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ECONOMIC VALUATION OF CARBON SAVINGS OF POLOKARTO RUBBER PLANTATIONS, SUKOHARJO

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ABSTRACT

Rubber plantations play a significant role in carbon absorption and storage, which can help mitigate the impact of climate change. The importance of rubber plantations can be identified through the economic valuation of carbon stocks. This study aims to calculate the economic value of carbon storage in the Polokarto Rubber Plantation. This research was done at the Polokarto Rubber Plantation, Sukoharjo Regency, Central Java. This study uses the plot method to measure biomass and carbon storage. The estimation of the economic value of carbon is carried out using a proxy market approach, namely, substituting carbon stocks into market prices. The results showed that the total estimated value of carbon storage was 6136.935 tons from 140 hectares of plantation area. The economic valuation of carbon savings in the Polokarto Rubber Plantation shows an economic value of Rp. 2,291,908,029.96. Several recommendations that can be made are to improve plantation management, take a sustainable approach to plantation management to maintain carbon stocks and other environmental benefits, combine satellite technology to monitor changes in carbon stocks in large plantation areas, and establish economic incentive policies for rubber farmers who participate in maintaining carbon stocks through conservation and good land management.

Keywords: *carbon stock; economic valuation; rubber plant*

INTRODUCTION

Climate change is one of the problems facing the world today. Climate change refers to a shift in climate patterns and intensity that occurs over an extended period. The main cause of climate change is global warming. The acceleration of global warming is the result of increasing greenhouse gases in the Earth's atmosphere. CO2 is one of the greenhouse gases that cause global warming and climate change (Rinjani et al., 2018). One of the triggers for the increase in greenhouse gases is the use of fossil fuels for energy in industry and

transportation (Ghifari et al., 2019). Reducing CO2 concentrations in the atmosphere can be done through absorption by forest vegetation. Forests are estimated to be able to reduce greenhouse gas (GHG) emissions by 17.4%, so mitigation management in this sector needs to be considered (Pratiwi et al., 2021). Components found in forest vegetation include trees, necromass, litter, undergrowth and soil organic matter, which can store carbon.

The function of forests in mitigating climate change can be attributed to their role in absorbing and storing excess atmospheric carbon in the form of biomass (Azzahra et al., 2020). The absorption of carbon dioxide by vegetation, including rubber plants, demonstrates an effort to reduce the carbon dioxide gas content in the atmosphere (Selfiany et al., 2020). Extensive forests with abundant vegetation will result in a significant accumulation of carbon absorption. The problem currently occurring in several areas is the conversion of forests and plantations from the perspective of socio-economic and ecological functions. The lack of comprehensive information for society about the value of natural resources and the environment leads to environmental degradation and economic costs, causing natural resources to be undervalued compared to their actual worth. Consequently, the market fails to reflect the actual scarcity of resources accurately. Community rubber plantations are a source of income for farming families in the community. According to Sari's statement (2022), existing rubber commodities are currently experiencing a decline in prices. This is a problem for rubber farmers because they depend on their livelihood as rubber tappers to meet their daily needs. This decline in rubber prices makes it difficult for people to earn as much income as they did when rubber prices were high. With the decline in rubber prices, the income of rubber farmers decreases, causing socio-economic impacts. This triggers changes in rubber plantation areas to areas that have higher economic value.

The Polokarto rubber plantation area is a rubber farming land that is managed to utilize its rubber products (Erfanto & Suharyani, 2021). The Polokarto rubber plantation in Sukoharjo Regency, Surakarta, was built independently by community members both individually and in groups. The economic factor that encourages people to establish rubber

plantations is the prospect of rubber as a source of income for smallholder farming families. On the other hand, the Polokarto rubber plantation serves as a carbon sink, absorbing and storing forest carbon that has economic value. This research aims to determine the value of carbon savings and assess the economic value of these savings at the Polokarto Rubber Plantation. By maintaining the Polokarto rubber plantation area, the ecological, social, and economic functions are preserved, particularly on the economic side. Non-rubber forest products have economic value, and forest carbon deposits also have economic value.

