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

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ABSTRACT. *Rangan Hiran Village, located in the upper reaches of the Kahayan River within the Mirimanasa Subdistrict, encompasses an officially designated area of 875 hectares assigned by the state. The necessity of conserving the forest in this region arises from the significant effects of community initiatives on the Kahayan watershed. Instiper Yogyakarta, a forestry educational institution, has launched a program to educate the community about the inherent value of ecosystem services, potential alternative sources of income, and the benefits they offer. The research methodology employed utilizes the Forest Inventory and Analysis Plus (FIA+) method, which was developed by USAID LESTARI in 2018 and is overseen by Michigan State University, USA. An analysis of 10 plots with a sampling intensity of 0.221% indicates a healthy state of the current forest. The carbon stock contributed by Rangan Hiran Forest amounts to 243,998.57 tons and consists of 40 different tree species. Ecologically, the forest exhibits a Menhenick Index of 2.58, a Margalef Index of 7.11, a Shannon Index of 3.43, a Simpson Index of 0.96, and an evenness value of 0.93. These identified potentials create opportunities for collaborative efforts between Rangan Hiran and Instiper Yogyakarta, concentrating on initiatives for forest conservation and the improvement of community well-being.*

KEYWORDS: Biodiversity, Carbon Sequestration, Social Forest; Environmental Partnership Instiper Yogyakarta

INTRODUCTION

Rangan Hiran, situted in the remote upper reaches of the Kahayan River in Gunung Mas Regency, plays a crucial role in the watershed dynamics of the area. Access to the village is notably limited, especially during the rainy season (Segah *et al*., 2023). A key highlight is the establishment of an 865-hectare Community Forest, recognized by Ministerial Decree Number: 6608/MENLHK-PSKL/PKPS/PSL.0/2016. This Community Forest, adjacent to a similar initiative in Harowu Village, showcases a growing interest in land ownership among residents, reflecting a shift in cultural norms towards more urbanized lifestyles. The rugged terrain surrounding Rangan Hiran, characterized by steep slopes and flourishing forests, is rich in clean water sources, such as mountain springs and waterfalls. These natural features offer potential for ecotourism, hydroelectric energy generation, and bottled water industries, indicating promising avenues for economic development (Harden & Fernández, 2022; Putri *et al*., 2020).

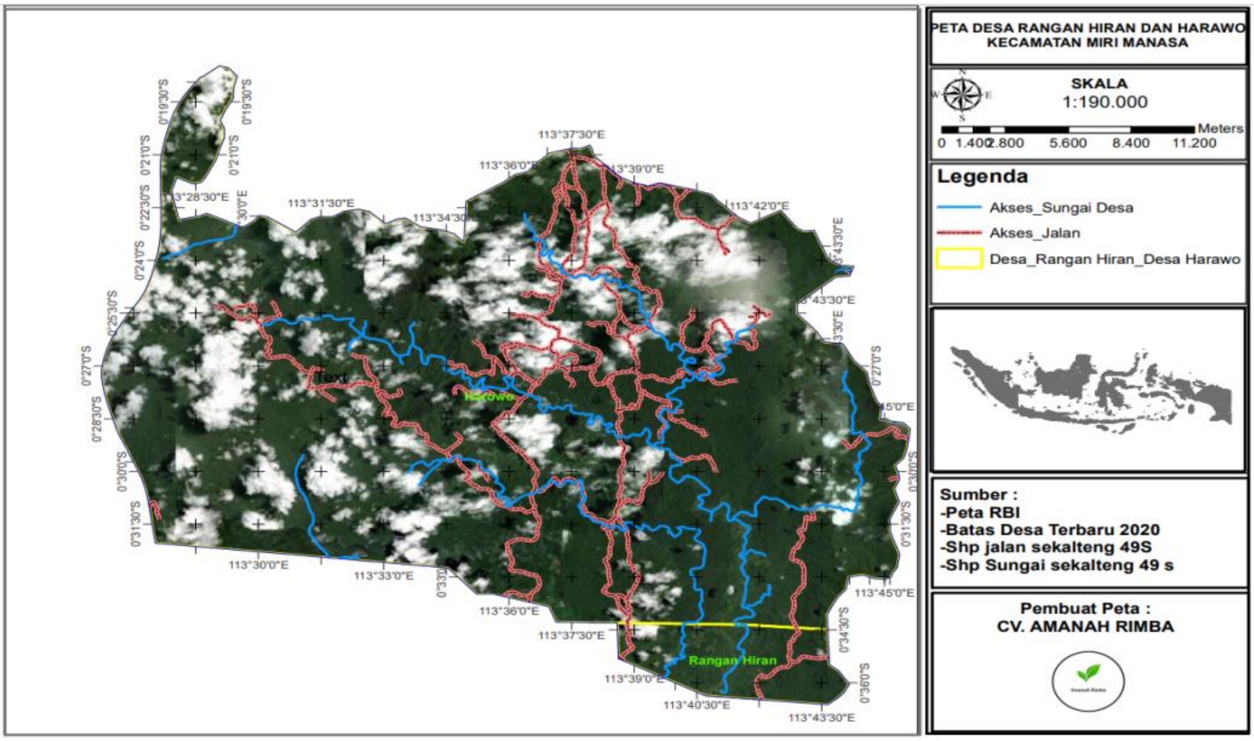
INSTIPER Yogyakarta, alongside its Faculty of Forestry, actively supports local communities involved in social forestry. Through various training programs, they enhance forest management skills and promote community participation in conservation efforts. This partnership, backed by the government and formalized through a Memorandum of Understanding (MoU), exemplifies collaborative forest management. INSTIPER and the Rangan Hiran Village Forest Management Institution are dedicated to conservation and sustainable practices within the designated forest area. This approach aligns with Indonesia's social forestry framework, which encourages community stewardship and reflects a commitment to environmental preservation, with support from the oil palm plantation company.

