BUKTI KORESPONDENSI
ARTIKEL JURNAL INTERNASIONAL BEREPUTASI

Judul Artikel	:	Spatial distribution of vegetation diversity, timber production, and carbon storage in secondary tropical rainforest at South Kalimantan, Indonesia
Link	:	https://doi.org/10.13057/biodiv/d231208
Jurnal	:	Biodiversitas Journal of Biological Diversity
Volume	:	23
Issue	:	12
Halaman	:	6147-6154
Penulis	:	Suyanto, Yusanto Nugroho, Moehar Marghiy Harahap, Lia Kusumaningrum, Pandu Yudha Adi Putra Wirabuana

No.	**Perihal**	**Tanggal**
1.	Bukti konfirmasi submit artikel dan draft artikel yang disubmit	20 Oktober 2022
2.	Bukti keputusan editor, artikel hasil review, dan artikel perbaikan	11 November 2022
3.	Bukti accepted	6 Desember 2022

UGM Mail **Pandu Yudha Adi Putra Wirabuana <pandu.yudha.a.p@ugm.ac.id>**

[biodiv] Submission Acknowledgement

1 message

Ahmad Dwi Setyawan <smujo.id@gmail.com> Thu, Oct 20, 2022 at 1:50 PM
To: Pandu <pandu.yudha.a.p@ugm.ac.id>

Pandu:

Thank you for submitting the manuscript, "Spatial distribution of vegetation diversity, timber production, and carbon storage in secondary tropical rainforest at South Borneo" to Biodiversitas Journal of Biological Diversity. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

Submission URL: https://smujo.id/biodiv/authorDashboard/submission/12632
Username: wirabuanayudha

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

COVERING LETTER

Dear **Editor-in-Chief,**

I herewith enclosed a research article,

- ☑ The submission has not been previously published, nor is it before another journal for consideration (or an explanation has been provided in Comments to the Editor).
- ☑ The submission file is in OpenOffice, Microsoft Word (DOC, not DOCX), or RTF document file format.
- ☑ The text is single-spaced; uses a 10-point font; employs italics, rather than underlining (except with URL addresses); and all illustrations, figures, and tables are placed within the text at the appropriate points, rather than at the end.
- ☑ The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines.
- ☑ Most of the references come from current scientific journals (c. 80% published in the last 10 years), except for taxonomic papers.
- ☑ Where available, DOIs for the references have been provided.
- ☑ When available, a certificate for proofreading is included.

SUBMISSION CHECKLIST

Ensure that the following items are present:

The first corresponding author must be accompanied with contact details:

- ☑ E-mail address
- ☑ Full postal address (incl street name and number (location), city, postal code, state/province, country)
- ☑ Phone and facsimile numbers (incl country phone code)

All necessary files have been uploaded, and contain:

- ☑ Keywords
- ☑ Running titles
- ☑ All figure captions
- ☑ All tables (incl title and note/description)

Further considerations

- ☑ Manuscript has been "spell & grammar-checked" Better, if it is revised by a professional science editor or a native English speaker
- ☑ References are in the correct format for this journal
- ☑ All references mentioned in the Reference list are cited in the text, and vice versa
- ☑ Colored figures are only used if the information in the text may be losing without those images
- ☑ Charts (graphs and diagrams) are drawn in black and white images; use shading to differentiate

Title:

Spatial distribution of vegetation diversity, timber production, and biomass accumulation in secondary tropical rainforests, South Borneo

Author(s) name:

Suyanto, Yusanto Nugroho, Moehar Maraghiy Harahap, Lia Kusumaningrum, Pandu Yudha Adi Putra Wirabuana

Address

(Fill in your institution's name and address, your personal cellular phone and email)

Universitas Gadjah Mada
Jln. Agro No.1 Bulaksumur Yogyakarta 55281
+6281226887738
pandu.yudha.a.p@ugm.ac.id

For possibility publication on the journal:

(fill in *Biodiversitas* or *Nusantara Bioscience* or *mention the others*)

- [x] Biodiversitas Journal of Biological Diversity
- [ ] Nusantara Bioscience
- [ ] Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia
- [ ] Asian Journal of Agriculture
- [ ] Asian Journal of Ethnobiology
- [ ] Asian Journal of Forestry
- [ ] Asian Journal of Natural Product Biochemistry
- [ ] Asian Journal of Tropical Biotechnology
- [ ] International Journal of Bonorowo Wetlands
- [ ] Cell Biology and Development
- [ ] Indo Pacific Journal of Ocean Life
- [ ] International Journal of Tropical Drylands

Novelty:

(state your claimed novelty of the findings versus current knowledge)

This study found varied vegetation diversity, timber production, and biomass accumulation in each compartment. The relative contribution of commercial species to wood production and carbon stock was substantially higher than non-commercial species. Interestingly, our study did not record a significant correlation between vegetation diversity and stand productivity. It was contrary to other studies that reported a strong relationship between biodiversity and forest productivity.

Statements:

This manuscript has not been published and is not under consideration for publication to any other journal or any other type of publication (including web hosting) either by me or any of my co-authors.
Author(s) has been read and agree to the Ethical Guidelines.

List of five potential reviewers

(Fill in names of five potential reviewers **that agree to review your manuscript** and their **email** addresses. He/she should have Scopus ID and come from different institution with the authors; and from at least three different countries)

1. Emad Hasan Elawad Yasin/Khartoum University/Scopus ID 57471006900/emad.yasin823@gmail.com
2. Budi Mulyana/University of Sopron/Scopus ID 57193322371 /mulyana.budi@phd.uni-sopron.hu
3. Joko Ridho Witono/Indonesian Institute of Science/Scopus ID 19436718100/jrwitono@yahoo.com
4. Rahmanta Setiahadi/Universitas Merdeka Madiun/Scopus ID 57194606572/ rahmanta_setiahadi@unmer-madiun.ac.id
5. Agustinus Murdjoko/Universitas Negeri Papua/Scopus ID 56188772400/ agustinus.murdjoko.papua@gmail.com

Place and date:

October 3, 2022

Sincerely yours,

(fill in your name, no need scanned autograph)

Pandu Yudha Adi Putra Wirabuana

Spatial distribution of vegetation diversity, timber production, and carbon storage in secondary tropical rainforest at South Borneo

SUYANTO[1], YUSANTO NUGROHO[1], MOEHAR MARAGHIY HARAHAP[2], LIA KUSUMANINGRUM[4], PANDU YUDHA ADI PUTRA WIRABUANA[5,♥]

[1] Faculty of Forestry, Universitas Lambung Mangkurat, Jln. Ahmad Yani km 36 Banjarbaru, South Kalimantan, Indonesia
[2] Faculty of Forestry, Universitas Sumatera Utara, Jln. Tri Dharma Ujung No. 1 Medan, North Sumatra, Indonesia
[3] Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Jln. Jend. Urip Sumoharjo No.116 Surakarta, Central Java, Indonesia
[4] Faculty of Forestry, Universitas Gadjah Mada, Jln. Agro No. 1 Bulaksumur, Yogyakarta, Indonesia.
♥email: pandu.yudha.a.p@ugm.ac.id

Manuscript received: ……………... Revision accepted: ....

