BorneoScience
The Journal of Science & Technology
Volume 45 Issue 1 : March 2024
Online ISSN : 2231-9085 | ISSN : 1394-4339

AN ASSESSMENT OF TREE BIODIVERSITY AND CARBON STOCKS IN HAROWU SOCIAL FORESTRY AREA, GUNUNG MAS, INDONESIA

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Received 27th April 2024; accepted 18th June 2024
Available online 1st November 2024
Doi: https://doi.org/10.51200/bsj.v45i1.5491

ABSTRACT*. Harowu Village, located in the upper reaches of the Kahayan River within the Mirimanasa Subdistrict, officially oversees a state-granted area of 1,750 hectares. The conservation of the forest in this region is of utmost importance due to its significant influence on the Kahayan watershed. Instiper Yogyakarta, a forestry educational institution, has initiated programs to educate the local community about the importance of alternative income sources and environmental services. Utilizing the Forest Inventory methodology created by USAID LESTARI in 2018 and coordinated by Michigan State University, the study involved analyzing 10 plots with a sampling intensity of 0.221. The Harowu Forest is identified as a major carbon sink, sequestering 626.957,75 tons of carbon in the area. The forest is home to 25 tree species and features a Menhenick Index of 1.57, Margalef Index of 4.34, Shannon Index of 2.98, Simpson index of 0.974, and an evenness value of 0.93. These findings highlight potential opportunities for collaboration between Harowu and Instiper Yogyakarta to promote forest conservation and improve community welfare.*

KEYWORDS: *Biodiversity, Carbon stock, Harowu Forest; Environmental Partnership, Conservation*

INTRODUCTION

Harowu is a village situated at the upper reaches of the Kahayan River, at the northern edge of Gunung Mas Regency, making it a remote location. Access to the village is particularly challenging, especially during the rainy season. Its position is critical as it lies within the primary section of the river basin, significantly affecting the continuity and sustainability of the water catchment area that serves as a source for the Kahayan River. Biodiversity in this area is often overlooked during monitoring efforts, as many species lack apparent economic value to the community. Nevertheless, this diversity is crucial and should be conserved due to its vital role in providing ecosystem services through forests (Maimunah et al., 2022).

Harowu features a social forestry institution in the form of a Village Forest, encompassing an area of 1,750 hectares, as per the Decree of the Minister of Environment and Forestry Number: 6603/MENLHK-PSKL/PKPS/PSL.0/2016. This village forest is located in Harowu Village, Miri Manasa District, Gunung Mas Regency, Central Kalimantan, and is contiguous with another forest area of the same type, though managed differently. There is a strong community interest in land ownership within the Village Forest zone, reflecting a cultural shift from traditional lifestyles to urbanized patterns. The village is surrounded by steep mountain cliffs and healthy forest ecosystems, contributing to an abundant supply of clean water. The presence of numerous mountain springs and waterfalls in the area highlights its potential for regional development in areas such as ecotourism, hydroelectric power generation, and the bottled water industry.

Instiper Yogyakarta is a university dedicated to agricultural sciences in its broadest sense, which includes a Forestry Faculty focused on community assistance programs, particularly in social forestry management. The university aims to develop initiatives and innovations that support communities in effectively managing their forests (social forestry), aligning with the community's strong commitment to nature conservation. This commitment was evident during training sessions on community plantation forest management organized by Instiper Yogyakarta, which inspired participants to actively engage in forest protection.

Instiper Yogyakarta is dedicated to fostering and supporting the community through a collaborative approach to managing social forestry. This effort contributes to sustainable economic development, forest conservation, and the facilitation of social forestry management activities within the Harowu Village Forest, enhancing the value derived from forests managed independently by the community. The objective is to ensure that village forest managers understand biodiversity's potential, as plant life plays a crucial role in maintaining air quality and soil conservation (Raven & Wackernagel, 2020). Additionally, there is a focus on identifying potential alternative income sources from non-timber forest products and environmental services, aiming to facilitate knowledge transfer. This will empower managers to competently identify and manage village forest biodiversity, enabling them to collaboratively protect these areas from threats. It is vital to undertake these activities, as changes in land cover from forest to agricultural use can significantly diminish carbon stocks (Priyadarshini *et al*., 2019).