The significance of this activity lies in its foundational role in forest conservation and management. It entails assessing the biodiversity value of flora and the carbon sequestration capabilities within the forest. The biodiversity of forest plants is essential for maintaining ecosystem balance and supporting human livelihoods (Brandon, 2014). A diverse array of plant species creates intricate food webs, affects nutrient cycles, and contributes to ecosystem stability (Bauhus *et al*., 2017; McMeans *et al*., 2015). Furthermore, the biodiversity of forest plants is vital for genetic conservation, which facilitates plant adaptation to environmental changes and enhances resistance to diseases (Isabel et al., 2020). Additionally, forest plants offer environmental advantages by filtering air, preventing soil erosion, and maintaining water quality (Burivalova *et al*., 2019). Simultaneously, the carbon sequestration potential of forest plants is crucial for addressing global climate change (Karimah, 2017; Rajeev & Hukum, 2020). By capturing carbon in their biomass, these plants contribute to lowering atmospheric carbon dioxide levels, thereby alleviating the greenhouse effect and slowing the pace of climate change (Favero *et al.*, 2017; Nunes *et al*., 2020).

MATERIALS AND METHODS

Research Location

The Rangan Hiran Village Forest is a type of social forestry that consists of community-managed plantations located in the Mirimanasa District of Gunung Mas Regency, Central Kalimantan Province, encompassing an area of 865 hectares. The predominant landscape features karst topography with significant elevation changes. Within this forest, one can find various natural elements such as springs, waterfalls, clear rivers, steep rock faces, caves, and large rare tree species, including ironwood (Eusideroxylon zwageri), different types of keruing (Dipterocarpus), and several varieties of meranti (Shorea montigena Slooten), as well as a diverse array of wildlife. However, the area faces challenges like extensive deforestation due to illegal activities, ineffective law enforcement, and insufficient monitoring and management, highlighting the need for support for local management groups.



Source: Kahayan Hulu Forest Management Unit (2023)

Plant Biodiversity and Carbon Sequestration Measurement

Field inventory data were gathered from sample plots located in two research sites. The inventory plots were arranged in a regular grid pattern, ensuring a minimum distance of 50 meters between each plot. Tree species were recorded within 20 × 20 m plots, while seedlings were noted in 2 × 2 m plots. Measurements included tree diameter at breast height (DBH) and total tree height, using nested plots: trees greater than 20 cm DBH were assessed in 20 × 20 m plots; those larger than 10 cm and up to 20 cm DBH were measured in 10 × 10 m plots; and trees greater than 5 cm and up to 10 cm DBH were evaluated in 5 × 5 m plots.

