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# Carbon Stock of Australian Pine (*Casuarina equisetifolia*) in Cemara Sewu Beach Jetis Cilacap

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**Abstract**
Beach is home to the richest ecosystems in the world and many components of the vegetation that store large amountsof carbon stock. Carbon compounds in the atmosphere are absorbed and metabolized. The metabolic products are stored in tree biomass. CemaraSewu Beach is one of the beach that has a relatively large amount of stored carbon potential. The purpose of this study was to determine the carbon stored in several types of trees at Cemara Sewu Beach. The method used in this study is a survey method with purposive sampling using without destroying. The samplingof Australian pine tree stands is grouped into certain diameter class. The coastal area was made into three research stations and each study was made into 5 replicated plots measuring 20 m x 20 m and placed on a transect line with a distance of 5 meters each. All of the Australian pine were plotted as samples. The main parameters observed were tree density, trunk diameter and the number of individuals for each tree species were calculated. The results of the research on the diameter class of Australian pine greatly affect the presence of biomass and carbonstock. The results obtained that carbon stocks in diameter class 15-20 store 74,914 ton.ha$^{-1}$, diameter class 21-25 as many as 164,599 ton.ha$^{-1}$, diameter class 26-30 as many as 270,372 ton.ha$^{-1}$, diameter class 31-35 store stocks carbon 462,478 ton.ha$^{-1}$ and in the diameter class 36-40 store as much as 462,478 ton.ha$^{-1}$. The larger the class diameter, the greater the carbon stock produced. The diameter class of Australian pine stands has a relationship between biomass and carbon stock, and has an exponential relationship.
**Key Words**: *Australian pine, biomass, carbon stock*

## INTRODUCTION

Cilacap is the largest district in Central Java. Cilacap Regency has an area of 225,360,840 ha and islocated on the southern coast of Central Java, which has the longest coasline in the province which reaches 103 km. Therefore, Cilacap has many tourist attractions. One ofthem is the Cemara Sewu beach. Jetis Beach, currently known as Cemara Sewu Beach, located in Nusawungu, Cilacap, Central Java, is one of the tourist attractions in Jetis Village, Nusawungu District, Cilacap Regency. The origin was given the name Cemara Sewu Beach because it was related to the government's planting of Australian pine seedlings carried out by residents (Sari *et al*., 2018). The world currently the attention of various parties to the issue of global warming caused bydisruption of the energy balance between the earth and the atmosphere, causing climate change and sea level rise. Global warming increases in temperature in the atmosphere, sea and land. Global warming is caused by the increase of greenhouse gases such as carbon dioxide ($CO_2$) and methane ($CH_4$). The gas comes from human activities such as burning fossil fuels, forest conversion, forest fires, and other activities that cause less cover (deforestation and degradation), which causes a decrease in carbon sequestration by trees (Natalia *et al*., 2014). This has impact on natural resources, which initially functioned as carbon stock, turning into carbon emissions. Things that can reduce the impact of global warming are efforts to stabilize the $CO_2$ level in the atmosphere by planting woody plants in degraded land areas (Hardjana, 2019). According to Chen *et al*. (2016) factors that affectthe level of carbon sequestration include: elevation and slope, rainfall, soil characteristics of the species, composition of tree age , and tree growth stage.

Australian pine (*Casuarina equisetifolia*) is a species of the Casuarinaceae family, native to tropical coastal regions of Australia and Southeast Asia (Favaretto *et al*., 2018). Australian pine (*Casuarina equisetifolia*) is fast growing tree, and it has been introduced to more than 60 countries across are America, Asia, Africa, Europe and Oceania (Muslim, 2017). Australian pine it has a characteristic of strong adaptability, improving ecological environment, and plays an important role in preventing wind and sand, and resisting natural disasters (Huang *et al*., 2020). According to Adinugroho *et al*. (2011), the close relationship between tree dimensions (tree height and tree diameter) and biomass lies in tree diameter. Naturally, coastal ecosystems take carbon in the form of CO, $CO_2$ & $CH_4$ from the atmosphere resulting from anthropogenic activities and respiratory activities of living things.