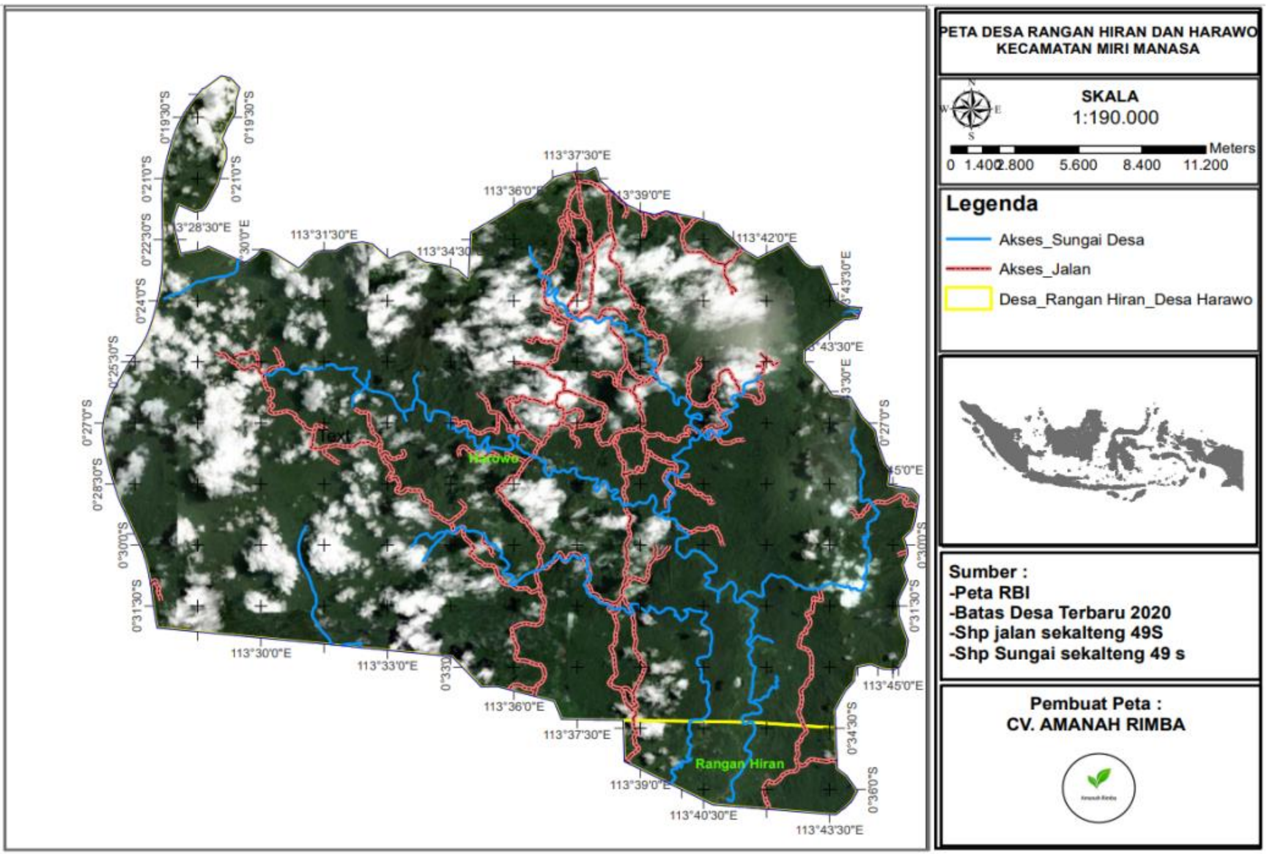
This collaborative management agreement has been officially documented as a cooperation agreement between the two parties and is recognized by the Government. This partnership serves as a model for the type of social forestry management envisioned by the Indonesian Government, which emphasizes multi-stakeholder support in empowering communities surrounding forests to manage social forestry areas authorized by the government. The partnership between Instiper Yogyakarta and the Harowu village forest management institute focuses on forest conservation and sustainable management of village forests, reflecting a commitment by oil palm plantation companies to preserve nature and the surrounding environment, including forest ecosystems.