MATERIALS AND METHODS

1. Time and Location

This research was conducted in November and December 2022. Field data collection was located in Alas Karet Polokarto, Sukoharjo Regency, Central Java, Indonesia (See **Figure 1**).

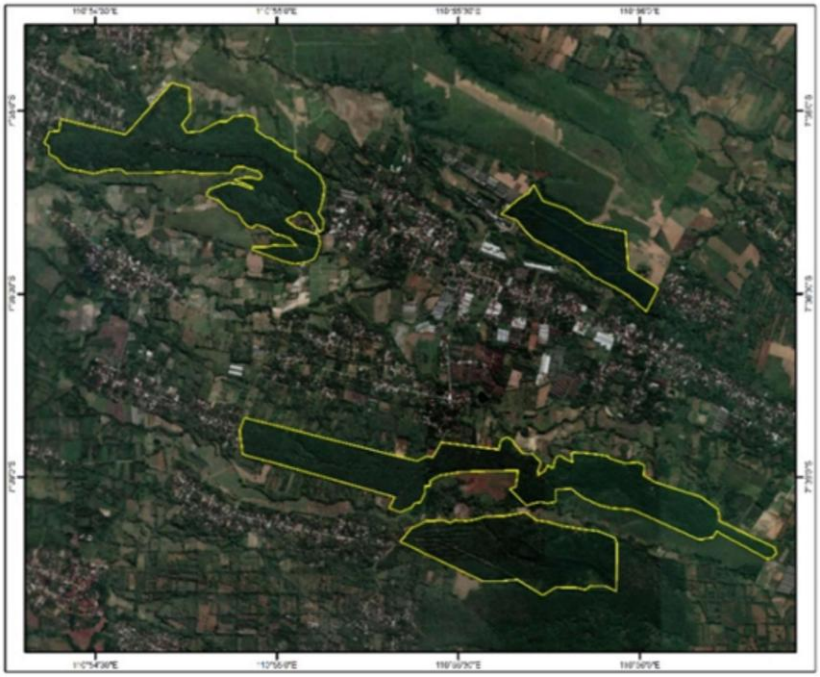

Figure 1. Map of the Rubber Plantation

Source: Researcher Analysis, 2024

2. Research Instrument

The instruments used in this research to obtain primary data were writing instruments, cloth meters, stakes, a laptop, a camera, Microsoft Word, and Microsoft Excel.

3. Data Collection Methods

The data collection method used in this research is an observation survey method

carried out directly at the research location. The data collected includes primary data and secondary data. The primary data collected in this research include tree type, tree height, and tree diameter. The method used was systematic random sampling, where plots measuring 6×6 m, 12×12 m, and 20×20 m were created, resulting in a total sampling area of 400 m². Meanwhile, the secondary data used are derived from theory or the results of previous research, obtained by studying scientific literature and regional information from the Sukoharjo Regency website.

4. Data Analysis

The data obtained in the form of diameter, age, and specific gravity were tabulated and then analysed using Microsoft Excel 2021 software to estimate biomass content, carbon storage, and carbon economic valuation.

a. Calculation of tree biomass

The data taken from each tree to calculate its biomass includes tree type and diameter. Calculation of tree biomass is carried out using the allometric equation for Rubber Trees (Stevanus and Sahuri, 2014) with **equation 1**:

$$BK = 0{,}11\pi D2{,}62 \quad (1)$$

Information:

BK = Dry Weight (kg)

π = Specific gravity of rubber wood (0.63 g/cm3)

D = Diameter at chest height (cm)

b. Calculation of tree carbon

Carbon stores in vegetation are estimated to be 47% of the total biomass (BSN, 2011); therefore, the following formula, as shown in **Equation 2**.

$$\text{Carbon (C)} = BK \times 0{,}47 \quad (2)$$

Information:

C = Total carbon stock (tons/ha)

BK = Biomass (tons/ha)