Carbon in the atmosphere can be found in the form of carbon dioxide. The existence of plants as carbonstorage causes the concentration of carbon dioxide in the atmosphere to decrease (Hikmatyar *et al*., 2015). Trees absorbs CO2 in the atmosphere through photosynthesis. The process of storing carbon in growing plants is called *(carbon sequestration)*. Initially, CO2 in the earth's atmosphere was high, the intensity of greenhouse emissions (ERK) was high, resulting in a high temperature of the earth (Putri & Wulandari, 2015). CO2 has increasedby 36%, methane by 17% and nitrous oxide by 151% in the earth's atmosphere. Measurement of the amount of C stored in living plants (biomass) in a land can describe theamount of CO2 in the atmosphere absorbed by plants, while measuring C that is still stored in dead plant parts (necromass) indirectly describes CO2 which is not releasedinto the air through combustion (Kurniawan & Dhany, 2015).

Carbon stock is the carbon content stored on the soil surface (plant biomass) or in the soil (soil organic matter or necromass). This change in the form of carbon then becomes the basis for calculating emissions, where the element carbon which decomposes into the air is usually bound to oxygen ($O_2$) then becomes $CO_2$. If land is planted with plants, then the process of binding element carbon from the air will return and become plant biomass gradually when the plant grows large. The size of the volume of a plant that makes up the land then becomes a measure of the amount of carbon stored as biomass, so that the greenhouse effect affected by the element of $CO_2$ can be reduced. This means that the $CO_2$ content in the air will automatically decrease. However, if the plants die, the greenhouse effect will increase (Kauffman & Donato, 2012). Biomass refers to the amount of material accumulated by plants in a unit area, and its essence is from organic matter and energy accumulated by photosynthesis of green plants through their assimilation organs (Lin *et al.*, 2018)

Tree biomass can be divided into two categories, namely biomass on the soil surface (stems, leaves, twigs, flowers, and fruits) and biomass in the soil (roots). Tree biomass is closely related to $CO_2$ absorption. The largest carbon storage is in the trunk of the tree. Biomass is determined by the height, diameter and density of the tree or wood (Bachmid *et al*., 2018). Biomass is a term for dry weight, wet weight, population, community, and part of the body in an organism. Biomass in plants can increase because plants absorb $CO_2$ from the air and convert it into organic matter through the photosynthetic process (Hamilton & King, 1988).

Vegetation is the entire plant community in a where there are place, both the communal combination of the types of flora that make up the plant and the ground cover it forms. Forest vegetation contains components such as trees, necromass, litter, undergrowth and soil organic matter that can store carbon well. Woody vegetation types that grow fast and absorb carbon are higher than slow plants (Butarbutar, 2009)

Various efforts have been made both nationally and internationally to stabilize the concentration of CO2 in the atmosphere at the global level. One of the efforts to hold the United Nations Framework Convention on Climate Change through the Kyoto Protocol (Schwerz *et al*., 2020). This program, developed countries must be ableto reduce their emission levels by around 5% below 1990 emission levels in the first period, namely 2008-2012. Oneof the agreements is the existence of a Clean Development Mechanism. Developed countries must carry out project activities to reduce emissions or absorb greenhouse gasesin developing countries, for example in the Land Use, Land Use Change and Forestry (LULUCF) sector. From these activities, it is necessary to carry out a method of measuring biomass, either directly or indirectly. There arethree approaches to biomass estimation, measurement, modeling, and remote sensing (Lukito & Rohmatiah, 2015).

To reduce global warming, carbon stock vegetation must be developed. Vegetation development can be done by making the beach a place to grow and develop carbon absorbing vegetation. Some activities are prohibited from being carried out in coastal areas, especially in areas where there are trees or other plants, because they can change the function of the area. Among the prohibited activities are cutting trees carelessly, picking trees without permission and destroying areas in the area (Napitu, 2007). The function of the beach is to research, prevent abrasion and protect the beach activities that can disturb or damage the coastal area (Sampurno, 2001). Coastal vegetation plays an important role as an abrasion barrier, prevents seawater intrusion, traps nutrients and increases the content of organic matter in the soil as well as being a producer in food webs as well as acting as a habitat for various types of fauna (Priosambodo *et al*., 2019)

The coastal area of Cemara Sewu Cilacap has greata potential for stock carbon. The large amount of stored carbon shows that the condition of Cemara Sewu Beach Cilacap which is dominated by Australian pine (*Casuarina equisetifolia*) is still preserved because it has of 1 highdifferent class, high variability of species and absrob relatively large emissions and carbon stock (Sari *et al*., 2018). According toHairiah & Rahayu (2007), this is the amount of biomass on land, especially trees, which is influenced by tree diameter, soil fertility, and tree density, is able to absorb vegetation and store carbon, as indicated by the size of thetree biomass.

