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Carbon Stocks in the Conservation Area of PT. Pertamina (Persero) Fuel Terminal Boyolali

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Abstract. Flora biodiversity has been known to have a vital function in reducing carbon emissions in the air and contributing oxygen in significant levels to the environment. PT. Pertamina (Persero) Fuel Terminal Boyolali (FTB) has an important role in the conservation programs, protection of flora biodiversity, and environmental management. This study aims to analyze carbon stocks found in trees, plants cover soil, litter, necromas, and carbon in the soil and evaluate conservation of flora and fauna. This study uses a purposive random sampling method of carbon sources followed by the determination of carbon stocks in three conservation areas managed by PT. FTB, namely in the Wonopotro Forest, in the Pepe River watershed, and Pertamina's operational area. The samples from carbon sources include trees, litter, ground cover plants, necromas, and soil. The trees and necromas carbon sources sampling at each location was carried out at 2 stations with a size of 10 x 50 m2. Meanwhile, the sampling of litter, ground cover plants, and soil was carried out at 2 stations, each consisting of 3 plots. The results showed that the total carbon stock in the conservation areas was 1,688,0791 tons. The Pepe River watershed has the highest total carbon stock, which was 1,466,0928 tons/ha. The FTB and Wonopotro Forest, respectively, have about 180.7569 and 41.2294 tons/ha. The novelty of this research is the method of calculating carbon stocks in a conservation area that can be used as a database for assessing environmental management performance to the preservation of biological resources.

Key words: carbon stock; carbon dioxide absorption; conservation; flora biodiversity; flora preservation

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INTRODUCTION

The development of relations between the industrial world and the stakeholders who interact with the industrial world increasingly penetrated into various sectors in the era of this globalization. The issue of environmentally sustainable development in every country in the world, including Indonesia, is getting stronger. These conditions demand company performance to be more creative and able to provide benefits, both for the company itself and for the wider community by giving rise to a triple bottom line approach, namely people, planet, profit (Rahayu *et al*., 2012).

Company performance in environmental management is an inseparable part from national performance in preventing global warming and climate change. One of the important indicators in environmental management is the value of carbon stock in the area. Carbon stocks have a correlation with carbon dioxide absorption and have a very important economic value in realizing sustainable development nationally (Sari *et al*., 2013). In this regard, PT. Pertamina (Persero) FTB as a company owned company state, whose operational and the construction areas consist of green areas or conservation, play an active role in mitigation efforts and maintain climate stability.

Green area or conservation is one area which has the potential to absorb CO_2 gas. Those made an important contribution to the decrease of greenhouse gas (GHG) concentrations, especially CO_2 emitted into the atmosphere, and will increase the function of the green area to maintain climate stability and improve the area's ability to store carbon. So, environmental management is needed in order to improve the function of green areas in reducing emissions and storing large amounts of CO_2. PT. Pertamina (Persero) FTB manages green areas in three locations, namely the area of FTB operations, Pepe River Watershed (PRW) in

Teras, and Forest Districts Wonopotro (FDW) in Klego District, respectively covering an area of 3.36; 4; and 0.16 ha (Sunarno *et al*., 2020).

This research is an effort to provide an overview and analyze the performance results of FTB on environmental management reflected in carbon stocks and carbon economic value. Data from research on carbon stocks in companies or government-owned agencies is very useful as a basis for obtaining compensation from governments or world institutions related to global carbon and can be used as a basis for consideration in determining policies related to the conservation and management of biological resources. in a managed area.

METHODS

Sampling, Biomass Measurement, and Counting Carbon Stock in Trees

This study uses a purposive random sampling method of carbon sources followed by the determination of carbon stocks in three conservation areas managed by FTB, namely the FDW, in the PRW, and FTB's operational area. The measurement of the tree diameter is carried out on the part of the tree, which is the height of the measured chest according to conditions of various tree species. The next stage is determining the specific gravity (BJ) of each wood tree species by finding BJ references of the plant species (Sunarno *et al*., 2020). Tree biomass is calculated by using allometric equations that have been developed by previous researchers. If the tree species is not known, the equation allometric, measured data is the diameter and height of the former branch to get the volume of wood (Safriani *et al*., 2017). Carbon accounting in trees refers to the formula used by Wibowo *et al*. (2013).