Abstract. Sustainable management in secondary tropical rainforests requires basic information about stand characteristics, mainly related to productivity and biodiversity. This study aimed to quantify vegetation diversity, timber production, and carbon storage from various sites of secondary forests in South Borneo. Forest inventory was conducted using a census method at seven different natural forest management unit compartments. Four parameters were measured from each tree, including the type of species, commercial categories, tree diameter, and tree height. Individual tree volume and biomass were estimated using allometric equations, while carbon storage was determined using a conversion factor from biomass. Three indicators were used to evaluate vegetation diversity: richness, heterogeneity, and evenness. The analysis of correlations was applied to examine the relationship between vegetation diversity and stand productivity with a significant level of 5%. Results found that there were 41 tree species in the study site comprising 20 commercial and 21 non-commercial species. The highest richness (*R′*) was recorded in compartment 18X by approximately 4.0, while the most increased heterogeneity (*H′*) and evenness (*E′*) were observed in compartment 18Y by around 2.4 and 0.7, respectively. The accumulation of timber production varied in each site, with a range of 45.46−68.32 m^3 ha^{-1}. The highest carbon storage was noted in compartment 19Y (38.74±1.79t ha^{-1}), while the lowest was found in compartment 18W (20.76±0.93 t ha^{-1}). The relative contribution of commercial species to timber production and carbon storage was substantially higher than non-commercial species at all sites. However, there was not a significant correlation between vegetation diversity and stand productivity ($P>0.05$). Overall, our study concluded that the secondary tropical forest ecosystems in the site had good vegetation diversity, timber production, and carbon storage.

Keywords: biodiversity, ecosystems, inventory, natural forest, productivity

Running title: Spatial distribution of vegetation diversity

INTRODUCTION

Biodiversity conservation, climate change mitigation, and economic development are essential issues in sustainable forest management, particularly in Indonesia. In this context, the management of forests is expected to stabilize wood supplies for commercial industries, support species conservation, and reduce carbon emissions in the atmosphere (Wirabuana et al. 2021b). To tackle these challenges, information about stand dynamics is required as baseline considerations to determine alternative forest management strategies (Pretzsch et al. 2014). It is related to timber production and includes vegetation diversity and carbon storage.

In general, the quantity of timber production will provide adequate information about the economic value of the forest and its capacity for supporting industry viability (Simmons et al. 2021). It also determines the maximum annual allowable cutting from the forest ecosystem (Asamoah et al., 2020). The number of timber production also describes the regeneration stock from different life stages of trees to maintain business sustainability (Zambiazi et al. 2021). Meanwhile, vegetation diversity information indicates the stability of environmental health and forest ecosystems (Pan et al. 2018). It also shows how many species live in the forest and their relative contribution to ecological functions (Matatula et al. 2021). The vegetation diversity can also be used to understand the natural competition in the ecosystems (Duan et al. 2021). On another side, the accumulation of carbon storage indicates the ability of the forest ecosystem to support climate change mitigation, primarily for reducing carbon emissions (Sadono et al. 2021a). Many studies explain forest vegetation generally absorbs CO_2 through the photosynthesis process. First, it converts it into biomass (Sasaki et al. 2016, Ma et al. 2017, Kocurek et al. 2020, Wirabuana et al. 2020, Sadono et al. 2021b, Setiahadi 2021). Then, the biomass will be distributed in components like roots, stems, branches, and foliage (Poorter et al. 2012, Yue et al. 2018, Altanzagas et al. 2019, Wirabuana et al. 2021a). Higher biomass indicates excellent carbon storage wherein the carbon absorption in forests will increase along with vegetation age (Arora et al. 2014). Another study report the critical role of vegetation on carbon absorption is also a part of the balance in biogeochemical cycles (Taillardat et al. 2018). To collect this information, forest inventory is necessary to support forest managers in monitoring the stand dynamics in each forest ecosystem, including secondary tropical rainforest (STR).

Before the 1990s, STR played an essential role in economic development. It provided wood materials for forest industries like furniture, veneer, and plywood. STR also occupied the second position of important sectors contributing to country revenue. However, the occurrence of deforestation has declined its contribution significantly to the gross domestic product. Most STR currently have low productivity and high biodiversity loss (Gaveau et al. 2014). To anticipate this condition, the government has conducted the effort of reforestation to recover forest productivity and prevent vegetation extinction. However, this program is not easy to implement because STR commonly has high variation in land configuration with low accessibility (Wardhana et al. 2020).

Moreover, soil quality in these sites is also dominated by mature soil with low fertility, like oxisols and ultisols (Fujii et al. 2018). Therefore, it causes the low survival rate of vegetation generated from the reforestation program. Nevertheless, several concession areas of STR still exist and maintain their functions for economic development, biodiversity conservation, and climate change mitigation. One of them is a secondary tropical rainforest area managed by PT Aya Yayang Indonesia (AYI) located in South Borneo. Although it has been managed for over 30 years, the information about forest dynamics in this location is still limited, mainly related to vegetation diversity and carbon storage. Therefore, it is essential to provide more comprehensive details on stand dynamics in this area to support better forest management efforts.

This study aims to document vegetation diversity, timber production, and carbon storage from several compartments of secondary tropical rainforests managed by AYI. This information will help forest manager to determine the forest planning strategy, mainly related to yield regulation and harvesting schedules. Thus, even though it is managed as a production zone, forest regeneration is still maintained and minimizes the risk of biodiversity loss. We hypothesize that:

(a) Every compartment has a different value for vegetation diversity, timber production, and carbon storage.
(b) Higher vegetation diversity significantly increases timber production and carbon storage.
(c) The contribution of non-commercial species on stand productivity is higher than commercial species.