Based on the description above, the problem in this study can be formulated how much carbon is stored in theAustralian pine with the carbon content are stored at Cemara Sewu Beach, Cilacap, Central Java. The benefit ofthis research is that it can provide information about the amount of carbon stock stored in Australian pine at Cemara Sewu Beach, Cilacap. The objectives of this research are as follows: Analysis the relationship betweendiameter class and carbon stock in Australian pine and know out which diameter class is the highest carbon stock in Australian pine at Cemara Sewu Beach, Cilacap.

## MATERIAL AND METHODS

The materials used in this study is the Australian pine (*Casuarina equisetifolia*) on the coast of Cilacap. The tools used in this study consisted were of stakes, raffia ropes to make square plots and limit the length of the transects, *Global Positioning System* (GPS) to determine the location, tape measure tree diameters, field books, camera and stationary to record data.

The method used in this research is survey method with purposive sampling using without destroying. Cemara Sewu Beach was made into three research stations and each research station was made intofive square plots measuring 20 m x 20 m which were placed alternately along the transect at the station. In each square, the number of tree species, the number of individuals of each type of tree, and the diameter of the tree trunk of each individual were calculated

The variables used were the independent variable and the dependent variable. The variables observed included the independent variable is the diameterclass of Australian pine and the dependent variable is the amount of biomass and carbon stock of Australian pine. The main parameters observed were tree density, stem diameter and the number of individuals for each treespecies.Tree density to assess the spatial distribution of trees within the area studied. Stem diameter, another important parameter, is measured as an indicator of tree growth and development. Subsequently, individual numbers for each tree species were documented, shedding light on forest composition and diversity. By examining these variables and parameters collectively, this study aims to reveal the relationship between tree size, biomass, carbon stock, tree density, stem diameter, and species composition in the context of Australian pine. This comprehensive approach contributes to a more holistic understanding of ecosystem dynamics and their potential implications for carbon sequestration and overall environmental health.

### 1. Density measurement

Tree density is measured by counting the number of individuals in a squared plot. The number of individuals obtained is then compared with the plot area used. The calculation of the stand density of Australian pine was carried out using the formula from Cox (1971).

$$Density = \frac{number\ individual\ of\ kind}{area\ of\ the\ entire\ plot}$$

### 2. Diameter calculation of Australian pine

Measurement of stem diameter is carried out on the stands contained in each plot made. The diameter of the tree stands measured is as high as 1.3 m from the ground or as high as the chest (Sutaryo, 2009). The initial data obtained is a circle. The measurement data obtained is then calculated and then entered into the formula:

$$D = K/\pi$$

Where:
D = Diameter
K = Circumference$\pi$ = 3.14

### 3. Biomass estimation of Australian

Measurement of biomass was carried out by measuring the stem diameter at breast height (DBH). Biomass is calculated using an allometric equation (Ketterings *et al*., 2001) as follows:

$$B = 0.11 \times \rho \times D^{2.62}$$

Where:
B = Tree Biomass (kg)
$\rho$ = Type of wood mass (0,83 $g.cm^{-3}$)
D = Stem diameter (cm)

$$\text{Total biomass} = B_1 + B_2 + B_n$$

### 4. Carbon stock of calculation

Calculation of the amount of carbon stock is calculated that 50% of the biomass from coastal vegetation is composed of carbon calculated from biomass in the form of carbon ($ton.ha^{-1}$) (Brown, 1997), with the formula:

$$C = Y \times 0.5$$

Where:
C = Carbon ($ton.ha^{-1}$)
Y = Total of biomass ($ton.ha^{-1}$)
0.5 = Conversion factor for carbon estimation

### 5. Data Analysis

Data were analyzed using Analysis of Variance (ANOVA) followed by the Least Significant Difference (LSD) test with an error rate of 5%. And regression analysis was calculated to determine the relationship diameter class, biomass and carbon stock of Australian pine trees. Correlation and regression analyze were performed using SPSS 16.0 software.