Litter Carbon Sampling, Measurement, and Counting

Litter biomass sampling was carried out in three locations with a purposive sampling method, covering the operational area of FTB, PRW, and FDW. Every location consists of two stations consisting of 3 plots. Litter biomass was measured by collecting all the litter and branches small on plots measuring 0.5 x 0.5 meters. Measurement of litter biomass is done through several stages. First, take all the litter located at ground level (5 cm thick) on a plot measuring 0.5 x 0.5 meters. Second, all the litter taken from the plot is then entered into the sieve having a pore hole of 2 mm to do the screening. The litter left behind after sifting was weighed wet. Take about 100 grams of subsample litter and dry it in the oven at 80°C for 48 hours. If a biomass sub-sample sample obtained only a small amount (< 100 g), the sub-sample is weighed everything. Third, weighing the dry weight of the sub-sample, data is recorded in the form. Last, litter samples are put in a plastic bag and given a label for carbon analysis. Carbon accounting for litter on the plot of 0.5 x 0.5 m is done by weighing the wet weight of litter from the measuring plot 0.5 x 0.5m and continuing to calculate the water content and dry weight of litter (Sunarno *et al*., 2020).

Sampling, Biomass Measurement, and Carbon Counting in Ground Cover Plant

Ground cover plant biomass sampling is carried out at three locations by the method of purposive sampling, covering the areas FTB, PRW, and FDW. Each location consists of 2 stations and each station consists of 3 plots. Measurement of ground cover plant biomass is carried out in a destructive way by cutting off all the vegetation above ground level on small plots measuring 0.5 x 0.5 meters. Then, all the undergrowth (trees < 5 cm in diameter, herbs, and grasses) were contained in the plot, is separated between leaves and stems. Sample undergrowth put in plastic bags, labeled according to the code sampling stations and locations. The undergrowth subsamples (leaves and stems) are taken and have a weight of about 100-300g. If the biomass sample is obtained in a little (< 100 g), then all the sample is weighed and made as a sub-sample. The biomass sub-sample undergrowth dried for 2 x 24 hours or until the weight is obtained constantly. Carbon accounting for the ground cover plant on the 0.5 x 0.5 m plot is done by measuring the wet weight of the ground cover plant from the 0.5 x 0.5 m plot, continued with calculating water content and dry weight the ground cover plant (Sunarno *et al*., 2020).

Sampling, Biomass Measurement, and Carbon Counting in Deadwood (Necromass)

Biomass in the form of trees and deadwood above ground level is measured by measuring all trees and deadwood on a plot of 10 x 50 meters. Measurement stages of the tree biomass and dead wood are carried out by measuring the diameter of dead trees at chest level, or the base and ends of deadwood. Next, measure the total height of a dead tree or the total length of deadwood. Next, calculate the specific gravity of the dead tree. Both standing, fallen, stump dead plants, branches, and twigs. The measurement of the dead trees with the criteria of trees still standing with a height of 1.3

m, dead trees on both the ends. As on a tree, not a dead tree with a diameter between 5-30 cm on a plot of 10 x 50 meters. If there are dead trees that cross in the plot, the diameter and length measurements are conducted only on wood in the plot. The specific gravity of a dead tree is calculated by taking a wood sample, usually 0.4 g/cm^3 (Sunarno *et al*., 2020).

