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Economic Value of Carbon Sequestration in Telaga Warna National Park

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ABSTRAK

Hutan di Indonesia, seperti di Taman Nasional Telaga Warna, memiliki peran penting dalam konservasi keanekaragaman hayati, kontribusi ekonomi, dan mitigasi perubahan iklim melalui penyerapan karbon. Penelitian ini mengevaluasi potensi penyimpanan karbon dan nilai ekonomi hutan pohon di Taman Nasional Telaga Warna, Jawa Barat, yang dikenal akan signifikansi ekologisnya. Penelitian berfokus pada tanaman pole (diameter 10–19,9 cm) dan pohon (diameter >20 cm), dengan data dikumpulkan dari subplot berukuran 10x10 meter untuk tanaman pole dan plot 20x20 meter untuk pohon. Spesies dominan yang diidentifikasi adalah *Riung Anak* (*Castanopsis javanica*), dengan nilai karbon sebesar US$2,96 per hektar untuk spesies pole dan US$98,49 per hektar untuk spesies pohon. Temuan ini menegaskan nilai ekonomi dan lingkungan yang signifikan dari hutan taman nasional ini, menyoroti peran pentingnya dalam pembangunan berkelanjutan dan upaya global untuk mengatasi perubahan iklim.

Kata kunci: Penilaian cadangan karbon, serapan karbon, nilai ekonomis karbon, karbon hutan.

ABSTRACT

Forests in Indonesia, such as those in Telaga Warna National Park, play a vital role in biodiversity conservation, economic contribution, and climate change mitigation through carbon sequestration. This study evaluats the carbon storage potential and economic value of pole-sized and mature trees in Telaga Warna National Park, West Java – an area renowned for its ecological significance. The research focuses on poled-sized trees (diameter:10-19.9 cm) and mature trees (diamter: > 20 cm). Data were collected from 10 X 10 meter subplots for pole-sized specimens and 20 X 20 meter plots for mature trees. The dominant species identified was Riung Anak (Castanopsis javanica), with carbon values quantified at USD 2.96 per hectare for pole-sized trees and USD 98.49 per hectare for mature trees. The findings underscore the significant economic and enviromental value of this national park forest, highlighting its critical role in sustainable development and global efforts to address climate change.

Keywords: carbon storage valuation, carbon sequestration, economic value carbon, carbon forest.

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1. INTRODUCTION

Forests as the largest natural resource in Indonesia one of the ecosystems storing biodiversity are national assets that need to be preserved for their existence because they have very significant functions and benefits for both the environment and people's lives (Harja, Dewi, Heryawan, & van Noordwijk, 2011). Forests are capable of providing a huge contribution to the country's economy, especially in the timber, food, and pharmaceutical industries. In addition, forests provide benefits to communities in meeting their daily basic needs, which are increasingly felt by communities living entirely dependent on forest resources; based on data from the Indonesian National Research and Innovation Agency 40 million Indonesians still rely on forests for their subsistence (Dewi, 2018). Furthermore, forests also play a very important role in addressing global climate change through the process of absorbing carbon dioxide (CO2) from the atmosphere. Trees in forests perform photosynthesis, converting CO2 into oxygen and storing carbon in their biomass. Therefore, preserving forest sustainability means maintaining an efficient natural reservoir for absorbing and storing carbon. Forest carbon storage refers to the process by which forests act as natural reservoirs for storing carbon dioxide (CO2) from the atmosphere. Through photosynthesis, trees and other vegetation absorb CO2 from the air and convert it into biomass, which includes roots, trunks, branches, and leaves (Russell, et al., 2022). This stored carbon remains locked within the forest ecosystem, contributing to the mitigation of climate change by reducing the amount of CO2 in the atmosphere. Forests play a crucial role in carbon sequestration, serving as vital sinks for atmospheric carbon.

Additionally, carbon can be sequestered in forest soil, further enhancing the capacity of forests to store carbon over the long term. Sustainable forest management practices, such as afforestation, reforestation, and avoiding deforestation, are essential for maximizing carbon storage and sequestration in forests, thereby helping to mitigate the impacts of climate change.

The global sustainability trend also increasingly emphasizes the importance of forest preservation in the context of environmental protection. Communities and businesses are increasingly realizing that preserving forests not only supports biodiversity and ecosystems but also represents a long-term investment in global climate resilience. In response to this awareness, efforts are being made to promote sustainable practices in forest management, including forest certification and environmentally friendly farming practices.

