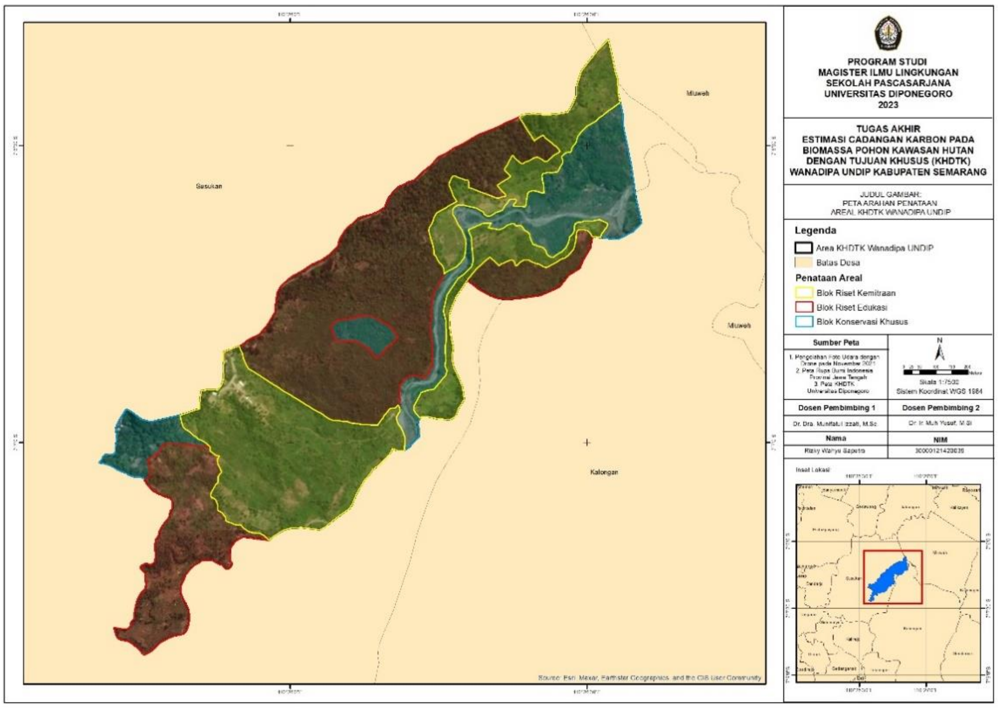


Figure 2. Research Map of SPECIAL PURPOSES FOREST AREA (SPFA) Wanadipa UNDIP

2.2.3. Determination of Sampling Method

The sampling method used for measuring tree biomass is the non-destructive method. The non-destructive method is a method that is carried out without destroying or taking all parts of the plant. Observation of carbon stock estimation was carried out on trees with a diameter of 5 cm – 30 cm, because they can accommodate a high amount of carbon stock in forests compared to trees with a diameter of < 5 cm (Chave et al., 2014).

The plot size at each station is 20 m x 20 m, then it is repeated 5 times at each station. The parameters that need to be recorded are tree diameter, tree height, and tree specific gravity for each individual.

a. Tree diameter is measured based on DBH (Diameter Breast Height) provisions, which are measured at chest height or 1.3 m from the ground.
b. Tree height was measured using a clinometer.
c. Tree density was obtained from the Global Wood Density Database (Zanne et al., 2009).

2.3. Data Analysis

Data analysis used was the calculation of tree biomass and carbon stocks, and statistical tests of the effect of tree diameter and tree height on carbon stocks in tree biomass. Parameters that need to be known before calculating tree biomass and carbon stocks are tree diameter, tree height, and tree specific gravity. This is because these parameters are used in calculating tree biomass and carbon stocks

1. Tree Diameter
   Tree Diameter is calculated using the following formula :

   $$D = \frac{C}{\Pi}$$

   Note :
   D : Tree diameter (cm)
   C : Tree circumstance (cm)
   ∏ : 3.14

2. Tree Height
   Calculation of tree height is calculated using the help of a clinometer tool. The working principle of the clinometer is to measure the angle of inclination formed between a flat line and a line connecting a point on the flat line to the top of the tree.