MATERIALS AND METHODS

Study area

This study was conducted in the secondary tropical rainforest concession area managed by PT Aya Yayang Indonesia. It is situated in Tabalong District, approximately 270 km from Banjarmasin, the capital city of South Borneo province. The geographic coordinates of this area are located in S1°39'−1°40' and E115°29'−115°30'. Altitude ranges from 225 to 470 m above sea level. Land configuration is dominated by hills with a slope level of 15−40%. The average daily temperature is 27.6°C with a minimum of 25.7°C and a maximum of 30.3°C. The mean annual rainfall during the past ten years is 2,589 mm $year^{-1}$, with an average air humidity of 87.6%. The highest rainfall is recorded in November. Dry periods are relatively short, only around two months from July to August. Oxisols and ultisols dominate soil types with high acidity levels.

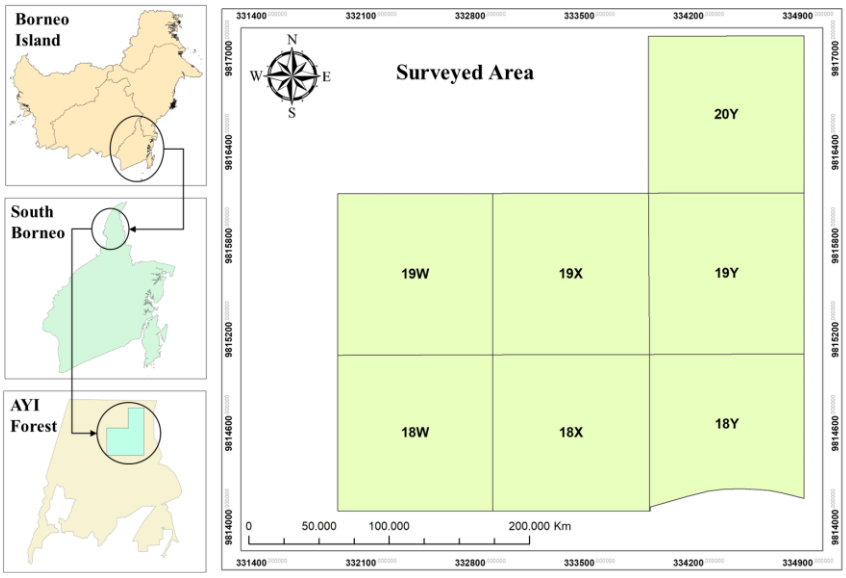


Figure 1. The study area of secondary tropical rainforest in South Borneo

Data Collection

Forest inventory was conducted using a census method at seven compartments of the secondary tropical rainforest management unit, namely 18W, 18X, 18Y, 19W, 19X, 19Y, and 20Y. The total surveyed area reached 700 ha, with each site 100 ha. To facilitate the measurement process, the field survey was conducted step by step using sub-plots of 20 m x 20 m. These sub-plots were arranged systematically; all trees in compartments could be covered and measured correctly. Four parameters were measured from each tree, i.e., type of species, commercial categories, tree diameter, and tree height. The determination of commercial and non-commercial species was undertaken, referring to the guidance from the company. Tree diameter was measured using a phi band at 1.3 m aboveground, while tree height was quantified using a haga altimeter from aboveground to the top crown. Moreover, the coordinate of trees was also recorded using a global positioning system (GPS).

Data Analysis

Three indicators were selected to describe vegetation diversity, i.e., richness, heterogeneity, and evenness. Vegetation richness was determined by Margalef Index (*R'*), while its heterogeneity was quantified using Shannon-Wiener Index (*H'*). On another side, the evenness of vegetation was assessed by Pielou Evenness Index (*E'*). Detail equations for calculating those indicators are expressed below (Nugroho et al. 2022):

$$R' = S\text{-}1/\ln(N) \quad (1)$$

$$H' = -\sum (n_i/N)(\ln n_i/N) \quad (2)$$

$$E' = H'/\ln(S) \quad (3)$$

where *S* was the number of species observed, *N* represented the total tree population in each compartment, and n_i described the sum of trees for each species.

To determine the quantity of timber production, individual tree volume was calculated using the following equation:

$$V = 0.25\,\pi\, dbh^2\, h\, f \quad (4)$$

where *V* was tree volume (m^3), *dbh* indicated tree diameter (cm), *h* represented tree height (m), and *f* showed a constant of form factor (0.6) (Akossou et al. 2013). Then, the timber production degree was assumed to be the mean stand volume in hectare units. This value could be derived by dividing the total tree volume in a compartment by its area.

The quantification of carbon storage and CO_2 absorption were also calculated using a similar principle to timber production. However, we used biomass accumulation as a conversion to compute both parameters. In this context, the individual tree biomass was estimated using a generalized allometric model for secondary tropical rainforest as given (Krisnawati et al. 2012):

$$B = 0.047454 dbh^{2.078} \quad (4)$$

B was aboveground biomass (kg), and *dbh* indicated tree diameter (cm). Next, the carbon stock of each tree was computed by multiplying its biomass with a conversion factor of 0.46 (Latifah et al. 2018), while CO_2 absorption was estimated by multiplying carbon stock with a constant of 3.67 (Latifah & Sulistiyono 2013). Then, the result was converted into a hectare unit.

Descriptive analysis was selected to compare the value of vegetation diversity, timber production, and carbon storage among different compartments based on the trend of the histogram and the summarized information from the table. Meanwhile, the spatial distribution of three parameters was processed using QGIS. Finally, to evaluate the relationship between vegetation diversity and stand productivity, both in timber production and carbon storage, Pearson correlation analysis was applied with a significant level of 5%.

RESULTS AND DISCUSSION

Vegetation Diversity

Results found that vegetation diversity among compartments was substantially different (Table 1). The highest species abundance was recorded in the compartment of 18Y, while the lowest number of species was observed in the compartment of 20Y. Similar trends were also discovered in the richness, heterogeneity, and evenness, wherein the highest value of those indicators was noted in compartment 18Y. These findings directly confirmed our first hypothesis that assumed there was different vegetation diversity between compartments in the study site.