After determining the tree's carbon storage value (tons/ha), find the carbon storage in one year by calculating the biomass multiplied by the age of the tree, as shown in **equation 3.**

$$\text{Carbon (C/year)} = BK \times \text{age} \quad (3)$$

Estimates of total carbon storage can be determined by calculating carbon storage (tons/ha) multiplied by the total area of Polokarto Rubber Mat (140 ha), namely with the **equation 4**:

$$C\ (\text{total}) = C\ (\text{ton/ha}) \times 140\ \text{ha} \quad ...(4)$$

c. Calculation of Estimated Economic Value of Carbon

Calculation of the estimated economic value of carbon, shown in **equation 5**.

$$Nk = C\ (total) \times Pi \quad (5)$$

Information:

Nk = Economic Value of Carbon

Pi = Carbon Price (Rp.) with a carbon price of €24.97 (Rp. 373,461.35).

RESULTS AND DISCUSSION

The Polokarto rubber plantation area spans approximately 140 hectares. Administratively, the Polokarto rubber plantation area is in Tepisari Village, Polokarto District, Sukoharjo Regency, Central Java Province. Rubber is an essential plantation commodity (Tran, 2020). Apart from being a source of employment, this commodity also makes a significant contribution as a source of non-oil and gas foreign exchange, a supplier of rubber raw materials, and plays a crucial role in encouraging the growth of new economic centres in the rubber development area. The characteristic of this area is the homogeneous plantation of Rubber Trees, which grow to a towering height of up to 20 meters and spread out wide with a neat, long-term planting arrangement.

This plant can grow in the lowlands, with a height ranging from 0 to 200 meters above sea level. The higher the location of the rubber plantation, the slower the growth and the lower the latex yield (Susanto et al., 2017). The Polokarto rubber plantation area is a rubber farming land that is managed to utilize its rubber products (Erfanto & Suharyani, 2021). Resources in the Polokarto rubber plantation play a crucial role in maintaining the survival of the community, particularly the surrounding community, the government, and the environment. These rubber plantations can provide wood and non-wood products, protect the water cycle, sequester carbon, provide oxygen, and serve as a recreational area. The existence of rubber plantations in people's lives should be the responsibility of the community and government to manage and preserve them. The management and preservation of the Polokarto rubber plantation is not only a physical activity but also an effort to maintain the value of the plantation. The concept of value in this case is

divided into several types, namely direct use value, indirect use value, option value, existence value, and future inheritance value.

Direct use value is the satisfaction value received directly by consumers. This direct use value is divided into three criteria: consumptive use value, which is the value given to natural products that are consumed directly without passing through the market; and productive use value, which is the value given to products that are harvested or produced commercially to meet market needs. Additionally, consumers value non-consumptive use, which is a service, not a good. Indirect use value refers to the benefits derived from the function of an ecosystem, such as regulating water and air, supporting recreation, and similar functions. The option value is the value that can be paid or not, which is a choice that allows you to use it in the future. Existence value is the value that consumers only give to the existence of existing environmental goods or services. Meanwhile, the value of future inheritance refers to the value paid by consumers who are willing to pay for the benefits that future generations will receive. This value concept also applies to natural resources such as the Polokarto rubber plantation.

In determining the economic value of carbon savings in Polokarto rubber plantations, primary data is used in the form of tree stand censuses. This tree stand census is used to determine the direct and indirect benefit value of the Polokarto rubber plantation in the form of carbon value. The stands in this plantation are entirely rubber trees because the research was carried out on a rubber plantation in Polokarto. The carbon savings value represents the indirect benefits obtained from the Polokarto rubber plantation.

Research conducted by Kusumaningrum et al. (2022) revealed the potential for carbon storage in Mount Merbabu National Park, utilising a biomass approach to estimate carbon storage in forest vegetation. Compared to Polokarto's study, the results showed that vegetation type, density, and tree size have a significant impact on carbon storage capacity. This method also supports the carbon economic valuation approach as carried out in Polokarto. Suyanto et al. (2022) investigated the spatial distribution of carbon storage in secondary tropical forests in South Kalimantan. Their results showed that

carbon storage was higher in areas with denser vegetation. This study shares similarities with Polokarto's research in highlighting the importance of vegetation density for carbon storage and its impact on the economic value of carbon sequestration. In this research, the benefit value of the Polokarto rubber plantation is calculated as a carbon store. The following table presents the calculation of carbon savings value in Polokarto rubber plantations (**Table 1**).