3. Tree Density
   Tree density was obtained from the Global Wood Density Database (Zanne et al., 2009).

4. Tree Biomass
   Tree biomass is calculated using the following allometric equation (Chave et al., 2014) :

   $$AGB = 0{,}0673.\ (D^2.\ H.\ \rho)^{2{,}62}$$

   Note :
   AGB : Above ground biomass (kg)
   D : Tree diameter (cm)
   H : Tree Height (m)
   ϱ : Tree Density (g/cm^3)

5. Carbon Stock in Tree Biomass
   Carbon stock is calculated using the following equation (Chave et al., 2014) :

   $$AGC = AGB \times \%\ C$$

   Note :
   AGC : Above ground carbon (ton/ha).
   AGB : Above ground biomass (ton/ha).
   % C : Coefficient factor of 0,5

6. The Effect of Tree Diameter and Tree Height on Carbon Stock in Tree Biomass
   The analysis used to examine the effect of tree diameter and tree height on carbon stocks in tree biomass is using a regression test. This analysis was performed using SPSS software.

3. Result and Discussion

The results of research on carbon stocks in tree biomass discuss the value of carbon stocks, the relationship between tree diameter and tree height to the value of carbon stocks.

3.1. Carbon stock in tree biomass

The results of calculating the overall carbon stock in the Special Purposes Forest Area (SPFA) Wanadipa UNDIP Semarang Regency is 395,573.75 kg/ha or 395.57 tons/ha. The value of carbon stocks in the area is classified as high. The classification of the value of carbon stocks is based on Bappenas of the Ministry of Forestry (2010) which groups them into three categories, namely low category if the value of carbon stocks is <35 tons/ha, medium category if the value of carbon stocks is 35 – 100 tons/ha, and high category if the value of carbon stocks is > 100 tonnes/ha. Complete data regarding the value of carbon stocks for each species and for all stations can be found in Table 1.

Based on the calculation of the carbon stock value at each research station, the conservation block is the station that has the highest carbon stock value compared to other stations, namely 213,621.25 kg/ha or 213.62 tons/ha (Table 4.10.). This is because this station has the highest number of individuals, especially the large number of individual trees at the tree level (Table 4.2), thereby contributing to a high carbon stock value. The partnership block is the station that has the lowest carbon stock, which is 19,478.25 kg/ha or 19.48 kg/ha. This is because this station has a small number of individuals, especially the small number of individual trees at the tree level (Table 4.2.).

Table 1. Tree Carbon Stock

No	Species Name	Local Name	AGC (kg/ha) 1st station (Conservation block)	2nd station (Partnership block)	3rd station (Research block)
1	*Anacardium occidentale*	Jambu monyet	62.75	723.00	-
2	*Annona muricata*	Sirsak	-	878.00	-
3	*Annona reticulata*	Mulwo	-	482.75	-
4	*Artocarpus communis*	Kluwih	4,807.00	740.00	-
5	*Artocarpus heterophyllus*	Nangka	-	13.75	-
6	*Caesalpinia pulcherrima*	Kembang merak	-	-	38.50
7	*Cananga odorata*	Kenanga	215.75	-	-
8	*Ceiba pentandra*	Randu	8,946.75	730.75	-
9	*Dalbergia latifolia*	Sonokeling	361.00	4,559.50	31.652.75
10	*Dimorcarpus longan*	Kelengkeng	5.00	-	-
11	*Ficus hispida*	Luwingan	-	-	5.50
12	*Ficus septica*	Awar-awar	98.00	3.25	9.00
13	*Gliricidia sepium*	Gamal	4.00	4.00	-
14	*Hibiscus tiliaceus*	Waru	3,107.00	69.25	-
15	*Leucaena leucocephala*	Lamtoro	56,227.75	1,816.50	5,549.25
16	*Litsea sp.*	Medang	-	-	6.00
17	*Mangifera indica*	Mangga	3,373.25	19.75	-
18	*Melia azedarach*	Mindi	-	1,165.75	-
19	*Parkia speciosa*	Pete	1,969.00	-	-
20	*Psidium guajava*	Jambu biji	-	159.75	-
21	*Senna siamea*	Johar	-	1,658.25	14,178.25
22	*Swietenia mahagoni*	Mahoni	5,978.25	241.75	106,875.00
		Total AGC (kg/ha)	213,621.25	19,478.25	162,277.50
		Total AGC (ton/ha)	213.62	19.48	163.28
		Total AGC of all station (kg/ha)	395,573.75		
		Total AGC of all station (ton/ha)	395.57		