In carbon trading, forests play a role as potential sources for carbon emission mitigation projects. This concept involves payments to countries or forest owners in return for conservation or forest restoration efforts, which effectively help reduce global carbon emissions. Initiatives such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation) attempt to provide financial incentives to countries that successfully preserve their forests (Angelsen & Atmadja, 2010). All of these create a close relationship between forest conservation, carbon absorption, and carbon trading in efforts to achieve sustainability goals globally.

A literature review of forest carbon storage valuation encompasses an examination of various studies and methodologies aimed at quantifying the economic worth of carbon sequestration within forest ecosystems. Researchers typically analyze factors such as forest type, age, density, and management practices to understand their impact on carbon storage capacity (Mandal, et al., 2020), (Alonso, Wetson, Gregg, & Morecroft, 2012). The different valuation approaches, including market-based mechanisms, such as carbon trading and payments for ecosystem services (Crossman, Bryan, & Summers, 2011), as well as non-market valuation techniques, such as contingent valuation (Tao, Yan, & Zhan, 2011), and hedonic pricing (Guitart & Rodriguez, 2010). The review also addresses challenges inherent in valuing forest carbon storage, such as spatial and temporal variability (Sun, et al., 2023), uncertainty in carbon accounting (Yanai, et al., 2020), and the integration of social and ecological considerations (Valatin, 2014).

Valuing ecosystem services, including the carbon advantages of forests, is widely recognized as crucial for informing both public policy and private choices. Evaluating the carbon stored in forests is significant for assessing the pros and cons of various projects, comparing forestry to other investment avenues, and incorporating it into natural capital evaluations. Developing a framework that assigns value to forest carbon is essential for offering financial incentives to businesses and households, encouraging them to consider the climate change implications of their actions (Valatin, 2014).

Carbon storage valuation, similar to property valuation, involves assessing the economic worth of carbon sequestration within natural ecosystems. Just as property valuation determines the market value of real estate assets, carbon storage valuation seeks to quantify the value of carbon stored within forests and other natural habitats. By measuring the carbon content within analyzed forest estates and correlating it with their financial value, we can assess the ecosystem service of carbon sequestration. Consequently, if environmental services are assigned financial worth, they can be viewed as income generated from the property housing the analyzed ecosystem (Kazak, Malczyk, & Castro, 2016). Carbon storage valuation can be used by the income approach that involves assessing the economic value of carbon sequestration based on the potential income generated from this ecosystem service. In this approach, the amount of carbon stored in the ecosystem is quantified, typically measured in metric tons of carbon dioxide equivalent (CO2e). Then, this carbon stock is translated into potential income by valuing the avoided or reduced emissions that result from maintaining or enhancing carbon storage in the ecosystem. This can be calculated based on prevailing carbon prices in markets such as carbon offset markets or carbon trading systems. The income approach to carbon storage valuation recognizes the ecosystem service of carbon sequestration as a form of income generated by the property or land where the ecosystem is located (Kazak, Malczyk, & Castro, 2016). This approach may be particularly relevant in contexts where financial instruments for carbon trading or payments for ecosystem services are available, as it allows for the estimation of the financial value of carbon storage over time.

There are two methods for calculating aboveground biomass in trees: a direct method employing allometric equations, and an indirect method utilizing biomass expansion factors. The indirect method is frequently applied in conjunction with temporary plots, which are commonly utilized in forest inventories (IPCC, 2003).

2. METHODS

2.1. Material

The objective of this study was to estimate the potential financial gain resulting from the absorption of carbon dioxide and the storage of carbon in the biomass of forest ecosystems. Using the systematic stratified sampling technique, data on individual trees were collected. The determination of plot locations must avoid bias and provide equal opportunities for an area to be surveyed. Purposive plot determination is usually carried out when conducting specific research, where the target population is very specific. In addition, to avoid high costs, plot location determination is often adjusted based on existing accessibility, whether following roads, rivers, or canals. The collected data consists of the number of plants at the pole level, according to the criteria, namely the pole growth rate (young trees with a diameter of 30 to 60 cm) and for trees (diameter >60 cm). The standard measurement for diameter uses Diameter at Breast Height (DBH), the diameter at breast height (DBH) is the diameter of a cross-section of a tree trunk 1.3 m above ground. Tree inventory data was collected at two observation points within one plot, with a total number of observation plots is 19. The data was collected within a subplot measuring 10x10 meters, and for trees within a plot measuring 20x20 meters.