## RESULT AND DISCUSSION

Greenhouse gases that play the most role in triggering global warming are $CO_2$, which accounts for about 9-26% of the total greenhouse gases. Potential radiation triggers global warming 56% of the total potential greenhouse gases. In addition, $CO_2$ is a gas that has the ability to last the longest in the atmosphere (the major long-lived greenhouse gasses) and circulates in the atmosphere for approximately 75 years. $CO_2$ is an important component in the process of photosynthesis. The process of photosynthesis is closely related to biomass, biomass increases because plants absorb CO2 from the air and convert it into organic compounds through the process of photosynthesis. Therefore, the amount of biomass can be used as a basis for determining the amount of carbon stock absorbed by a tree stand.

The study of tree diameter class distribution is a studyof scattered stands. This can be determined by examining the diameter distribution of each individual tree found in the observation plot, in each observation plot, the diameterclass of each tree in it is determined. The diameter class obtained in this study was divided into 5 classes, namely the first class 15-20 cm, the second class 21-25 cm, the third class 26-30 cm, the fourth class 31-35 cm and the last class or fifth class 36-40 cm. (Table 1), the results showed that the density of the Australian pine stands studied in the diameter class 13-40 ranged from 30-370 trees per hectare. Australian pine stands with diameter class have a very low density, but the results obtained are Australian pine stands with a diameter class of 21-25 cm have a very high total density, compared to the low diameter class (15-20) cm. This happened because of the planting activity in the past. It is suspected that wood planting activities are carried out at a growth rate becausethe community generally uses wood as fuel. The high andlow number of individuals in a certain diameter class describes the condition of the coast that has changed the stand structure. These stands affect the sustainability of tree regeneration on the coast (Salunkhe *et al*., 2018).According to Rahayu *et al*. (2007) stated that the presence of trees with a diameter of >30 cm on a land contributed significantly to the total carbon stock.

The results of the analysis of variations in the diameter class of Australian pine stands showed that the diameter class greatly influenced the stand diameter class.The stem diameter of Australian pine stands increased with increasing diameter class. The results of the LSD test showed that there was an increase in the diameter of the stem with a range of 16,771-38,587 cm. The highest stemdiameter was in the 36-40 cm diameter class, while the lowest was in the 15-20 cm diameter class. The amount of carbon dioxide caused the large diameter size in the 36-40cm class absorbed and stored by the stands on the stems. This is in accordance with the research of Lee & Ming (2019), carbon dioxide has been predicted to stimulate thegrowth of tree stands. The factor for the reducing the number of individual trees in the large diameter class is thecompetition factor, the competition factor is the altitude factor from sea level. the results of this study indicate that there is a relationship between diameter class and carbon dioxide storage capacity in Australian pine stands. Each time there is an increase in the diameter class of Australianpine stands, the amount of carbon dioxide absorbed and stored by the stands will increase. Some of the carbon absorbed by the stand will be converted into energy for thephotosynthesis process and some will enter the stand structure and become plant parts, such as cellulose stored in roots, stems, twigs, and leaves.

The results of the regression analysis showed that the diameter class and the size of the stem diameter had an exponential relationship with the equation model $Y = 14{,}448e^{0{,}2055x}$ with R2 = 97,92%. These results indicated that 97,92% of the diameter of the stem was affected by the diameter class, because the stands with the higher diameter class had a larger diameter than the stands of the lower diameter class, while other factors

**Table 1.** Average of density, biomass, and carbon stockand Least Significant Different Test (LSD) onAustralian Pine

| Diameter class | Density ($Tree.ha^{-1}$) | Biomass ($kg.ha^{-1}$) | | Cabon Stock ($ton.ha^{-1}$) | |
|---|---|---|---|---|---|
| 15-20 | 215 | 149,430 | D | 74,914 | d |
| 21-25 | 370 | 337,198 | C | 168,599 | c |
| 26-30 | 300 | 537,522 | C | 270,372 | c |
| 31-35 | 150 | 918,696 | B | 462,478 | b |
| 36-40 | 30 | 1312,972 | A | 656,486 | a |