Sampling, Biomass Measurement, and Carbon Counting in Soil

Soil samples are taken from 3 points on each station. Soil samples were taken with the composite method, namely mixing soil from the three soil sample points on each depth (0-10 cm, 10-20 cm, and 20-30 cm). A ring soil sampler is placed on each soil sampling point and at each depth of soil sampling. The soil in each ring of soil samplers is weighed wet in the field. Then, analyze the specific gravity of the soil and soil organic carbon content. Soil carbon accounting is done by calculating soil carbon contained in 3 layers. The soil carbon content is calculated sequentially by weighing the soil per hectare, calculating soil organic carbon content per ton, as well as calculating the content of soil carbon per hectare of soil (Wibowo *et al*., 2013).

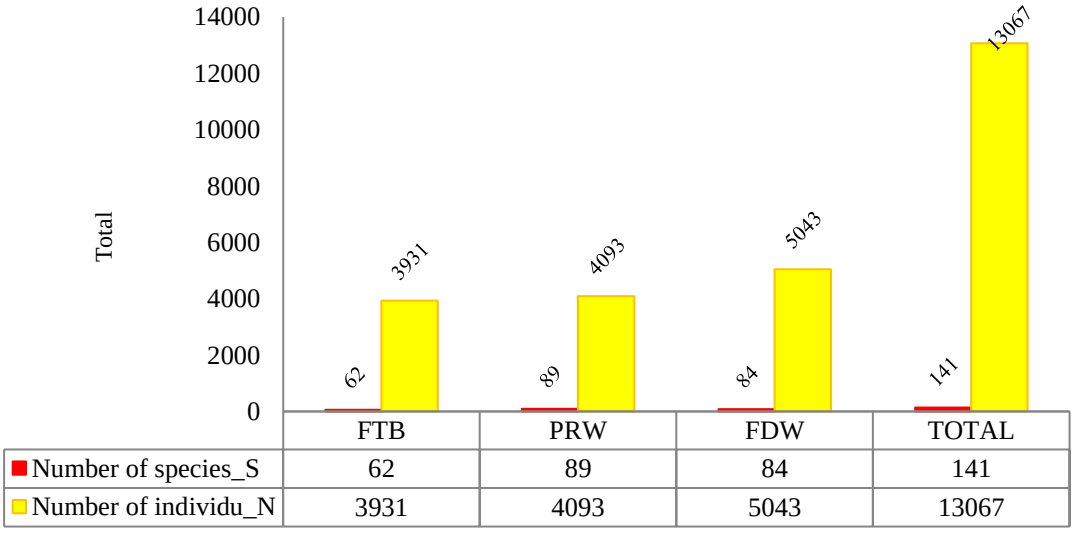
Calculation of Total Carbon Stock per Hectares (ha)

Calculation of the total carbon stock per hectare in the FTB operational area is carried out by adding up the carbon content found in trees, litter, ground cover plants, necromass, and soil.

RESULTS AND DISCUSSION

This research is to calculate the stock of carbon stored in the conservation area managed by FTB, which includes 3 conservation areas, namely the operational area of the FTB, the PRW in Tawangsari Village Teras District and the FDW in Blumbang Village Klego District.

The results of the analysis and evaluation that have been carried out have found differences in the type and density of vegetation in the 3 conservation areas managed by PT. Pertamina (Persero) FTB, whether in the form of biodiversity of trees, saplings, poles, lianas, herb-grass or ground cover plants, and shrubs. Flora biodiversity has been known to have a vital function and an important role in reducing carbon emissions in the air, sequestering carbon, and contributing oxygen at a significant level to the environment. Data on flora and fauna that were analyzed, evaluated, and found from 3 conservation areas consisted of 141 flora species, with the number of species at each location ranging from 62 to 89 plant species per hectare. In the green area of the FTB, 62 species were found, while in the PRW 89 species, and the FDW with 84 species of flora. The Shannon-Wiener Diversity Index (H') in total is 3,946 with 13,067 individuals monitored and a species richness index of 14.770 (high criteria). Based on Sunarno *et al*. (2020) the value of H'> 3.5 is included in the high category. Meanwhile, the FDW (H') values from the three locations were 2.593; 3.757; and 3.258.