Data collected from the field were analyzed using Excel-based tools developed by Michigan State University as part of the USAID LESTARI project (2018). The first tool calculated the total tree carbon stock (tC), wood volume (m^3/ha), and stand density (trees/ha). The second tool was utilized to compute various biodiversity indices, including species richness, evenness, and dominance, for trees (greater than 2 cm DBH) and seedlings. Allometric models based on tree DBH were used to estimate total live tree biomass (kg). Carbon content was derived from biomass using a conversion factor of 0.47, which is the standard value provided by the IPCC. The carbon stocks for each tree size class within the nested plots were totaled and converted to tons (tC). These totals were then aggregated to determine the overall carbon per plot and scaled for reporting carbon per hectare (tC/ha). Finally, averages across all plots were calculated and multiplied by the site area to estimate total carbon stocks (tC) (Krisnawati *et al.*, 2012).

$$B = 0.75 \times Dt^{2.23} \quad \text{Eq. 1}$$

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

The wood volume (m^3) was determined using measurements of diameter at breast height (DBH) and tree height, applying a numerical equation. The calculations were aggregated for all trees within the plot and converted to a per-hectare basis. Subsequently, averages were calculated for all plots. To ensure conservative estimates for wood volume, an equation incorporating form factor coefficients was utilized.

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

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

Stand density (trees per hectare) was determined by counting the number of trees within three nested plots of different size classes, with each count scaled to a per-hectare basis. The average density for all plots at the site was then calculated according to tree size class. Biodiversity indices were derived from species counts within designated sample plot areas, allowing for the computation of various biodiversity indices for both trees and seedlings. Table 1 outlines the biodiversity indices, and the methods used for their calculation with the Biodiversity Calculator tool.

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/(√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

RESULT AND DISCUSSION

Biodiversity of Rangan Hiran Forest

Table 2 outlines the number of trees and seedlings recorded within each sample plot. A total of 6 plots were surveyed, with the trees distributed evenly across them. The table lists various biodiversity indices calculated for both locations, along with the dominant species for trees greater than 5 cm in diameter at breast height (DBH) and seedlings. As expected in a thriving forest ecosystem, both the species richness of trees and the biodiversity indices reflect moderate values, indicative of a healthy forest system.

Table 2. Plant biodiversity analysis in Rangan Hiran Forest

Indices	**Trees (n=40)**	**Seedlings (n=22)**
Speciess Richness	40	22
Menhinick's Richness Index	2,58	1,69
Margalef's Richness Index	7,11	4,09
Shannon Index	3,43	2,56
Simpson Index of Diversity	0,96	0,90
Evenness	0,93	0,83
Dominant species	Jambu merah (*Syzygium spp.*) Meranti bitik(*Shorea parvifolia*.) Jambu putih (*Syzygium spp.*) Plepek *(Shorea johorensis* Foxw.) Emang (*Hopea dryobalanoides*)	Meranti bitik (*Shorea parvifolia*) Keruing bayan Tuwung (*Dipterocarpus rigidu*s) Plepek *(Shorea johorensis* Foxw.) Benuas (*Shorea xanthophylla*) Timun-timun (*Hopea sericea*)
Other Floras	Lianas (n = 79) Shrubs (n = 90)	Ferns (n = 10) Pandanus (n = 5) Brushwood (n = 30) Other Herbs (n = 24)

The biodiversity indices for the surveyed trees and seedlings, consisting of 40 and 22 individuals respectively, are summarized in Table 2. The species Richness Index stands at 40 for trees and 22 for seedlings, indicating a notable diversity across different life stages within the Rangan Hiran forest ecosystem. Menhinick's Richness Index is 2.58 for trees and 1.69 for seedlings, while Margalef's Richness Index is 7.11 for trees and 4.09 for seedlings. These Richness Indices for both trees and seedlings suggest significant species diversity within the forest. The results from Menhinick's and Margalef's Indices, along with overall species richness, reflect a diverse composition that contributes to the overall biodiversity. This indicates that the surveyed forest area supports a rich array of plant species across various life stages, which is a sign of a healthy and resilient ecosystem (Maimunah et al., 2021).