Tectona grandis (Jati) is a species that has the highest carbon stock in the conservation block and partnership block compared to other types, respectively, namely 128.47 tons/ha and 6.41 tons/ha. This is because the number of individual teak is more and the diameter of the tree is wider than other types in the conservation block and partnership block. This is in accordance with Mustikaningrum's research (2023) that teak has the highest biomass and carbon stock values compared to other types. Fast growth and the ability of teak trees to absorb carbon dioxide (CO2) make this tree the one with the most carbon stored among other tree species.

Swietenia mahagoni (Mahoni) is a species that has the highest carbon stock in the research block compared to other types, namely 106.88 tonnes/ha. This difference is due to the higher number of mahogany individuals and the wider tree diameter compared to other species in the research block.

(a) (b)

Figure 3 . *Tectona grandis* (Jati) and *Swietenia mahagoni* (Mahoni)

The high or low value of carbon stocks at each research station is caused by the diversity of species and the number of individual trees found in each research plot, which varies greatly, so that the carbon stock stored in each tree varies greatly according to the diversity of species and the number of individual trees in each research plot. Another thing that affects the value of carbon stocks is the value of tree biomass. According to Irundu et al (2020) and Indrajaya (2017), tree biomass can be determined by tree diameter, tree species diversity, number of individual trees, and tree density.

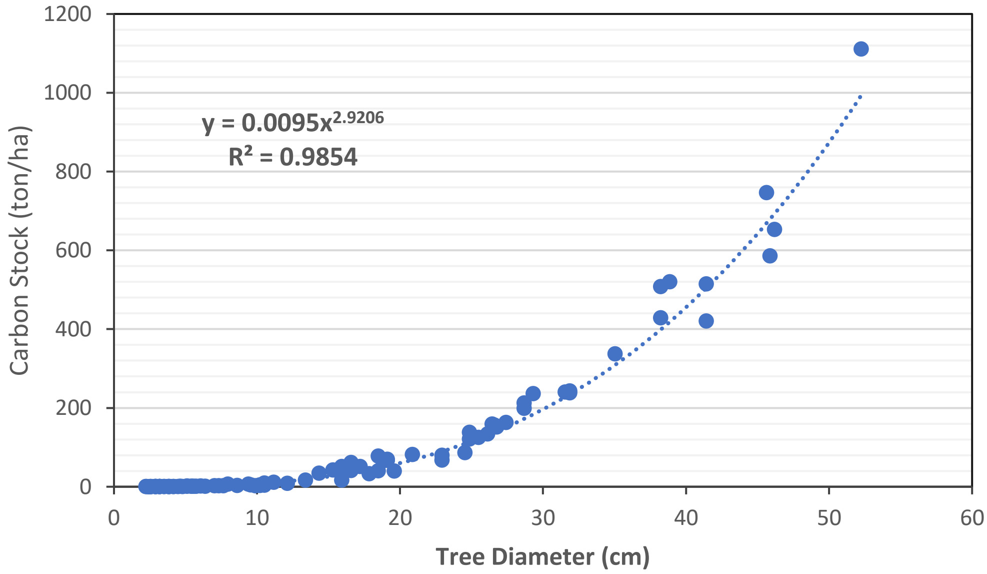
Differences in the value of carbon stocks in an area are affected by the condition of the trees that grow. Increasing the diameter of a tree trunk will determine the amount of carbon absorbed in a tree. This condition causes an increase in the ability of trees to store carbon from nature (Mustikaningrum, 2023). According to Komul et al (2016) and Sribianti et al (2022), trees have a large trunk diameter. This is because the results of the photosynthesis process are stored in the stem, causing the stem diameter to increase. The amount of tree carbon stock is also affected by the age of the plant. According to Hairiah et al (2011), older trees have a greater biomass content, because stem volume, stem diameter, tree height, and wood density have increased.