The diversity of vegetation in secondary tropical rainforests was generally caused by the interaction between vegetation and the environment. This process generated natural competition wherein trees compete with each other to obtain sufficient resources to support their survival (Wirabuana et al. 2022b). On another side, environmental variation also became a limiting factor for certain species; thus, it could inhibit several vegetation from growing well (Wang et al. 2019). Consequently, the regeneration capacity of each species in this ecosystem was highly dynamic depending on their adaptation to environmental conditions. Several previous studies also reported similar results wherein the natural regeneration in secondary tropical rainforests was exceptionally dynamics due to the impact of intraspecific and

interspecific competition between trees for obtaining light, water, nutrients, and space (Barabás et al. 2016, Adler et al. 2018, Yang et al. 2019).

Table 1. Comparison of species abundance, richness, heterogeneity, and evenness among compartments

Compartment	N species	Richness	Heterogeneity	Evenness
18W	32	4.01	1.91	0.55
18X	31	3.79	2.10	0.61
18Y	36	4.43	2.42	0.68
19W	32	3.99	1.96	0.57
19X	30	3.59	1.84	0.54
19Y	31	3.89	1.86	0.54
20Y	4	0.38	0.81	0.58

This study recorded that the heterogeneity of vegetation in the study location was dominated by medium classes with a range of 1.51−3.50 (Table 1) (Hidayat 2013). It was similar to previous studies that documented the secondary tropical rainforests commonly had medium vegetation biodiversity (Siregar and Undaharta 2018, Murdjoko et al. 2021, Tawer et al. 2021). This condition could happen because this site was managed using a selective cutting system; thus, only certain species were maintained to support the ecological function of the forest (Butarbutar 2014). In addition, most trees with a limit diameter of more than 50 cm and having commercial values were harvested to provide better-growing space for younger trees (Matangaran et al. 2019). Therefore, this scheme was expected to stabilize the regeneration capacity of secondary forests without sacrificing its economic benefits.

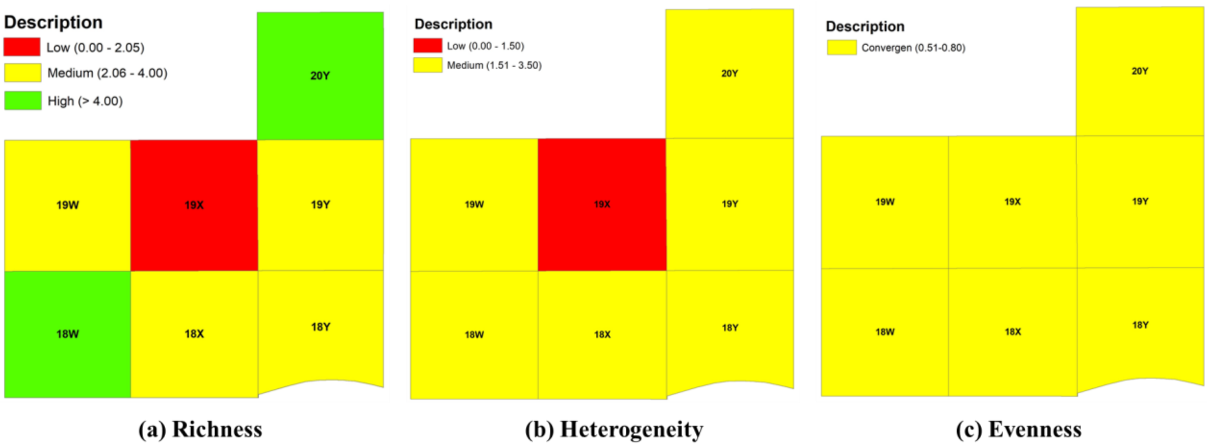


Figure 2. Spatial distribution of vegetation diversity in the study site

Our results also indicated that species distribution in the study site was not evenly distributed. It was shown by the evenness index value ranging from 0.54 to 0.68 (Table 1). These outcomes signified that most species in this location grew in groups (Hussain et al. 2012). It was not surprising since Dipterocarpaceae families dominated most species in secondary tropical rainforests. Many studies explained that these families naturally live in groups and have a specific preference for their habitat (Purwaningsih 2004, Hadi et al. 2019, Sari et al. 2019).

According to the results, it was seen that vegetation diversity in the study site was still maintained well. It also implied that the forest management activity in this area fulfills the principle of sustainability by minimizing the risk of biodiversity loss. However, the effort of enrichment planting is required to improve biodiversity in the compartment with low diversity level. This scheme will also facilitate the conservation of native species from the secondary tropical rainforests.

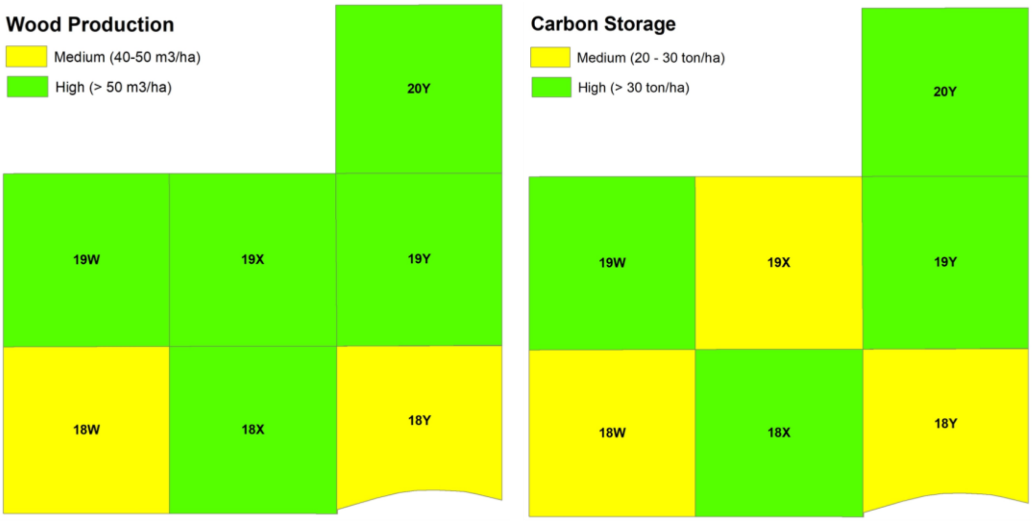
Timber Production

Summarized observation results documented that timber production in the study area ranged from 44.49±1.72 m^3 ha^{-1} to 68.32±2.69 m^3 ha^{-1} (Table 2). These values were substantially higher than the average productivity of Borneo's natural forests, ranging from 30 m^3 ha^{-1} (KLHK, 2019). Therefore, it indicated that the secondary tropical rainforest in this area had high productivity and could still support industry development. Moreover, this study recorded that the average timber production in each compartment was relatively different, wherein the most increased timber production was found in the compartment of 19Y. These findings also confirmed our first hypothesis that timber production was highly varied between compartments in secondary tropical rainforests.