Information: Numbers followed by the same letter in one column are not significantly different (same)

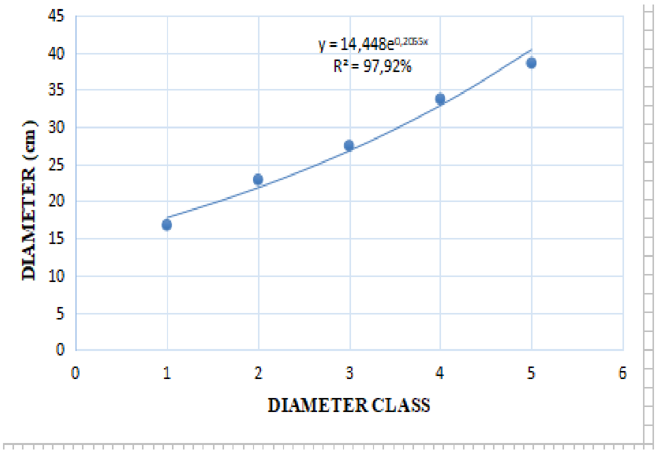


**Figure 1.** Relationships between diameter class and stem diameter on Australian pine

influenced the remaining 2,08%. Another factor that affects the diameter of the stand is the density and intensity of sunlight entering the tree stand. According to Talbot & Dupraz (2012) that a high density of tree stands will affect the ratio of light enters the plant canopy. Meanwhile, stands that receive sunlight will experience slow growth, so that the stem diameter is less developed. In addition, the intensity of light that enters the plant canopy. Stands that get little sunlight will experience slow growth, so that the stem diameter is less developed. In addition, light intensitywill also affect the growth of height, leaf size and structure of leaves and tree trunks.

The results of the LSD further test showed that the diameter class with the largest $CO_2$ storage was in the 36-40 cm diameter stand biomass class, while the smallest $CO_2$ storage was in the 15-20 class. Factors that affect tree biomass stands include volume, density, and height. Diameter class affects biomass because the stand diameter class affects stem volume and wood density. The older thestand, the greater the volume and density of the wood. Wood density is very influential on the growth rate, location of growth and the wood's position on the trunk.

The results of the regression analysis showed that thediameter class of Australian pine stands and biomass in Australian pine stands had an exponential relationship pattern with the equation model $Y = 101.65e^{0,.535x}$ with $R2 = 97,92\%$. The value of $R2 = 97,92\%$ shows a close resultbetween diameter class and biomass, meaning that 97,92%is influenced by diameter class and the remaining 2,08% is influnced by other factors.. These factors include light, temperature, and humidity. According to Uthbah *et al*. (2017), that sunlight has a major role in the process of photosynthesis and other plant physiological processes such as respiration, growth and development, closing and opening of stomata, plant germination and metabolism of green plants so that its availability determines the level ofplant production. The rate of photosynthesis of the stands was related to the chlorophyll content, the number of stomata per unit, and the leaf area. The larger the leaf areaof the stand per unit of land, the greater the amount of $CO_2$ absorbed by the stand. Leaf area will increase with increasing diameter class. Therefore, the stand diameter class will affect the biomass and carbon stock stored in a stand. Stand biomass will also continue to increase with increasing certain diameter classes expressed by age and then will decrease until productivity decreases.

The calculation of carbon stock shows that the amount of carbon stock is influenced by the amount of stand biomass. The amount of carbon stock in the Australian pine stands in this study was obtained based onthe amount of biomass in the stand. This is due in part to the amount of carbon stored by standing carbon stocks. The results of the analysis of variance showed that there was a very significant effect between the diameter class and the carbon stock. The results of this study indicate thatdiameter class has an effect on diameter size, biomass and carbon stock. Thus, every increase in stand biomass content was accompanied by an increase in carbon content, because carbon and stand biomass had a positive relationship. Anything that causes an increase or decreasein biomass will have an affect on increasing or decreasingthe stand. by the amount of stand biomass.