	FTB	PRW	FDW	TOTAL
Number of species_S	62	89	84	141
Number of individu_N	3931	4093	5043	13067

Figure 1. Biodiversity index (BI) are monitored in the FTB conservation area

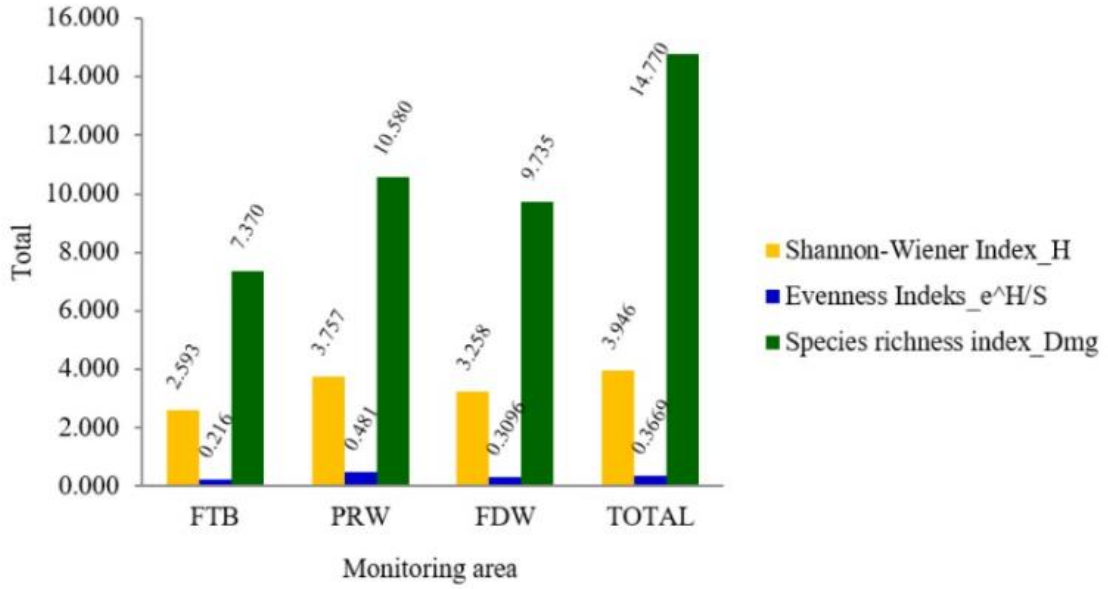


Figure 2. Flora ecological parameters are monitored in the FTB conservation area

This data shows the quality of environmental management carried out by PT. Pertamina (Persero) FTB in 3 work areas. It has been well proven that the level of diversity of flora species in 3 conservation areas has a high value, distribution of each species can be declared stable, community stability is good, and disturbance by humans is very small.

The composition of the vegetation as a result of monitoring and evaluation in the 3 green areas of the FTB is dominated by flora vegetation which functions as shade plants, absorbent pollutants, fruit trees, ornamental plants, and hedges. The dominant flora species found were Angsana (*Pterocarpus indicus*), squirrel tail palm (*Wodyetia bifurcata*), kanyere rhino (*Bridelia tomentosa*), pole tree (*Polyalthia longifolia*), trembesi (*Samanea saman*), and japanese ifurc (*Thyrsostachys siamensis*). Different compositions of flora and fauna are found in the PRW. The watershed, which is located in Tawangsari Village, Teras District, Boyolali Regency, is dominated by wild and semi-wild plants. The results of monitoring and evaluation also noted that the dominant flora species were kersen (*Muntingia calabura*), mahogany (*Swietenia mahagoni*), and lamtoro (*Leucaena glauca*). FDW is a limestone hill forest area located in Blumbang Village, Klego District, Boyolali Regency. The results of a comprehensive collection of flora vegetation in the monitoring area found types of flora that have an important role as ground cover plants. The dominance of this vegetation consists of herbs and wild shrubs. Herbs and shrubs have important benefits to prevent erosion and are also known to be able to absorb high amounts of carbon (Zulfidli *et al*., 2017). Herbs and wild shrubs are plants that contribute to capturing the carbon dioxide load from the atmosphere in the process of photosynthesis, synthesis carbohydrates and store carbon in their biomass.