The biodiversity indices and evenness values offer important insights into the ecological dynamics and health of the surveyed forest ecosystem. The Shannon Index values of 3.43 for trees indicate a high level of species diversity, while the value of 2.56 for seedlings reflects a moderate level within their respective populations. This suggests that the forest sustains a variety of species at different life stages, enhancing overall ecosystem resilience and functionality. The relatively high Shannon Index values further imply that the forest is ecologically rich and diverse, characteristic of a healthy ecosystem. Additionally, the Simpson Index values of 0.96 for trees and 0.90 for seedlings indicate a comparatively high degree of floral biodiversity and heterogeneity. This index also suggests an even distribution of species abundance within the populations, as evidenced by the calculated evenness values of 0.93 for trees and 0.83 for seedlings. The evenness in the forest indicates a balanced representation of different species within the ecosystem. This balanced distribution of species abundance further reinforces the idea of a healthy and resilient forest ecosystem, suggesting that no single species exerts disproportionate influence over the others.

The dominant tree species, including *Syzygium* spp., *Shorea dasyphylla*, *Shorea johorensis* F*oxw*., and *Hopea dryobalanoides*, along with the prevalent seedling species such as *Shorea dasyphylla*, *Dipterocarpus rigidus*, *Shorea scrobiculata*, *Shorea xanthophylla*, and *Hopea sericea*, highlight their ecological importance in shaping the structure of the forest community. Moreover, the presence of other plant groups, including lianas, shrubs, ferns, pandanus, brushwood, and various herbs, further enhances the overall botanical diversity of the area, underscoring its ecological richness. Collectively, these biodiversity metrics illustrate a flourishing and resilient forest ecosystem, marked by a variety of species assemblages and balanced ecological dynamics across different life stages.

Carbon Sequestration of Rangan Hiran Forest

Table 3 presents various site characteristics relevant to data collection and calculations, including the number of plots, total area, and plot size, along with site-level carbon stocks (average tC/ha across all plots, range, and standard deviation of carbon across all plots, as well as total tC for the site). It also documents sample errors and accuracy ranges based on the number of plots at a 95% confidence level. The mean carbon stock is 282.08 tons C/plot, with total carbon within the plots amounting to 1,692.48 tons C/ha, reflecting a total carbon stock of 243,998.57 tons C across all carbon plots. The accuracy of these carbon estimates is somewhat improved and is determined by the number of sample plots, the sample size of each plot, and the carbon variation across all sampled plots.

Table 3. Carbon Stock Measurement Recapitulation in Rangan Hiran Forest

Properties	Value
Number of Plot (n)	6
Forest Area (ha)	865
Total Carbon in Plot (tons)	1692.48
Averaage Carbon in Plot (tons)	282.08
Standard Deviation (tons)	192.71
Plot Size (ha)	0.04
Population (N)	21625
t-student value (α=5%)	2.57
Average default error rate (tons)	78.66
CI95% average (lower limit) (tons)	259.28
CI95% average (upper limit) (tons)	304.88
Sampling Error (%)	8.08
Total carbon stock (tC) – Lower (tons)	224,277.59
Total carbon stock (tC) (tons)	243,998.57
Total carbon stock (tC) – Upper (tons)	263,719.54

The carbon stock data for the Rangan Hiran tropical secondary rainforest offers important insights into the ecosystem's carbon sequestration capabilities. Encompassing a total area of 865 hectares and housing 21,625 trees, the forest exhibits considerable potential for carbon storage. The findings indicate that across six sample plots, the average carbon content per plot is 282.08 tons, with a standard deviation of 192.71 tons, signifying a moderate variation in carbon density throughout the forest. The estimated total carbon stock for the entire forest amounts to 243,998.57 tons, presenting a 95% confidence interval from 224,277.59 tons to 263,719.54 tons. The average default error rate is 78.66 tons, and the sampling error is 8.08%, providing insights into the accuracy and precision of the carbon estimates. Additionally, the t-student value of 2.57, along with the confidence intervals, aids in evaluating the reliability of the calculated carbon stock figures. Overall, this data highlights the significant carbon sequestration potential of the Rangan Hiran tropical secondary rainforest, emphasizing its vital role in combating climate change and maintaining the global carbon balance (Maimunah *et al*., 2023).