METHODOLOGY

Research Locations

Harowu Village Forest represents a model of social forestry through a community plantation forest situated in the Mirimanasa District of Gunung Mas Regency, Central Kalimantan Province, covering an area of 1,750 hectares. This forest predominantly consists of karst landscapes with challenging topography, featuring springs, waterfalls, clear rivers, steep rock walls, caves, and a variety of rare tree species such as ironwood (*Eusideroxylon zwageri*), various keruing species (Dipterocarpus), and several types of meranti (*Shorea montigena* Slooten), all coexisting with diverse wildlife. The location presents significant challenges, including widespread illegal land clearing for other uses, while law enforcement and management oversight remain inadequate, emphasizing the need for assistance for area management groups.

Field inventory data was gathered from sample plots distributed across two research locations. The inventory plots were arranged on a regular grid with a minimum distance of 50 meters between them. Tree species were documented within 20 x 20 meter plots, while seedlings were surveyed in 2 x 2 meter plots. Measurements of tree diameter at breast height (DBH) and total tree height were conducted using nested plots: trees with a DBH greater than 20 cm were measured in 20 x 20 meter plots, those between 10 cm and 20 cm DBH were measured in 10 x 10 meter plots, and trees with a DBH greater than 5 cm but less than or equal to 10 cm were recorded in 5 x 5 meter plots.



Source: Kahayan Hulu Forest Management Unit (2023)

Field data was analyzed using a calculator and an Excel-based tool developed by Michigan State University as part of the USAID LESTARI project (2018). One of these tools calculates total tree carbon stock (tC), wood volume (m^3 ha^{-1}), and tree density (trees ha^{-1}). The second tool is designed to compute various biodiversity indices, including species richness, evenness, and dominance for trees (greater than 2 cm DBH) and seedlings. The allometric model employs the tree's DBH to estimate its total live biomass (kg). Carbon is then derived from biomass using a conversion factor of 0.47, which is the default value provided by the IPCC (Hiraishi *et al*., 2014). Carbon stocks for each tree size class within nested plots are summed and converted to tons (tC). These values are aggregated to determine the total carbon per plot, which is subsequently scaled to report tC per hectare. The averages across all plots are calculated and multiplied by the site area to estimate the overall carbon stock (tC) (Krisnawati *et al*., 2012).

$$B = 0.75 * Dt\text{^}2.23 \qquad \text{Eq. 1}$$

Where
B = total tree biomass in kg
Dt = diameter at breast height (1.3 m above ground) in cm

Timber volume (m^3) was determined by applying measurements of diameter at breast height (DBH) and tree height in a numerical equation, then summing the results for all trees within the plot and scaling it to hectares. The average was subsequently calculated across all plots. Using equations modified for shape coefficients yields conservative estimates of wood volume.

$$Dw = ((1/4) * ((PI() * ((Dt/100)\text{^}2)) * Ht) * 0.6) \qquad \text{Eq. 2}$$

Where
Dw = wood volume in m^3
Dt = diameter at breast height (1.3 m above ground) in cm
Ht = total height of the tree in m

Tree density (trees ha^{-1}) was determined by counting the number of trees in three nested size class plots, with each size class count scaled to the hectare level. The average density was then calculated for all plots on the site according to tree size class. The biodiversity tool employs species counts from fixed-area sample plots to compute various biodiversity indices for both trees and seedlings. The indices and calculation methods are presented in Table 1.

Table 1: Plant Biodiversity Indices and measurement methods utilized by the biodiversity calculator tool

Indices	**Computation Method**
Species Richness	S = number of species or taxa
Menhinick's Index (Menhinick, 1964)	D = S/(SQRT N); where S = the number of different species in the sample and N = the total number of individual organisms in the sample
Margalef's Richness Index (Margalef, 1958)	(S-1)/ln(N)
Shannon Index of Species Diversity (Shannon, 1948)	$H = -\sum_{i=1}^{S} p_i \ln p_i$; where pi = the proportion of the total number of individuals

Simpson Index of Diversity (Simpson, 1949)	1 - D = 1 -∑ (n / N)2; where D is the Simpson Index which measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species)
Evenness Index	Evenness = H'/lnS uses Shannon index and species richness values

RESULTS AND DISCUSSION

Biodiversity of Harowu Forest

The counts of each tree and seedling recorded in every sample plot are detailed in Table 2. Trees were assessed in six plots, where they were evenly distributed. Table 2 includes various biodiversity indices calculated for both sites, along with the dominant species for trees exceeding 5 cm DBH and for seedlings. As anticipated in a robust forest ecosystem, both tree species richness and biodiversity indices displayed elevated values.