Table 2. Comparison of timber production, biomass accumulation, carbon storage, and CO_2 absorption among compartments

Compartment	Timber production (m^3 ha^{-1})	Biomass accumulation (t ha^{-1})	Carbon stock (t ha^{-1})	CO_2 absorption (t ha^{-1})
18W	44.49±1.72	45.13±2.02	20.76±0.93	76.18±3.40
18X	56.05±2.05	68.35±2.85	31.44±1.31	115.38±4.81
18Y	54.3±2.43	69.25±3.74	31.86±1.73	116.92±6.32
19W	45.56±1.86	48.83±2.42	22.46±1.12	82.44±4.08
19X	54.96±1.55	67.11±2.44	30.87±1.12	113.29±4.11
19Y	68.32±2.69	84.22±3.89	38.74±1.79	142.17±6.56
20Y	50.57±2.30	46.37±2.36	21.33±1.09	78.29±3.98

Interestingly, the compartment of 18Y only occupied the fourth position of the most productivity compartments, even though it had the highest vegetation diversity (Table 2). Our study also did not find a significant correlation between vegetation diversity and timber production (Table 3). It was in contrast to previous studies that documented a substantial effect of vegetation diversity on stand productivity in tropical rainforest ecosystems (Cai et al. 2016, Gevaña et al. 2017, McNicol et al. 2018). These findings rejected our second hypothesis that higher vegetation diversity significantly increases timber production in the study site. However, several kinds of literature also found a similar outcome to ours wherein there was no significant relationship between vegetation diversity and forest productivity (Belote et al. 2011, Bravo-Oviedo et al. 2021). In this context, forest ecosystems may have diverse patterns regarding the connection between biodiversity and productivity.



(a) Timber Production **(b) Carbon Storage**

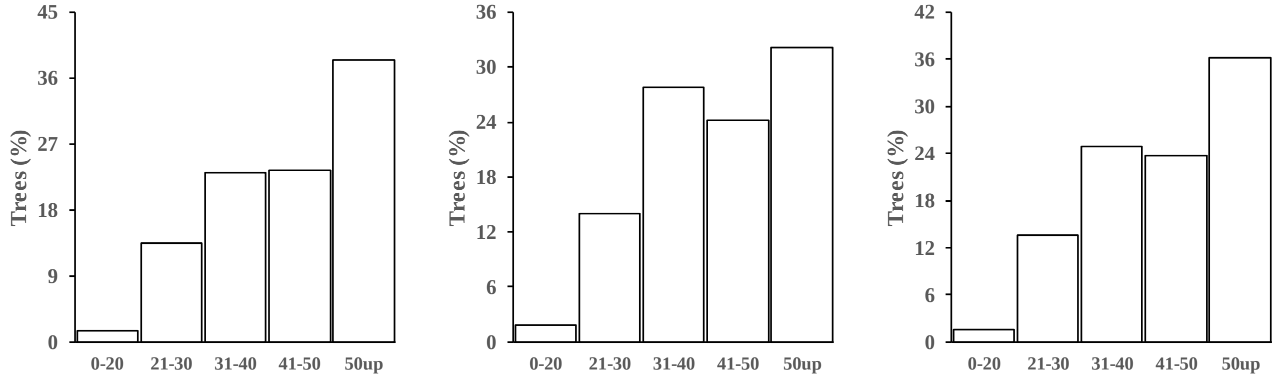
Figure 3. Spatial distribution of timber production and carbon storage in the study site

Table 3. Correlation between diversity indicators and stand productivity parameters

Diversity parameter	Productivity parameter	
	Timber production	Carbon Storage
Richness	0.123^{ns}	0.420^{ns}
Heterogeneity	0.116^{ns}	0.442^{ns}
Evenness	-0.056^{ns}	0.098^{ns}

ns: non-significant based on correlation test

Forest ecosystems in the study site had high productivity since their vegetation was dominated by trees with a diameter of more than 50 cm (Figure 4). On another side, the frequency of trees with a diameter lower than 20 cm was only around 2%. These indicated there was sufficient stock of timber production for selective cutting. Moreover, the relative contribution of non-commercial species to total timber production was considerably lower than commercial species (Figure 4). It demonstrated that the current standing stock had high economic value. These results confirmed our third hypothesis that commercial species' relative contribution to stand productivity was higher than non-commercial species. Although this site had increased productivity, forest managers should be careful to determine the quantity of annual allowable cutting (AAC) since the implementation of timber extraction can be impacted young trees' regeneration. Most importantly, the process of timber extraction should not harvest trees that generate seeds for maintaining natural regeneration.



(a) Commercial (b) Non Commercial (c) All Species

Figure 4. Diameter distribution of tree species in the study site

Carbon Storage

Carbon storage in each compartment varied, wherein the carbon stock in the study site ranged from 20.76±0.93 t ha^{-1} to 38.74±1.79 t ha^{-1} (Table 3). The highest CO_2 absorption was recorded in the compartment of 19Y by around 142.17±6.56 t ha^{-1}. In addition, the relative contribution of commercial species on carbons stock was considerably higher than species non-commercial (Figure 4). These findings directly verified our first and third hypotheses in this study. However, similarly to timber production, our study did not find a significant effect of vegetation diversity on carbon storage in this area (Table 3).