The dominant vegetation recorded at this location, among others, is the teak plant (*Tectona grandis*) with a diameter of less than 20 cm. Other cultivated plants are mahogany (*Swietenia mahagoni*), sengon (*Albizia chinensis*), and sono keling (*Dalbigeria latifolia*). The composition of the vegetation in the FTB area consists mostly of trees. Trees, as woody plants, are good carbon sinks. Trees or tree parts that have died will become necromas. Carbon stored in biomass will enter the food chain or be stored in the soil as soil carbon (Sharma *et al*., 2020). Vegetation flora with a high level of biodiversity has an important function in absorbing CO_2 from the environment as raw material for the photosynthesis process and storing it in the form of organic material in the form of tree biomass (Ali & Yan, 2017).

The results of monitoring, analysis, and evaluation of carbon stocks from 3 locations working areas of PT. Pertamina (Persero) FTB obtained data showing an increase in carbon stocks. This evidence shows an improvement in hydrological conditions, an increase in the number of flora species found, the value of the biodiversity index, and the species richness index. The value of carbon stock resulting from environmental

Table 1. Carbon stocks in the operational area of FTB, PRW, and FDW which are managed by PT. Pertamina (Persero) FTB.

Green area	Carbon component	Carbon content (ton/ha)	Location area	Carbon total (ton)
Fuel Terminal Boyolali (FTB)	Tree	35.6096	3.36	180.7569
	Ground cover plant	3.7632		
	Litter	6.2720		
	Necromass (dead wood)	0.1340		
	Soil	8.0179		
	Sub total	**53.7967**		
Pepe River Watershed (PRW)	Tree	331.2534	4.00	1.466.0928
	Ground cover plant	5.3067		
	Litter	9.0400		
	Necromass (dead wood)	10.0571		
	Soil	10.8660		
	Sub total	**366.5232**		
Forest District Wonopotro (FDW)	Tree	245.7935	0.16	41.2294
	Ground cover plant	1.3877		
	Litter	2.3595		
	Necromass (dead wood)	6.3309		
	Soil	1.8120		
	Sub total	**257.6836**		
	Carbon Content Total (ton)			**1,688.0791**

monitoring and evaluation was carried out using the Biomass Expansion Factor method with non-destructive sampling. This method is carried out by minimizing the occurrence of damage to flora at the sampling location, with higher rainfall conditions and good hydrological conditions. FTB operational areas with a large number of trees have a correlation with high carbon stocks. A tall tree, the base area of all trees (diameter=5-30 cm), and a large tree base area (diameter>30cm) is the main factor influencing carbon stock (Markum *et al*., 2017). Trees have a very important function as a store of carbon stocks. The amount of C stored in plant biomass globally exceeds CO_2 in the atmosphere, and nearly 90% of C plant biomass is stored in tree biomass (Ali & Yan, 2017). The final result of calculating the total carbon stock obtained from the three locations, the PRW has the highest total carbon stock, which is 1.466,0928 tons/ha, and the next is the FTB and the FDW, respectively 180.7569 tons and 41.2294 tons (Table 1.).

The highest carbon stock from the research was found in the KPW watershed located in Tawangsari Village, Teras Boyolali District with the widest area of approximately 4 ha. The amount of carbon stored in this location comes from the high carbon stored in trees, then carbon stored in the soil, deadwood, litter, and undergrowth or soil cover, which respectively are 331.2534; 10.8660; 10.0571; 9.0400; and 5.3067 tons/ha. Trees and undergrowth or ground cover in this location generally have the ability to absorb and store carbon from their environment optimally. Kalipepe watershed is a habitat with a composition of flora vegetation or has a very high biodiversity of trees, long-lived, has a high trunk, and has a wide diameter.