LSD test results for Australian pine carbon stocks (Table 1) show that the average amount of carbon stocks ranges from 74,914 $tons.ha^{-1}$ to 656,486 $tons.ha^{-1}$. The highest carbon stock of Australian pine stands was in the 36-40 cm diameter class, while the lowest carbon stock was in the 15-20 class. These results indicate that the larger the diameter class, the greater the amount of

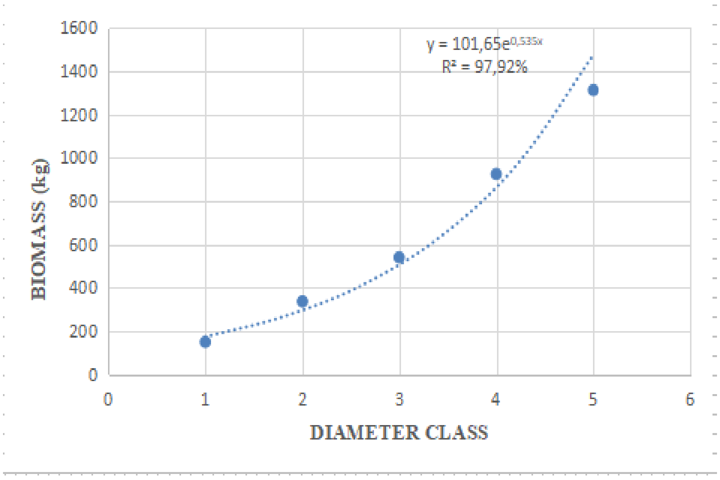


**Figure 2.** Relationships between diameter class and biomass on Australian pine

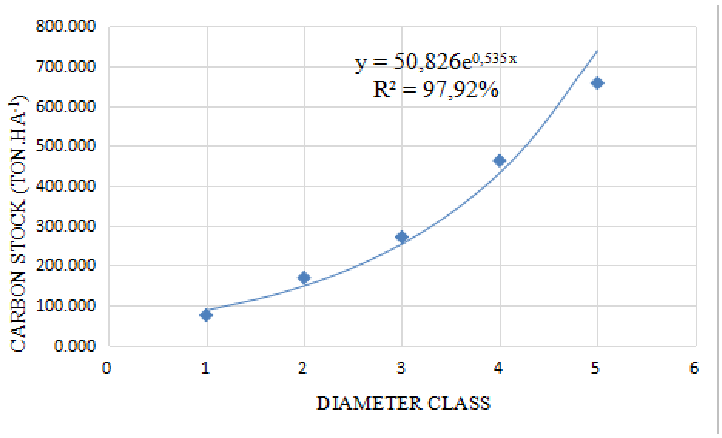


**Figure 3.** Relationships between diameter class and carbon stock on Australian pine

carbonstock produced. According to Suwardi *et al*. (2013), each individual has a different contribution to biomass and total carbon stock. According to Sari *et al*. (2018), the standing carbon stock increased in stem diameter and a decrease incarbon stock occurred when the number of stands or the density found in the diameter class was small. This is in accordance with the research results obtained. In the highest diameter class, it has a high carbon storage potential as well.

Based on (Figure 3) the results of the regression analysis between diameter class and carbon stock have an exponential relationship pattern with the equation $Y= 50.826e^{0,535x}$ with R2 = 97,92%. The equation model shows that 97,92% of the carbon stock of Australian pine stands is influenced by diameter class and other factors influence 2,08. Other factors that can affect carbon stock are pH, environmental factors, topography, and soil composition.

The coastal area of Cemara Sewu Cilacap is dominated by Australian pine which is currently entering the exponential stage. According to Anggreini. (2020), the exponential stage is a population growth model that describes an ideal population for an infinite environment, which means that the constant population growth must be proportional to the original population. This illustrates thatthe population will increase with the number of residents.

## CONCLUSION

Based on the result and discussion, it can be concluded that the diameter class of Australian pine affects the presence of biomass and carbon stock. The relationship between classes of standing diameterof the Australian pine stands has an exponential relationship of 97,92%. The highest amount of carbon stock is in the diameter class 36-40 cm with a total carbon stock of 656,486 $tons^{-1}$.

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