Wood Volume and Tree Density

Table 4 provides a summary of the volume calculations for trees based on size classes, including wood volume and tree density. The distribution of tree size classes in the Rangan Hiran forest shows a distinct skew towards the largest size class, which includes trees larger than 15 cm in diameter at breast height (DBH), in comparison to saplings and poles. However, the count of trees per plot by size class may be somewhat misleading, as data were collected from nested plots measuring 5 x 5 m (for saplings), 10 x 10 m (for poles), and 20 x 20 m (for large trees). The table also provides the sample sizes for saplings and poles in parentheses and estimates the number of trees in the 20 x 20 m plot based on the counts from the nested plots or observed data.

Table 4. Wood Volume and Tree Density of Rangan Hiran Forest

Stage of Development	Wood Volume (m^3 ha^{-1})	Tree Density (tree ha^{-1})
Seedlings	0	0
Saplings	20.81	1,933
Poles	70.73	733
Trees	422.09	242

The data on wood volume and tree density provide valuable insights into the structural composition and dynamics of the Rangan Hiran tropical secondary rainforest. Large trees lead in volume, with 330.55 m^3 per hectare, followed by poles at 70.73 m^3 and saplings at 20.81 m^3, resulting in a total of 422.09 m^3 per hectare. Tree density varies as well, with saplings at 1,933 trees/ha, poles at 733 trees/ha, and large trees at 242 trees/ha. This distribution reflects ongoing forest regeneration and a dynamic ecosystem characterized by active growth. The abundance of saplings and poles emphasizes the forest's regeneration capacity, which is vital for long-term resilience and biodiversity. Therefore, conservation efforts are essential to protect and support these younger tree populations to ensure the forest's sustained vitality (Maimunah *et al*., 2022).

CONCLUSION

The results of this study emphasize the importance of analyzing field inventory data in forests to provide insights into ecosystem service levels. In this research, both biodiversity and carbon stocks were evaluated. The Social Forest of Rangan Hiran showcases a wealth of tree species, as demonstrated by a Richness Index of 2.58 (Menhinick) and 7.11 (Margalef), indicating a diverse range of species. Additionally, the tree plots in Rangan Hiran Forest exhibit a diversity index of 3.43 (Shannon-Wiener) and 0.96 (Simpson), signifying high species diversity with an evenness of 0.93. For the seedling plots, the richness is 1.69 (Menhinick) and 4.09 (Margalef), with a biodiversity index of 2.56 (Shannon-Wiener) and 0.90 (Simpson), along with an evenness value of 0.83. The total estimated carbon stock for Rangan Hiran Forest is 243,998.57 tons.

Ongoing measurements to monitor changes in carbon stocks are vital for further studies. It is essential to track carbon gains from tree growth and losses from tree mortality to formulate effective management plans for the forest area. Lastly, engaging the local community, particularly those who directly benefit from the Rangan Hiran Village forest in Gunung Mas Regency, is crucial for fostering their active participation in conservation efforts and enhancing local economic prosperity.

REFERENCES

Bauhus, J., Forrester, D. I., Gardiner, B., Jactel, H., Vallejo, R., & Pretzsch, H. (2017). Ecological Stability of Mixed-Species Forests. In H. Pretzsch, D. I. Forrester, & J. Bauhus (Eds.), *Mixed-Species Forests* (pp. 337–382). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-54553-9_7

Brandon, K. (2014). Ecosystem Services from Tropical Forests: Review of Current Science. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2622749

Burivalova, Z., Allnutt, T. F., Rademacher, D., Schlemm, A., Wilcove, D. S., & Butler, R. A. (2019). What works in tropical forest conservation, and what does not: Effectiveness of four strategies in terms of environmental, social, and economic outcomes. *Conservation Science and Practice*, *1*(6), e28. https://doi.org/10.1111/csp2.28

Favero, A., Mendelsohn, R., & Sohngen, B. (2017). Using forests for climate mitigation: Sequester carbon or produce woody biomass? *Climatic Change*, *144*(2), 195–206. https://doi.org/10.1007/s10584-017-2034-9

Harden, C. P., & Fernández, A. (2022). Mountain Waterscapes: Geographies of Interactions, Transformations, and Meanings. In F. O. Sarmiento (Ed.), *Montology Palimpsest* (Vol. 1, pp. 275–292). Springer International Publishing. https://doi.org/10.1007/978-3-031-13298-8_16