Table 1. Calculation of the Estimated Value of Carbon Savings for Polokarto Rubber Plantations

No	Circumference (cm)	Diameter (cm)	BK (kg)	C (kg)
1	60	19,11	157,59	74,07
2	56	17,83	131,53	61,82
3	55	17,52	125,47	58,97
4	56	17,83	131,53	61,82
5	54	17,20	119,58	56,20
6	52	16,56	108,32	50,91
7	50	15,92	97,74	45,94
8	50	15,92	97,74	45,94
9	60	19,11	157,59	74,07
10	53	16,88	113,86	53,52
11	56	17,83	131,53	61,82
12	70	22,29	236,01	110,93
13	56	17,83	131,53	61,82
14	54	17,20	119,58	56,20
15	61	19,43	164,57	77,35
16	58	18,47	144,20	67,77
17	50	15,92	97,74	45,94
18	53	16,88	113,86	53,52
19	54	17,20	119,58	56,20
21	60	19,11	157,59	74,07
22	51	16,24	102,95	48,38
23	60	19,11	157,59	74,07
24	60	19,11	157,59	74,07
25	55	17,52	125,47	58,97
26	55	17,52	125,47	58,97
27	56	17,83	131,53	61,82
28	46	14,65	78,56	36,92
Mean			133,24	62,62
Total			3730,66	1753,41

Source: Researcher Analysis, 2024

Determining the importance of an ecosystem can be done not only through an ecological approach but also by valuing each function of the biotic and abiotic components within the ecosystem economically. The dominance of species

with a high average diameter and height can influence the value of carbon storage (Kepel et al., 2017). Based on the tables and calculations carried out, it is evident that the value of carbon savings per hectare for the Polokarto Rubber Plantation area is 43.83525 tons/ha. The larger the circumference and diameter of the tree, the higher the amount of carbon stock. Based on the data obtained, it is known that the tree with the largest circumference and diameter is tree number 12, with a circumference of 70 cm and a diameter of 22.29 cm. This tree produces a dry weight of 236.01 kg and a carbon storage stock of 110.93 kg. Meanwhile, trees with the smallest circumference and diameter also have a carbon storage stock of small value.

- Carbon absorption per 400 m^2:
  = 1753.41 kg
  = 1.75341 tons
- Carbon uptake/ha:
  = 43.83525 tonnes/ha
- Estimated total uptake:
  = Carbon stock/ha x total plantation area (140 ha)
  = 6136.935 tons
- Economic Valuation of Carbon (Nk):
  = C x Pi
  = 6136,935 x Rp. 373,461.35
  = Rp. 2,291,908,029.96

The tree with the smallest circumference and diameter is tree number 28, with a circumference of 46 cm and a diameter of 14.65 cm. This tree produces a dry weight of 78.56 kg and a carbon storage stock of 36.92 kg. Sari et al. (2021) stated that each tree has a different biomass. Where the larger the diameter, the greater the biomass. Carbon is an element that is absorbed from the atmosphere through the process of photosynthesis and stored in the form of biomass (Kusumaningrum et al, 2022). The amount of CO2 absorption is directly proportional to the diameter of the tree; the larger the diameter, the greater the CO2 absorbed (Dharmawan and Siregar, 2008). In this research, it is also possible to calculate the estimated value of the total carbon savings for the entire area, resulting in an estimated value of 6,136,935 tonnes from 140 hectares of plantation area. The economic valuation of carbon savings in the Polokarto Rubber Plantation, with a land area of 140 ha, reveals carbon savings of 6,136,935 tons at a carbon price of Rp. 373,461.35, so that the economic value is Rp2,291,908,029.96.