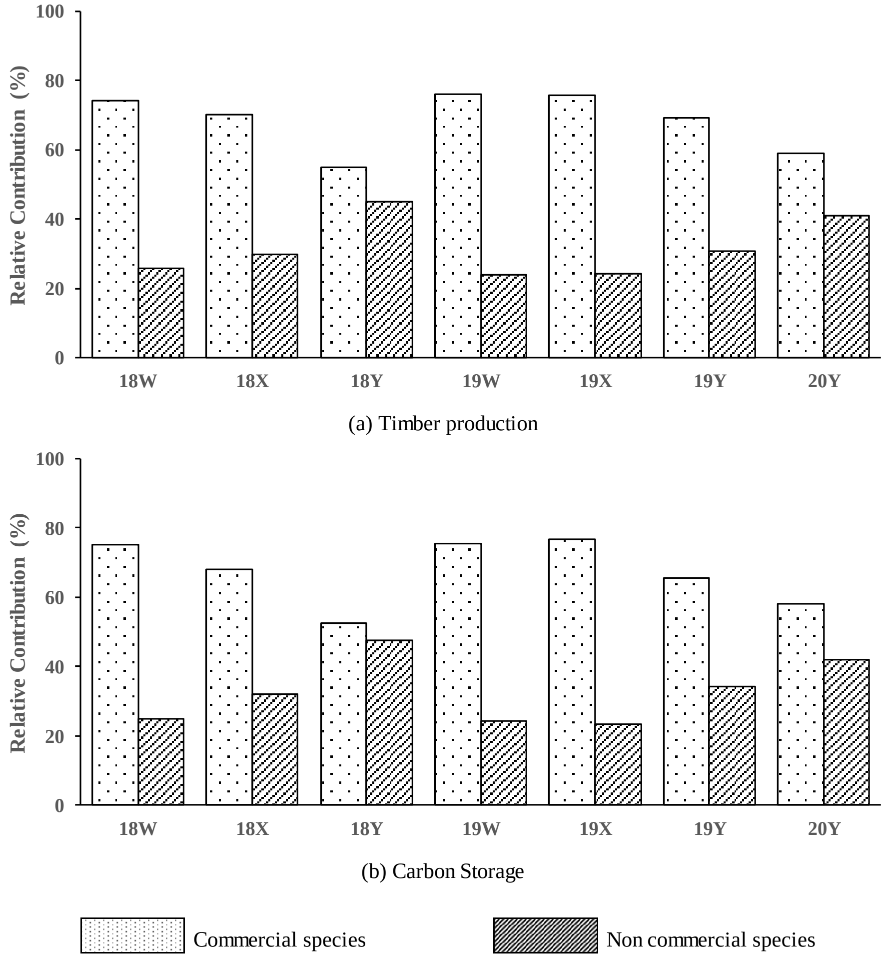


Figure 4. The relative contribution of commercial and non-commercial species on timber production and carbon storage

The accumulation of carbon storage in forest ecosystems has a positive relationship with stand productivity. Higher stand productivity increases carbon stock since it was generated from photosynthesis (Cai et al. 2016, Brancalion et al. 2019, Alam et al. 2022, Wirabuana et al. 2022a). A study reported the average carbon stock in tropical rainforest ecosystems was 51.18 t ha^{-1} (Butarbutar et al. 2019). This value is higher than carbon storage in the study site. However, this study's carbon stock measurement is still limited to the tree level. We still have not quantified the carbon stock in other life stages like poles, saplings, seedlings, and understorey. Thereby, the actual carbon storage in the study area may be higher than the current estimation. It is also essential for forest managers in the study location to consider the quantity of carbon stock as the additional value of sustainable natural resources management.

Implication Results

This study concluded that the secondary tropical rainforest ecosystems in the study site had good vegetation diversity, timber production, and carbon storage. Furthermore, it indicated that forest managers had applied sustainability principles in the context of operation scale. Nevertheless, some improvements are still required to increase the value of forest management on this site. Besides conducting enrichment planting in the compartment with low biodiversity levels, we also suggest forest managers determine the scheme of yield regulation to minimize forest disturbance due to the impact of harvesting operations. Furthermore, the cutting process has a high potential to decline regeneration capacity since the felled trees will override the younger plants like seedlings and saplings.

We also suggest forest managers identify the distribution of mother trees in their concession area for obtaining seed as plant material in artificial regeneration. The seed collection is also essential to maintain the genetic diversity in this area. On another side, it is also necessary to document the carbon dynamics during the rotation periods, including loss and increment, since it will provide comprehensive information about forest management's effectiveness in tackling the climate change mitigation issue. We also encourage forest managers in this area to share their knowledge with other natural resources managers who fail to manage the secondary tropical rainforest ecosystems. It is highly required since forest ecosystems play an essential role in economic development, climate change mitigation, and biodiversity conservation. They have a strategic position in hydrological cycles related to food security and natural disaster.

ACKNOWLEDGEMENTS

The authors address our appreciation to the management of PT Aya Yayang Indonesia, who allows us to conduct this study in their concession forest area. We are also grateful to the Faculty of Forestry, Lambung Mangkurat University, which provides a surveyor team to help with forest inventory. Finally, the authors also thank the anonymous reviewer who offers suggestions to improve this article.

REFERENCES

Adler PB, Smull D, Beard KH, Choi RT, Furniss T, Kulmatiski A, Meiners JM, Tredennick AT, Veblen KE. 2018. Competition and coexistence in plant communities: intraspecific competition is stronger than interspecific competition. Ecology Letters 21: 1319–1329. - DOI: 10.1111/ele.13098

Akossou AYJ, Arzouma S, Attakpa EY, Fonton NH, Kokou K. 2013. Scaling of teak (*Tectona grandis*) logs by the xylometer technique: accuracy of volume equations and influence of the log length. Diversity 5: 99–113. - DOI: 10.3390/d5010099

Alam S, Ginting S, Hemon MT, Leomo S, Kilowasid LMH, Karim J, Nugroho Y, Matatula J, Wirabuana PYAP. 2022. Influence of land cover types on soil quality and carbon storage in Moramo Education Estate, Southeast Sulawesi, Indonesia. Biodiversitas Journal of Biological Diversity 23: 4371–4376. - doi: 10.13057/biodiv/d230901

Altanzagas B, Luo Y, Altansukh B, Dorjsuren C, Fang J, Hu H. 2019. Allometric equations for estimating the aboveground biomass of five forest tree species in Khangai, Mongolia. Forests 10: 1–17. - DOI: 10.3390/f10080661