Based on the carbon stock value of each type, the recommendation that can be given to the manager of the Special Purposes Forest Area (SPFA) Wanadipa UNDIP in order to optimize the role of tree species as a carbon sink and have a high carbon stock value is that it is necessary to plant tree species that have the potential to absorb carbon. and has a periodic high carbon stock value. The recommended tree species are *Tectona grandis* (Jati) and *Swietenia mahagoni* (Mahoni). This is because teak trees and mahogany trees apart from having high economic value as timber-producing trees, are both tree species that have the highest carbon stock value compared to other types. In addition, it is also supported that both of them have the highest IVI at the tree level (Table 4.6.). This means that Jati and Mahoni in the Special Purposes Forest Area (SPFA) Wanadipa UNDIP have a high ecological role, one of which is as a carbon sink in nature.

3.2. Relationship of Tree Diameter and Carbon Stock in Tree Biomass

Based on the curve of the relationship between tree diameter and carbon stock values in tree biomass (Figure 4.), the relationship between tree diameter and carbon stock value shows that almost all points are on a non-linear exponential regression line. It means that the relationship between the two variables is not linear, but follows an exponential pattern.

The coefficient of determination (R2) value of 0.9811 means that the value of the variable The R2 value is classified as a strong relationship. According to Sugiyono (2012), the coefficient of determination value which is 0.6 – 0.799 means that there is a strong relationship with the dependent variable (carbon reserves) and the independent variable (tree diameter). It means that there is a strong relationship between tree diameter and carbon stock values.



Note : X (Tree Diameter), Y (Carbon Stock), dan R^2 (Determination Coefficient)

Figure 4 . Relationship of Tree Diameter and Carbon Stock in Tree Biomass

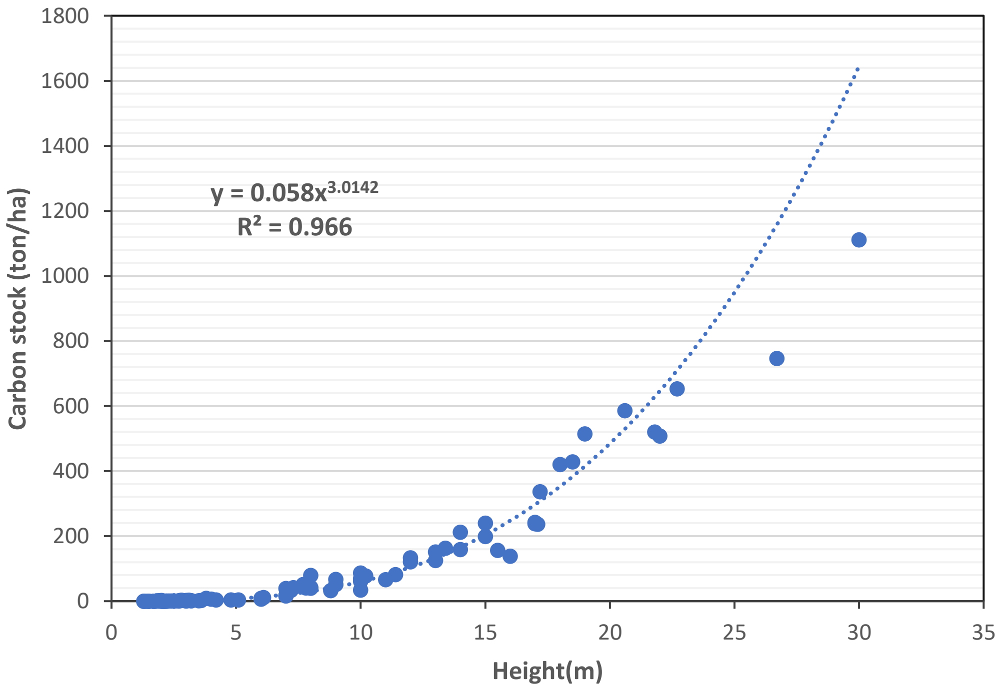
The results of the regression analysis show that tree diameter has a relationship pattern with the equation model $y = 0.0095x^{2.9206}$. This equation can function to obtain parameter coefficient estimates. The parameter 0.0095 is stated as a scale parameter that determines the level of increase in the value of tree carbon stocks in relation to tree diameter. This value indicates how much change in carbon stocks is expected when the tree diameter (x) increases. Parameter 2.9206 is stated as an exponential parameter which determines the exponential growth form of the relationship between tree diameter and tree carbon stock value. This value determines how quickly carbon stocks increase exponentially as the tree diameter increases. It can be concluded that the higher the exponential parameter value, the faster carbon stocks increase exponentially along with increasing tree diameter.