The value of the rubber plantation ecosystem in Polokarto can be viewed from its use value and non-use value. This use value consists of direct use value, indirect use value, option use value and inheritance value. Meanwhile, what is not use value consists of inheritance value and existence value. The direct use value of rubber plantations in Polokarto is in the form of wood from rubber trees, which can be used for home furnishings or furniture and processed rubber raw materials, as well as non-wood products, which can be obtained in the form of rubber latex, which can be used in the synthetic industry, food additives, and several other uses. The indirect use value of the Polokarto rubber plantation includes being a carbon sequester, an oxygen provider, and a protector of the water cycle, as well as providing opportunities for tourism and recreation, which can also create jobs.

According to Kusumaningrum et al. (2022), the absorption of carbon in the atmosphere by plants helps mitigate climate problems through the processes of photosynthesis and respiration, making the carbon cycle crucial in addressing climate change. The opportunity to open recreational tourism can improve the community's economy, but it will be concerning from a conservation perspective. This is because it can cause damage if not accompanied by effective environmental management. Meanwhile, the use value of options in rubber plantations in Polokarto refers to how this plantation can continue to exist or maintain consistency in fulfilling both direct and indirect use values in the future. The heritage value of rubber plantations can be found in the form of recreational needs, such as natural picnics and nature preservation for future generations. The value of its existence lies in its role in protecting rubber trees, which is supported by the community, visitors, and the government.

The Polokarto rubber plantation ecosystem has good vegetation (**Figure 2**), wood production and carbon storage. In managing rubber plantations, it is essential to apply sustainability principles within the operational context. This is necessary to provide complete information to support the effectiveness of rubber forest management, ensuring it plays a crucial role in economic development and climate change mitigation (Suyanto et al., 2022). Given the numerous benefits that can be obtained, both in terms of quality and

quantity, the community and government must work together actively to continually monitor and preserve this place.

Figure 2. Rubber Plantation Polokarto
Source: Researcher Documentation, 2024

The form of management and utilisation must be in direct proportion so that existing resources can continue to be utilised in the future. If this is related to carrying capacity, then demand must not exceed supply so that environmental conditions can remain stable. Several policies can be implemented, namely planning, management, and evaluation. Planning for rubber plantations in Polokarto can be done by identifying benefits that do not only calculate land use value. Management can be carried out by strengthening central or regional institutions in matters of carrying capacity analysis, economic valuation of natural resources and the environment, natural resource balance sheets, and ecological risk assessment.

Meanwhile, the evaluation that can be carried out is to provide the community with access to participate in monitoring and evaluating the management of natural resources and the environment. Several solutions can be implemented by the government so that the management of natural resources in the form of the Polokarto Rubber Plantation can carry out its functions stably and remain sustainable, namely by providing

improvements in control rights over natural resources and the environment so that they can be well maintained, improving the management of natural resources and the environment so that external costs are reduced. Can be internalised with a command and control system or economic incentive system, and also includes the polluter pays principle, using social pressure to reduce pollution from the initial stage of utilization or extraction of rubber latex to the final stage, and providing awards or financial support for the management and maintenance of the good for this rubber plantation.

CONCLUSIONS

The Polokarto rubber plantation is very important for the surrounding community because it provides both direct and indirect use value, including the production of wood and non-wood products, protection of the water cycle, carbon absorption, oxygen provision, and recreational benefits. The carbon storage value per hectare of the Polokarto Rubber Plantation area is 43.83525 tons/ha. Based on these results, the estimated value of the total carbon storage area is 6136,935 tons from 140 hectares of plantation area. The economic valuation of carbon savings at the Polokarto Rubber Plantation, with a land area of 140 ha, shows an economic value of Rp. 2,291,908,029.96. Based on the research findings, several recommendations can be made to improve plantation management, take a sustainable approach to plantation management to maintain carbon stocks and other environmental benefits, combine satellite technology to monitor changes in carbon stocks in large plantation areas, and establish economic incentive policies for rubber farmers who participate in maintaining carbon stocks through conservation and good land management. Some limitations of this study are that it was conducted only in the Polokarto plantation, which may not represent the various geographical and environmental conditions in a wider area. Additionally, the use of the plot sampling method can provide variations in results depending on the size and number of plots taken. Further research is expected to complement the limitations of this study.

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