Arora G, Chaturvedi S, Kaushal R, Nain A, Tewari S. 2014. Growth , biomass , carbon stocks , and sequestration in an age series of Populus deltoides plantations in Tarai region of central Himalaya. Turkish Journal of Agriculture and Forestry 38: 550–560. - DOI: 10.3906/tar-1307-94

Asamoah O, Kuittinen S, Danquah JA, Quartey ET, Bamwesigye D, Boateng CM, Pappinen A. 2020. Assessing wood waste by timber industry as a contributing factor to deforestation in Ghana. Forests 11: 1–15. - DOI: 10.3390/f11090939

Barabás G, Michalska-Smith MJ, Allesina S. 2016. The effect of intra- and interspecific competition on coexistence in multispecies communities. American Naturalist 188: 1–12. - DOI: 10.1086/686901

Belote RT, Prisley S, Jones RH, Fitzpatrick M, de Beurs K. 2011. Forest productivity and tree diversity relationships depend on ecological context within mid-Atlantic and Appalachian forests (USA). Forest Ecology and Management 261: 1315–1324. - DOI: 10.1016/j.foreco.2011.01.010

Brancalion PHS, Campoe O, Mendes JCT, Noel C, Moreira GG, van Melis J, Stape JL, Guillemot J. 2019. Intensive silviculture enhances biomass accumulation and tree diversity recovery in tropical forest restoration. Ecological Applications 29. - DOI: 10.1002/eap.1847

Bravo-Oviedo A, Kastendick DN, Alberdi I, Woodall CW. 2021. Similar tree species richness-productivity response but differing effects on carbon stocks and timber production in eastern US and continental Spain. Science of the Total Environment 793: 1–10. - doi: 10.1016/j.scitotenv.2021.148399

Butarbutar T. 2014. Silviculture system of Indonesia selective cutting for mitigation on climate change in the perspective of REDD+. Jurnal Analisis Kebijakan Kehutanan 11: 163–173. - doi: 10.20886/jakk.2014.11.2.163-173

Butarbutar T, Soedirman S, Neupane PR, Köhl M. 2019. Carbon recovery following selective logging in tropical rainforests in Kalimantan, Indonesia. Forest Ecosystems 6: 1–14. - doi: 10.1186/s40663-019-0195-x

Cai H, Di X, Chang SX, Jin G. 2016. Stand density and species richness affect carbon storage and net primary productivity in early and late successional temperate forests differently. Ecological Research 31: 525–533. - doi: 10.1007/s11284-016-1361-z

Duan T, Zhang J, Wang Z. 2021. Responses and indicators of composition, diversity, and productivity of plant communities at different levels of