3.3. Relationship of Height Diameter and Carbon Stock in Tree Biomass

Based on the curve of the relationship between tree height and carbon stock values in tree biomass (Figure 5.), the relationship between tree height and carbon stock value shows that almost all points are on a non-linear exponential regression line. This means that the relationship between the two variables is not linear, but follows an exponential pattern.

The coefficient of determination (R2) value of 0.9422 means that the value of the variable The R2 value is classified as a strong relationship. This is in accordance with the opinion of Sugiyono (2012) that the coefficient of determination value which is 0.6 - 0.799 means that there is a strong relationship with the dependent variable (carbon reserves) and the independent variable (tree diameter). It means that there is a strong relationship between tree height and carbon stock value.

The regression equation obtained from the relationship between tree height and carbon stock value in tree biomass is $y = 0.058x^{3.0142}$. This equation can function to obtain parameter coefficient estimates. The parameter 0.058 is a scale parameter that determines the level of tree carbon stock value in relation to tree height. This value shows how much change in the value of tree carbon stocks is expected when tree height (x) increases. Parameter 3.0142 is an exponential parameter that determines the exponential growth form of the relationship between tree height and tree carbon stock value. This value determines how quickly the tree's carbon stock value increases exponentially as the tree's height increases. It can be concluded that the higher the exponential parameter value, the faster the tree carbon stock value increases exponentially along with increasing tree height.



Note : X (Tree Height), Y (Carbon Stock), dan R^2 (Determination Coefficient)

Figure 5. Relationship of Tree Height and Carbon Stock in Tree Biomass

Based on the description of the regression results above, it can be identified and measured the further impact of the two variables, namely tree diameter and tree height on the value of tree carbon reserves, as well as how quickly an increase in the value of tree carbon reserves will have an impact on changes in the diameter and height values of a tree. different ones. Therefore, exponential non-linear regression equations can help in better understanding how the relationship between tree characteristics, such as tree diameter and tree height, influences the accumulation of tree carbon stock values in forest ecosystems.

3.4. The Urgency of Carbon Stocks in Mitigation Effort to Minimize Global Warming Effect in Special Purposes Forest Area (SPFA) Wanadipa UNDIP Semarang District

Global warming is a world problem that must be addressed immediately. The existence of global warming will have an impact on changes in ecological events throughout the world. Efforts that can be made to overcome the occurrence of global warming is through the forestry sector. This is because the forestry sector has the potential of the trees in it to absorb carbon from the atmosphere through the process of photosynthesis and store it in the form of biomass throughout the body of the tree. Ripple et al. (2020) also reinforces that the process of absorbing and storing carbon in trees is an important effort that needs to be done so that greenhouse gases in an area can be reduced.

Trees are one of the main biotic components that compose the Special Purposes Forest Area (SPFA) Wanadipa UNDIP. The presence of trees can be used as an effort in the process of absorbing carbon from the atmosphere. According to Ajayi (2016), trees are components that can play a role in the carbon sequestration process and help in climate change and global warming.

The value of carbon stocks stored in each tree in the forest has an important meaning that the forest is a natural ecosystem that can regulate the dynamic cycle of carbon. Carbon found in nature can be absorbed by trees in the form of biomass stored in the stems. The amount of carbon that is increasing at this time must be balanced with the amount of absorption, in order to avoid global warming events. This can be done by conserving the forest, namely through regular tree planting and paying attention to its regeneration, so that the trees in carrying out their ecological role can be maintained. Tree planting can be used as an aspect of forest management. This is because it can preserve biodiversity in forest ecosystems and help in efforts to mitigate global warming.

4. Conclusion

The research station that has the highest carbon stock value is the conservation block of 213,621.25 kg/ha or 213.62 tons/ha. Species that has the highest carbon stock value is *Tectona grandis* (Jati) in the conservation and partnership blocks, and *Swietenia mahagoni* (Mahoni) in the research block. The value of carbon stock in tree biomass are influenced by tree diameter and tree height.

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