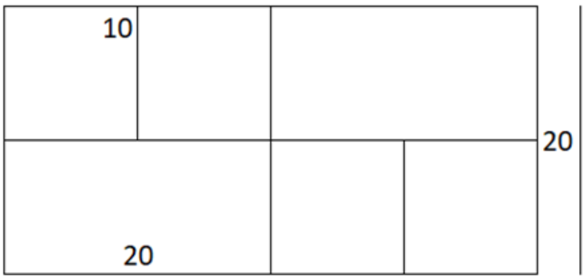

Figure 1: Plot Form That Can Be Used in Biomass Measurements (Sources: Sutaryo, 2009)

The data obtained from measurements of diameter and specific weight are mapped out in a table. Primary data collected directly in the field, which includes tree diameter at breast height and identification of vegetation types, will serve as the basis for estimating biomass. The estimation of biomass calculation in poles and trees resulting from sampling uses the formula proposed by Kettrings et all (2001), the formula used in calculating pole and tree biomass is $B = 0.11\rho D^{2.62}$

B = Biomass (kg/tree)
ρ = Wood Density (grams/cm3)
D = Diameter of trees at breast height (1.3 m)

To determine the amount of carbon stored in biomass, calculations are used based on values from the National Standardization Agency in accordance with SNI number: SNI 7724:2011. The total carbon content according to this standard is 47% of biomass. The formula to estimate carbon storage is C = 0.47 B.
C = Carbon
B = Biomass

3. RESULTS

3.1. Trees Collected

The data collection resulted in 62 poles and 199 trees across 19 sample plots, with several plant species dominating as shown in Table 1.

To obtain the biomass value based on the formula derived from (Ketterings, Coe, Noordwijk, Ambagau, & Palm, 2001) which involves multiplying the wood density of the tree by the diameter of the tree raised to the coefficient, an example calculation for the biomass of Kiseeur/Antidesma tetandrum is provided. The given diameter data is 18.47, and its wood density is 0.6. Therefore, the biomass obtained is calculated as 0.11 * 0.6 * 18.47^2.62 = 137.33 kg. To convert this to tons, divide 137.33 by 1000, resulting in 0.14 tons.

Table 1. The Tree Data Sample Collected from 19 Plots

Plot Dimension	Tree Species	Quantity	Biomass (Ton)
10 x 10 m	Kijeruk / Acronychia pedunculata	7	0.56
	Kileho Merah / Saurauia bracteosa	1	0.04
	Kiseeur / Antidesma tetandrum	1	0.14
	Kitam baga / Syzygium antisepticum	1	0.08
	Puspa / Schima wallichii	17	1.52
	Riung Anak / Casitanopsis javanica	31	2.96
	Saninten / Casitanopsis argentea	2	0.22
	Sloanea Sigun	2	0.12
20 x 20 m	Huru / Neolitsea cassiaefolia	2	0.55
	Kijeruk / Acronychia pedunculata	13	3.78
	Pasang / Litocarpus sundaicus	4	18.44
	Puspa / Schima wallichii	54	31.29
	Riung Anak / Casitanopsis javanica	115	98.49
	Saninten / Casitanopsis argentea	6	2.99
	Sloanea Sigun	5	2.88

Sources: Own Study

The Estimation of ρ (Wood Density) derived from https://worldagroforestry.org/ as the study by Ketterings, Coe, Noordwijk, Ambagau, & Palm, (2001).

The biomass calculation in Table 1 is for one type of vegetation within the sample plot. To obtain the biomass value per hectare, the density of each tree species obtained in each plot needs to be calculated using the following formula:

$$\frac{\Sigma\, tree}{(\Sigma\, plot \times (plot\ dimension/10{,}000)}$$

3.2. Economic Value of Carbon Storage

The tree biomass (B) per hectare is the product of the volume of biomass for each tree multiplied by the tree density. This calculation expresses the biomass in tons per hectare. To estimate the carbon content in plants, the equation used is C = B x 47%, where C represents the Tree Carbon and 47% represents the Carbon Constant according to SNI 7724:2011. The results of the calculations carbon in trees, have been shown in the Table 3.