Table 2 Biodiversity of trees and seedlings

Indices	Trees (n=40)	Seedlings (n=22)
Species Richness	25	12
Menhinick's Richness Index	1,57	0,88
Margalef's Richness Index	4,34	2,11
Shannon Index	2,98	2,08
Simpson Index of Diversity	0,94	0,84
Evenness	0,93	0,84
Dominant species	Pisang-pisang/mahawai (*Polyathia lateriflora* King.) Karipak nangka (*Artocarpus kemando*) Mahang kirik (*Macaranga triloba*) Mandarahan merah (*Horsfieldia irya*) Pampaning bitik (*Querqus subsericea*)	Kopi-kopi (*Fragraea racemosa*) Jambu merah (*Syzygium spp*) Meranti bunga (*Shorea parvifolia*) Keruing bayan tuwung (*Dipterocarpus rigidus*) Cangal gading (*Upuna borneensis)*
Others Floras	Lianas: 70 Shrubs: 90	Ferns: 10 Pandan: 5 Small Check: 30 Others Herbal Plants: 24

Table 2 presents that the Richness Value is 25 for trees and 12 for seedlings, with Menhinick's Richness Index at 1.57 for trees and 0.88 for seedlings. Margalef's Richness Index stands at 4.34 for trees and 2.11 for seedlings, while the Shannon Index is 2.98 for trees and 2.08 for seedlings. The Simpson Index of Diversity is 0.94 for trees and 0.84 for seedlings, with Evenness values of 0.93 for trees and 0.84 for seedlings. These high biodiversity indices indicate a healthy forest ecosystem (Maimunah et al., 2021).

The dominant species among trees include Pisang-pisang/mahawai (*Polyathia lateriflora* King.), Karipak nangka (*Artocarpus kemando*), Mahang kirik (*Macaranga triloba*), Mandarahan merah (*Horsfieldia irya*), and Pampaning bitik (*Quercus subsericea*). For seedlings, the dominant species are Kopi-kopi (*Fragraea racemosa*), Jambu merah (*Syzygium* spp), Meranti bunga (Shorea johorensis), Keruing tuwung bayan (*Dipterocarpus rigidus*), and Cangal gading (*Upuna borneensis*). The red Mandarahan (*Horsfieldia irya*) and Jambu merah (*Syzygium* spp) species have also been identified by Mirmanto (2009) and Kalima et al. (2020) in the same province, indicating their status as indigenous species.

Carbon Stock of Harowu Forest

Table 3 presents various site characteristics for data collection and analysis, including the number of plots, total area, and plot size. It also details site-level carbon stocks, which encompass the average tC ha^{-1} across all plots, along with the range and standard deviation of total carbon for the sites. Additionally, the table includes the sampling error and accuracy range based on the number of plots, assessed at a 95% confidence level.

Table 3. Recapitulation of calculation of carbon stocks in the Harowu forest area

Properties	Value
Number of Plot (n)	6
Forest Area (ha)	1750
Total Carbon in Plot (tons)	2149,57
Averaage Carbon in Plot (tons)	358,26
Standard Deviation (tons)	645,97
Plot Size (ha)	0,04
Population (N)	43750
t-student value (α=5%)	2,57
Average default error rate (tons)	263,7
CI95% average (lower limit) (tons)	316,52
CI95% average (upper limit) (tons)	400
Sampling Error (%)	11,65
Total carbon stock (tC) – Lower (tons)	553.907,40
Total carbon stock (tC) (tons)	626.957,75
Total carbon stock (tC) – Upper (tons)	700.008,09

The average carbon stock in community forests is 358.26 tons C ha^{-1}, which is comparable to the average total carbon per hectare found in natural forests within Gunung Mas Regency, as reported by Astuti *et al*. (2020). This indicates that community-managed forests show no signs of carbon reduction. The total carbon observed at the research site exceeds the figures reported by Besar *et al*. (2020), suggesting that the community is effectively managing the village forest, ensuring its sustainability. The total carbon in the plot amounts to 2,149.57 tons C ha^{-1}, and the range of carbon values across all sample plots indicates a total carbon stock of 626,957.75 tons C. Estimating carbon stocks is crucial, as it helps sequester greenhouse gases and mitigate emissions into the atmosphere that contribute to climate change (Maimunah *et al*., 2023). The accuracy of these carbon estimates is enhanced due to the number of sample plots, the size of the plots, and the variability of carbon across the samples.