Various types of trees are found in this location, including trembesi (*Albizia saman*), mahogany (*Swietenia mahagoni*), breadfruit (*Artocarpus altilis*), lamtoro (*Leucaena leucocephala*), mindi (*Melia azedarach*), petai (*Parkia speciosa*), and coconut (*Cocos nucifera*). Trees with wide diameters, tall trunks, lots of leaves, and exposed to light with optimal intensity will have the ability to photosynthesize effectively so that the greater the environmental CO_2 (CO_2-eq) that is absorbed and stored in the tree. The carbon stock per hectare stored in this location, which is 366.5232 tons/ha, is higher than the green area of FTB or FDW. Generally, the biomass of tree parts such as leaves, branches, twigs, and trunks is positively correlated with the diameter and total height of the tree. Every time there is an increase in the diameter and total height of the tree, it will always be followed by an increase in the carbon content of that part of the tree. Trees with an increasing diameter will be followed by an increase in the amount of carbon stocks. This is in

accordance with previous research evidence which states that trees with a diameter of between 5-30 cm can store considerable biomass. The biomass of tree parts is distributed 60-65% in the trunk, 5% in the canopy, 10-15% in the leaves and branches, 5-10% in the stump, and 5% in the roots. Necro Trees or deadwood are the second-largest sources of carbon stocks found in the KPW. Necro Trees or deadwood is a component of vegetation that has died and has undergone a weathering process (Syam'ani *et al*., 2012).

In this study, woody necro trees were found in the form of dead trees, branches, and twigs with the largest amount of carbon stock in woody necromass in the green area of the PRW. Besides carbon stocks sourced from trees and necro trees, the large carbon stocks in the green area of the PRW are also sourced from soil carbon. Soil carbon is an important indicator of environmental quality.

Soil carbon is obtained through the process of sequestering carbon from the air through the process of photosynthesis. During the decomposition of plant residues, the carbon content is fixed in the process of photosynthesis, transferred to the soil surface, and the rest is transferred to the soil. Carbon that moves to the soil is then incorporated into soil aggregates through the humification process. Furthermore, it is stated that carbon in soil is also sourced from various trapping processes in the soil, which include hydrodynamic trapping, residual trapping, dissolved materials trapping, and mineral trapping.

The high soil carbon stock is related to the number of tall and large-diameter trees and the number of ground cover plants. Types of ground cover plants contribute to the flow of carbon from the atmosphere into the soil through the process of photosynthesis. High carbon stocks are also supported by various natural processes that allow carbon to be trapped in the soil (Samsoedin & Heriyanto, 2019).

Biomass is the weight of organic matter per unit area in the ecosystem at a certain time. The results showed (Reza *et al*., 2017), biomass is the total amount of plant organic matter living above the soil which is expressed as plant dry weight per unit area. The biomass calculated in this study is above-ground biomass consisting of trees, underground vegetation, woody necromass (deadwood), litter, and soil. Krisnawati *et al*. (2012) states, biomass is influenced by the density of vegetation, the diversity of diameter sizes, and the distribution of the specific gravity of the vegetation.

Unlike the carbon stock in the green area in the PRW, the carbon stock in the FTB was found to be lower but higher than in the WPF. The results of carbon measurements in this area found carbon stocks per hectare of 53.7967 tons. The largest contribution of carbon stocks come from trees, namely 35.6096 tons, then from the soil as much as 8.0170 tons, litter (necromass) amounting to 6.2720 tons, undergrowth or ground cover reached 3.7632 tons, and the last one came from deadwood (necro trees) which was 0.1340 tons. Furthermore, the carbon stock in the WPF based on the results of monitoring and measurement is 257.6836 tons/ha.