The amount of carbon stock for each type of vegetation is then multiplied by the carbon market price at the time of the valuation date. The market price of carbon in Indonesia at the time this research was conducted was US$ 4.9 per ton. The total area of

Telaga Warna National Park is 549.66 hectares, with an area of land that has plants is 368.25 hectares. Therefore, the potential carbon value is US$15,339,368.54. This value is obtained by multiplying the carbon value of each vegetation type by the area of Telaga Warna National Park covered by trees.

4. DISCUSSION

Forests serve as significant carbon sinks, absorbing carbon dioxide (CO2) from the atmosphere through a variety of processes and components within the ecosystem. Photosynthesis, the primary mechanism by which forests sequester carbon, involves trees and other vegetation absorbing CO2 and converting it into organic compounds using sunlight. This process results in the accumulation of carbon in the biomass of trees, including their roots, trunks, branches, and leaves, as they grow. Additionally, forest soils contain substantial carbon stored in organic matter derived from decomposing plant material, roots, and soil microbes (Ravindranath & Ostwald, 2007). The litter layer formed by fallen leaves and organic debris on the forest floor also contributes to carbon storage as it decomposes over time. Deadwood, consisting of standing and fallen trees, slowly releases carbon as it decays, providing habitat for various organisms and supporting ecosystem processes. Understory vegetation, though less significant than trees, contributes to biomass carbon storage and soil carbon maintenance. Forest regeneration further enhances carbon sequestration by young trees and regenerating vegetation, particularly in areas affected by disturbances such as logging or wildfires. Overall, proper forest management practices are crucial for maximizing carbon sequestration capacity, thereby contributing to climate change mitigation efforts.

Table 2. The Tree Density

Plot dimension	Tree Species	Tree Density (trunk/Ha)
10 x 10 m	Kijeruk / Acronychia pedunculata	36.84
	Kileho Merah / Saurauia bracteosa	5.26
	Kiseeur / Antidesma tetandrum	5.26
	Kitam baga / Syzygium antisepticum	5.26
	Puspa / Schima wallichii	89.47
	Riung Anak / Casitanopsis javanica	163.16
	Saninten / Casitanopsis argentea	10.53
	Sloanea Sigun	10.53
20 x 20 m	Huru / Neolitsea cassiaefolia	2.63
	Kijeruk / Acronychia pedunculata	17.11
	Pasang / Litocarpus sundaicus	5.26
	Puspa / Schima wallichii	71.05
	Riung Anak / Casitanopsis javanica	151.32
	Saninten / Casitanopsis argentea	7.89
	Sloanea Sigun	6.58

Sources: Own Study

Table 3. The Economic Value of Carbon Storage

Plot dimension	Tree Species	Biomass (Ton/ha)	Carbon Storage (Ton/ha)	Carbon Value (US$/ha)
10 x 10 m	Kijeruk / Acronychia pedunculata	20.80	9.78	48.20
	Kileho Merah / Saurauia bracteosa	0.21	0.10	0.48
	Kiseeur / Antidesma tetandrum	0.72	0.34	1.67
	Kitam baga / Syzygium antisepticum	0.41	0.19	0.95
	Puspa / Schima wallichii	136.41	64.11	316.06
	Riung Anak / Casitanopsis javanica	483.02	227.02	1,119.21
	Saninten / Casitanopsis argentea	2.30	1.08	5.33
	Sloanea Sigun	1.30	0.61	3.02
20 x 20 m	Huru / Neolitsea cassiaefolia	1.45	0.68	3.35
	Kijeruk / Acronychia pedunculata	64.73	30.42	149.98
	Pasang / Litocarpus sundaicus	97.03	45.60	224.83
	Puspa / Schima wallichii	217.44	102.20	503.84
	Riung Anak / Casitanopsis javanica	14,902.80	7,004.32	34,531.28
	Saninten / Casitanopsis argentea	23.62	11.10	54.72
	Sloanea Sigun	18.97	8.92	43.96