Wood Volume and Tree Density

Table 4 summarizes the calculations of tree volume by size class, including the number of trees in the sample plot, wood volume, and tree density. The distribution of tree size classes in both locations was notably skewed towards the largest size class, specifically trees with a diameter at breast height (DBH) of more than 15 cm, compared to poles and saplings. However, the number of trees per plot by size class can be somewhat misleading due to data being collected in nested plots of 5 x 5 m (for saplings), 10 x 10 m (for poles), and 20 x 20 m (for large trees). The table includes the sampling and tree counts in brackets, estimating totals for a 20 x 20 m plot based on observed nesting plots or actual counts. The overall average wood density for all trees (m^3 ha^{-1}) was higher at site 2 by one and had a greater volume than site 1. At both sites, large trees contributed to 90% of the total average tree wood volume. Regarding tree density, the number of trees per hectare included a larger proportion of old trees, with the large tree class comprising 66% and 62%, respectively.

Table 4 Wood volume and tree density in Harowu Village Forest

Stage Development	Volume (m^3 ha^{-1})	Average Tree Density (tree ha^{-1})
Saplings	82,31	0
Poles	123,77	2.533
Trees	796,18	717
Total	1002,26	254

Harowu Village Forest features a karst forest ecosystem intermingled with secondary tropical forest, hosting a variety of wildlife, including numerous bird species and rare animals like haruwei, partridges, porcupines, deer, and wild pigs, all of which inhabit the forest alongside several rare tree species such as ironwood, various types of meranti and keruing, gutta-percha, binuang, and several plants used for traditional medicine. The forest's key habitat elements include distinctive caves, rock formations, waterfalls, springs, and mineral lakes, providing essential areas for wildlife. The volume and density of trees in the sapling category are recorded at 82.31 m^3 ha^{-1}, for poles at 123.77 m^3 ha^{-1}, and for larger trees at 796.18 m^3 ha^{-1}, with densities of 2.53 trees ha^{-1} for poles and 717 trees ha^{-1} for larger trees. These figures indicate that the forest is continuously regenerating, thereby preventing degradation (Maimunah *et al.*, 2022). The carbon stocks in this area are also significant, totaling 626,957.75 tonnes C/ha, which must be preserved and enhanced despite the challenges posed by illegal land clearing activities. Potential solutions include raising awareness and creating new job opportunities that promote long-term forest conservation.

CONCLUSION

The findings of this research highlight the importance of analyzing field inventory data in forests to provide insights into ecosystem service levels. In this study, the biodiversity metrics for tree categories are as follows: Richness (25), Menhinick's Richness Index (1.57), Margalef's Richness Index (4.34), Shannon Index (2.98), and Simpson Index of Diversity (0.94). For the seed categories, the values are: Richness (12), Menhinick's Richness Index (0.88), Margalef's Richness Index (2.11), Shannon Index (2.08), Simpson Index of Diversity (9.84), and Evenness (0.84). The carbon stock is measured at 358.26 tons C ha^{-1}. Both carbon stocks and biodiversity serve as critical indicators of forest health. Although the tree biodiversity reported in this area is relatively low, it suggests that the forest functions as a reasonably healthy ecosystem. Expanding biodiversity assessments to include non-tree biota would be beneficial, as these measurements could demonstrate the richness of forest habitats in terms of diverse flora and fauna.

Estimating carbon stocks is vital to illustrate the role these forests play in sequestering greenhouse gases within their biomass, thus preventing emissions that contribute to climate change. Conducting repeated measurements to track changes in carbon stocks is essential for understanding whether these areas are increasing their carbon sequestration over time or emitting carbon. Monitoring carbon additions from tree growth or losses is crucial for developing effective management strategies for these forest areas. Given that the site is designated for ecotourism, informing visitors about the forest's carbon stock will enhance their awareness and may foster contributions to tropical forest conservation. Lastly, the inclusion of local communities, especially those who directly benefit from the forests of Harowu Village in Gunung Mas Regency, is of utmost importance and cannot be overstated.

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