Isabel, N., Holliday, J. A., & Aitken, S. N. (2020). Forest genomics: Advancing climate adaptation, forest health, productivity, and conservation. *Evolutionary Applications*, *13*(1), 3–10. https://doi.org/10.1111/eva.12902

Karimah. (2017). Peran Ekosistem Hutan Mangrove Sebagai Habitat Untuk Organisme Laut. *Jurnal Biologi Tropis*, 51–57. https://doi.org/10.29303/jbt.v17i2.497

Krisnawati, H., Adinugroho, W. C., & Imaduddin, R. (2012). *Monograph allometric models for estimating tree biomass at various forest ecosystem types in Indonesia.* Research and Development Center for Conservation and Rehabilitation, Forestry Research and Development Agency, Ministry of Forestry.

Maimunah, S., Hanafi, I., Subhan, Anhar, A., & Samek, J. H. (2021). An assessment of tree biodiversity and carbon stocks in mangrove forests, Langsa City, Aceh, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *886*(1), 012085. https://doi.org/10.1088/1755-1315/886/1/012085

Maimunah, S., M. Amin, A., P. Lubis, A. F., Iskandar, I., Yansah, P., & H. Samek, J. (2022). Studi kemanfaatan hutan bagi masyarakat hutan desa Sembelangaan Kabupaten Ketapang Provinsi Kalimantan Barat. *Jurnal Hutan Tropis*, *10*(1), 8. https://doi.org/10.20527/jht.v10i1.13083

Maimunah, S., Remario, R., Hendriansyah, H., F, A., Am, A., Fatchurrohman, A., Samek, J. H., & Supriyanto, B. (2023). Keanekaragaman hayati, kemanfaatan hutan dan simpanan karbon HKM Sukses Manyam Sejahtera di Lamandau Kalimantan Tengah. *Jurnal Hutan Tropis*, *11*(3), 371. https://doi.org/10.20527/jht.v11i3.17632

Margalef, R. (1958). Information theory in ecology. *Gen Syst*, *3*, 36–71.

McMeans, B. C., McCann, K. S., Humphries, M., Rooney, N., & Fisk, A. T. (2015). Food Web Structure in Temporally-Forced Ecosystems. *Trends in Ecology & Evolution*, *30*(11), 662–672. https://doi.org/10.1016/j.tree.2015.09.001

Menhinick, E. F. (1964). A Comparison of Some Species-Individuals Diversity Indices Applied to Samples of Field Insects. *Ecology*, *45*(4), 859–861. https://doi.org/10.2307/1934933

Nunes, L. J. R., Meireles, C. I. R., Pinto Gomes, C. J., & Almeida Ribeiro, N. M. C. (2020). Forest Contribution to Climate Change Mitigation: Management Oriented to Carbon Capture and Storage. *Climate*, *8*(2), 21. https://doi.org/10.3390/cli8020021

Putri, H., Ichsan, A. C., & Setiawan, B. (2020). The Potential Study Of Segenter Waterfall As A Tourist Destination In The Tahura Nuraksa. *Journal of Sylva Indonesiana*, *3*(02), 97–106. https://doi.org/10.32734/jsi.v3i02.2850

Rajeev, J., & Hukum, S. (2020). Carbon sequestration potential of disturbed and non-disturbed forest ecosystem: A tool for mitigating climate change. *African Journal of Environmental Science and Technology*, *14*(11), 385–393. https://doi.org/10.5897/AJEST2020.2920

Segah, H., Liano, A., Yulianto, S., Setiarno, S., & Yanciluk, Y. (2023). Analysis of Flood Vulnerability using Geographic Information Systems in the Kahayan Watershed, Gunung Mas District, Central Kalimantan: Analisis Tingkat Kerawanan Banjir Menggunakan Sistem Informasi Geografis Pada DAS Kahayan Kabupaten Gunung Mas, Kalimantan Tengah. *Journal of Peat Science and Innovation*, *1*(1), 16–25. https://doi.org/10.59032/jpsi.v1i1.5541

Shannon, C. E. (1948). A Mathematical Theory of Communication. *Bell System Technical Journal*, *27*(3), 379–423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Simpson, E. H. (1949). Measurement of Diversity. *Nature*, *163*(4148), 688–688. https://doi.org/10.1038/163688a0