The largest carbon storage in this location comes from tree carbon as much as 245.7935 tons/ha, followed by necro trees (deadwood) at 6.3309 tons, litter at 2.3595 tons, soil carbon at 1.8120 tons, and from plants undergrowth or ground cover of 1.3877 tons/ha. Plants that have the highest amount of carbon stock are found in the green area of the Fuel Terminal Boyolali, which includes guava boll (*Syzygium malaccense*) and trembesi (*Albizia saman* Jacq.). The plants with the highest amount of carbon stocks found in the Kalipepe watershed are bamboo reeds (*Bambusa sp*), mahogany (*Swietenia mahagoni*), trembesi (*Albizia saman* Jacq.), coconut (*Cocos nucifera*), breadfruit (*Artocarpus altilis*), and sengon (*Albizia chinensis*).

For the green area of the Wonopotro Forest, the plant with the highest amount of carbon stock is teak (*Tectona grandis*). Trees have the largest percentage of carbon stocks due to the presence of tree trunks which are the largest storage places for photosynthetic reserves for growth (Syam'ani *et al*., 2012).

The increase in carbon stocks in each location is closely related to the improvement of hydrological conditions, high rainfall, biodiversity with a higher total number of individuals, and the number of flora species as well as an increasing index of flora species richness. The results of monitoring and measurement of carbon stocks at each location increased due to the increase in carbon stocks contained in each sample measured, either in trees, in necro trees or deadwood, ground cover plants (necrolitter), litter (necromass), and carbon in the soil. Carbon stocks stored in various green cover areas are strongly influenced by the variety of vegetation that grows and develops. The success of environmental quality management has a significant influence on the amount of carbon stock in the area. The variety and age of vegetation

will have an impact on the effectiveness of the photosynthesis process and the amount of carbon stored (Stevens *et al*., 2020). Carbon stocks in an area depend on the type of habitat, types of trees, shrubs, herbs, shrubs, cover crops, and the age of the plant or plant). The biodiversity of plants plays a role in shaping ecosystem functions (Con *et al*., 2013).

The results of monitoring and measuring carbon stocks in this study indicate that carbon stocks in 3 conservation areas are managed by PT. Pertamina (Persero) FTB is very high. High carbon stock value in each conservation area location of PT. Pertamina (Persero) FTB finally has an influence on the total carbon stock. This large carbon stock cannot be separated from the performance and attention of PT. Pertamina (Persero) FTB related to environmental management and conservation which is carried out in a sustainable manner.

This environmental quality needs to be maintained in a sustainable manner by implementing community empowerment policies around the location. Community involvement in the management and conservation of biological resources will have economic benefits, but also has another important function, namely the creation of a quality environment that can support human life and other living things, and also contribute to exploration activities for the development of research and technology-oriented towards the benefit of human life in a sustainable manner. De Deyn *et al*. (2018) states, plant diversity has consequences for functional and structural diversity and become a supporter of increasing carbon stocks in an ecosystem.

The main plant organs are the stem, leaves, branches or twigs and roots have the ability to store carbon stocks. Cuong *et al*. (2020) states, during the process of photosynthesis, CO_2 in the atmosphere will be used by leaves for food production in the form of glucose and used to increase biomass through growth. Therefore, plants with high biomass usually have a complex stand structure, and are able to store more carbon stocks. Functional change in tree basal diameter and tree height have been shown to directly increase carbon stocks. Heinrich *et al*. (2021) states, plants with large biomass in form of leaf litter and wood per unit area of land contribute directly to the carbon stock in the litter or in the organic matter in the soil.

Total carbon stock is an important variable used to measure the success of an institution's performance on environmental management and preservation. The Ministry of Environment and Forestry of the Republic of Indonesia stated that every activity carried out by companies or agencies with the aim of reducing carbon emissions will make an important contribution to the country. It showed that the government has a high commitment to reducing the rate of environmental damage and has implemented policies related to environmental management and preservation of existing biological resources throughout Indonesia.

CONCLUSION

The total carbon stock in three conservation areas is managed by PT. Pertamina (Persero) FTB is 1,688.0791 tons. High carbon stocks are indicators of excellent management and preservation of biodiversity and the environment.

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