Sources: Own Study

The research conducted in Telaga Warna National Park revealed a rich diversity of plant species within the ecosystem. Specifically, the study concentrated on two distinct categories of plants: pole plants, characterized by diameters ranging from 10 cm to 19.9 cm, and trees, distinguished by diameters larger than 20 cm. Through careful observation and analysis, a total of 8 species of pole plants and 7 species of tree plants were identified. The sample data only utilizes 19 plots with an area per plot of 20 square meters may initially seem insignificant when compared to the total area of the national park, which spans 382 hectares. However, the data from these 19 plots actually holds significant value in representing carbon values within the national park. This assertion is based on the similarity of vegetation types across the entire national park. Despite the relatively small sample size, the chosen plots are strategically placed to capture the variability of vegetation types and carbon storage potential within the park. Additionally, utilizing a consistent plot size ensures uniformity in data collection methodology, facilitating accurate comparisons and analysis. While it is acknowledged that extrapolating findings from a limited number of plots to the entire national park requires caution, the homogeneity of vegetation across the park lends credibility to the extrapolated results. Therefore, although the sample size may appear modest, the data collected from these 19 plots provide valuable insights into the carbon storage dynamics of Telaga Warna National Park. Future research endeavours could aim to expand the sample size or employ additional methodologies to further enhance the robustness of the findings. This focused examination underscores the importance of understanding the composition and distribution of vegetation types within the national park.

Based on the valuation of carbon storage in Telaga Warna National Park, the value exceeds 15 million dollars. This value is relatively small compared to the total area of forests in Indonesia. According to data from the Ministry of Forestry and Environment of the Republic of Indonesia, the total forest area in Indonesia is 96 million hectares. In assessing the aforementioned carbon valuation, we used carbon market prices from the Indonesian carbon exchange. Whereby, carbon market prices in Indonesia are still lower compared to global carbon market prices. Carbon prices in European countries are generally higher compared to countries in other regions. Referring to the global average prices, the carbon reserve value of Telaga Warna National Park will be higher. This difference in carbon prices underscores the importance of considering both local and global market dynamics in valuation methodologies.

Although the nascent carbon market in Indonesia reflects sustainable efforts, carbon pricing mechanisms still need to align with prevailing market price developments to harmonize with international standards. Furthermore, this indicates the potential for increased realization of carbon value in Indonesian forests as global carbon markets mature and carbon pricing mechanisms strengthen. Additionally, in order to maintain the stability of carbon reserves in Telaga Warna National Park, continuous monitoring and supervision are required. This is to ensure that the existing trees do not decrease due to human activities or disturbances from nature. This assessment of carbon storage solely calculates the economic value of carbon absorbed by plants within the forest. Although carbon content can be absorbed by the soil beneath the forest, fallen or dead trees, and even leaves, whether still on the tree or already fallen. Therefore, the results of this assessment of carbon storage may not be maximal, and it is possible that the potential value of carbon storage in Telaga Warna National Park as a whole will be even greater. The existence of carbon trading agreements under the Kyoto Protocol will provide an opportunity for developing countries like Indonesia to develop and maintain existing forests and vegetation for trade with industrialized nations, potentially increasing national revenue.

5. CONCLUSIONS

The research obtained 261 poles and trees consisting of 10 types of vegetation from 19 sample plots. The assessment results of carbon storage in trees show that their diameter and wood density influence the carbon absorption capacity of plants. The larger the diameter of the plant, the higher its carbon content; similarly, the higher the wood density, the greater the carbon content. The valuation of carbon storage in Telaga Warna resulted in a value of US$15,339,368.54. The potential economic value of carbon storage would be even greater when considering all components capable of carbon absorption in the Telaga Warna National Park area.

By recognizing the economic value of carbon storage, stakeholders can develop strategies to enhance forest protection, restoration, and sustainable management practices. This holistic approach not only contributes to climate change mitigation goals but also promotes biodiversity conservation, enhances ecosystem resilience, and supports local livelihoods. In conclusion, the economic value of carbon sequestration in Telaga Warna National Park underscores the critical role of forests in addressing global environmental challenges. This study provides valuable insights into the economic benefits of forest conservation and underscores the need for concerted efforts to preserve and sustainably manage Indonesia's forest ecosystems. By recognizing and harnessing the economic value of carbon sequestration, policymakers, conservationists, and local communities can work together to safeguard our natural heritage and build a more resilient and sustainable future.

The carbon sequestration values presented in this study are limited to the data collected from the sampled plots within Telaga Warna National Park. The calculations assume that the vegetation across the study population exhibits characteristics similar to those of the sampled data during field collection. Consequently, variations in vegetation composition, growth conditions, or other environmental factors outside the sampled areas may affect the generalizability of the findings

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