disturbance in a wetland ecosystem. Diversity 13: 13–16. - DOI: 10.3390/d13060252
Fujii K, Shibata M, Kitajima K, Ichie T, Kitayama K, Turner BL. 2018. Plant–soil interactions maintain biodiversity and functions of tropical forest ecosystems. Ecological Research 33: 149–160. - DOI: 10.1007/s11284-017-1511-y
Gaveau DLA, Sloan S, Molidena E, Yaen H, Sheil D, Abram NK, Ancrenaz M, Nasi R, Quinones M, Wielaard N, Meijaard E. 2014. Four decades of forest persistence, clearance and logging on Borneo. PLoS ONE 9: 1–11. - DOI: 10.1371/journal.pone.0101654
Gevaña DT, Camacho LD, Camacho SC. 2017. Stand density management and blue carbon stock of monospecific mangrove plantation in Bohol, Philippines. Forestry Studies 66: 75–83. - doi: 10.1515/fsmu-2017-0008
Hadi S, Rafdinal R, Linda R. 2019. Density and distribution pattern of *Shorea Leprosula* Miq. in Panti branch research station Gunung Palung National Park South Borneo. Jurnal Protobiont 8: 229–235. - doi: 10.26418/protobiont.v8i3.36877
Hidayat O. 2013. Diversity avifauna species in KHDTK Hambal, East Nusa Tenggara Timur. Journal of Forestry Research Wallacea 2: 12. - DOI: 10.18330/jwallacea.2013.vol2iss1pp12-25
Hussain NA, Ali AH, Lazem LF. 2012. Ecological indices of key biological groups in Southern Iraqi marshland during 2005-2007. Mesopotamian Journal of Marine Science 27: 112–125.
Kementerian Lingkungan Hidup dan Kehutanan (KLHK). 2019. Public press release: improving productivity of natural forest using intensive silviculture. SP. 028/HUMAS/PP/HMS.3/01/2019
Kocurek M, Kornas A, Wierzchnicki R, Lüttge U, Miszalski Z. 2020. Importance of stem photosynthesis in plant carbon allocation of Clusia minor. Trees - Structure and Function 34: 1009–1020. - DOI: 10.1007/s00468-020-01977-w
Krisnawati H, Imanuddin R, Adinugroho WC. 2012. Monograph allometric models for estimating tree biomass at various forest ecosystems types in Indonesia. Ministry of Forestry, Center for research and development of conservation and rehabilitation, Bogor, pp. 1–141. - DOI: 10.13140/RG.2.1.4139.2161
Latifah S, Muhdi M, Purwoko A, Tanjung E. 2018. Estimation of aboveground tree biomass Toona sureni and Coffea arabica in agroforestry system of Simalungun, North Sumatra, Indonesia. Biodiversitas Journal of Biological Diversity 19: 620–625. - doi: 10.13057/biodiv/d190239
Latifah S, Sulistiyono N. 2013. Carbon Sequestration Potential in Aboveground Biomass of Hybrid Eucalyptus Plantation Forest. Journal of Tropical Forest Management 19: 54–62. - doi: 10.7226/jtfm.19.1.54
Ma L, Shen C, Lou D, Fu S, Guan D. 2017. Ecosystem carbon storage in forest fragments of differing patch size. Scientific Reports 7: 1–8. - DOI: 10.1038/s41598-017-13598-4
Matangaran JR, Putra EI, Diatin I, Mujahid M, Adlan Q. 2019. Residual stand damage from selective logging of tropical forests: A comparative case study in central Kalimantan and West Sumatra, Indonesia. Global Ecology and Conservation 19: 1–9. - DOI: 10.1016/j.gecco.2019.e00688
Matatula J, Afandi AY, Wirabuana PYAP. 2021. A comparison of stand structure, species diversity, and aboveground biomass between natural and planted mangroves in Sikka, East Nusa Tenggara, Indonesia. Biodiversitas Journal of Biological Diversity 22: 1098–1103. - doi: 10.13057/biodiv/d220303
McNicol IM, Ryan CM, Dexter KG, Ball SMJ, Williams M. 2018. Aboveground carbon storage and its links to stand structure, tree diversity and floristic composition in South-Eastern Tanzania. Ecosystems 21: 740–754. - DOI: 10.1007/s10021-017-0180-6
Murdjoko A, Djitmau DA, Ungirwalu A, Sinery AS, Siburian RHS, Mardiyadi Z, Wanma AO, Wanma JF, Rumatora A, Mofu WY, Worabai D, May NL, Jitmau MM, Mentansan GAF, Krey K, Musaad I, Manaf M, Abdullah Y, Mamboai H, Pamuji KE, Raharjo S, Kilmaskossu A, Bachri S, Nur-Alzair NA, Benu NMH, Tambing J, Kuswandi R, Khayati L, Lekitoo K. 2021. Pattern of tree diversity in lowland tropical forest in Nikiwar, West Papua, Indonesia. Dendrobiology 85: 78–91. - doi: 10.12657/denbio.085.008
Nugroho Y, Suyanto, Makinudin D, Aditia S, Yulimasita DD, Afandi AY, Harahap MM, Matatula J, Wirabuana PYAP. 2022. Vegetation diversity, structure and composition of three forest ecosystems in Angsana coastal area, South Kalimantan, Indonesia. Biodiversitas Journal of Biological Diversity 23: 2640–2647. - doi: 10.13057/biodiv/d230547
Pan Y, McCullough K, Hollinger DY. 2018. Forest biodiversity, relationships to structural and functional attributes, and stability in New England forests. Forest Ecosystems 5: 1–12. - DOI: 10.1186/s40663-018-0132-4
Poorter H, Niklas KJ, Reich PB, Oleksyn J, Poot P, Mommer L. 2012. Biomass allocation to leaves, stems and roots: Meta-analyses of interspecific variation and environmental control. New Phytologist 193: 30–50. - doi: 10.1111/j.1469-8137.2011.03952.x
Pretzsch H, Biber P, Schütze G, Uhl E, Rötzer T. 2014. Forest stand growth dynamics in Central Europe have accelerated since 1870. Nature Communications 5: 1–10. - DOI: 10.1038/ncomms5967
Purwaningsih. 2004. Ecological distribution of Dipterocarpaceae species in Indonesia. Biodiversitas Journal of Biological Diversity 5: 89–95. - doi: 10.13057/biodiv/d050210
Sadono R, Wardhana W, Idris F, Wirabuana PYAP. 2021a. Carbon storage and energy production of *Eucalyptus urophylla* developed in dryland ecosystems at East Nusa Tenggara. Journal of Degraded and Mining Lands Management 9: 3107–3114. - DOI: 10.15243/JDMLM.2021.091.3107
Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021b. Allometric equations for estimating aboveground biomass of Eucalyptus urophylla S.T. Blake in East Nusa Tenggara. Journal of Tropical Forest Management 27: 24–31. - DOI: 10.7226/jtfm.27.1.24
Sari VM, Manurung TF, Iskandar AM. 2019. Identification of tree species in the Dipterocarpaceae Family at Sambas Botanical Gardens Sambas Regency West Kalimantan. Jurnal Hutan Lestari 10: 370–386.
Sasaki N, Asner GP, Pan Y, Knorr W, Durst PB, Ma HO, Abe I, Lowe AJ, Koh LP, Putz FE. 2016. Sustainable management of tropical forests can reduce carbon emissions and stabilize timber production. Frontiers in Environmental Science 4: 1–13. - doi: 10.3389/fenvs.2016.00050
Setiahadi R. 2021. Comparison of individual tree aboveground biomass estimation in community forests using allometric equation and expansion factor in magetan, east java, Indonesia. Biodiversitas Journal of Biological Diversity 22: 3899–3909. - doi: 10.13057/biodiv/d220936
Simmons EA, Morgan TA, Hayes SW, Ng K, Berg EC. 2021. Timber use, processing capacity, and capability within the USDA forest service, rocky mountain region timber-processing area. Journal of Forestry 118: 233–243. - doi: 10.1093/JOFORE/FVAA011
Siregar M, Undaharta NKE. 2018. Tree standing dynamics after 30 years in a secondary forest of Bali, Indonesia. Biodiversitas Journal of Biological Diversity 19: 22–30. - doi: 10.13057/biodiv/d190104
Taillardat P, Friess DA, Lupascu M. 2018. Mangrove blue carbon strategies for climate change mitigation are most effective at the national scale. Biology Letters 14: 1–7. - doi: 10.1098/rsbl.2018.0251
Tawer P, Maturbongs R, Murdjoko A, Jitmau M, Djitmau D, Siburian R, Ungirwalu A, Wanma A, Mardiyadi Z, Wanma J, Rumatora A, Mofu W, Sinery A, Fatem S, Benu N, Kuswandi R, Lekitoo K, Khayati L, Tambing J. 2021. Vegetation dynamic post-disturbance in tropical rain forest of bird's head peninsula of west Papua, Indonesia. Annals of Silvicultural Research 46. - doi: 10.12899/ASR-2145
Wang Z, Du A, Xu Y, Zhu W, Zhang J. 2019. Factors limiting the growth of eucalyptus and the characteristics of growth and water use underwater and fertilizer management in the dry season of Leizhou Peninsula, China. Agronomy. 9: 1–17. - DOI: 10.3390/agronomy9100590
Wardhana W, Widyatmanti W, Soraya E, Soeprijadi D, Larasati B, Umarhadi DA, Hutomo YHT, Idris F, Wirabuana PYAP. 2020. A hybrid approach of remote sensing for mapping vegetation biodiversity in a tropical rainforest. Biodiversitas Journal of Biological Diversity. 21: 3946–3953. - doi: 10.13057/biodiv/d210904
Wirabuana PYAP, Hendrati RL, Baskorowati L, Susanto M, Mashudi M, Budi Santoso Sulistiadi H, Setiadi D, Sumardi D, Alam S. 2022a. Growth performance, biomass accumulation, and energy production in age series of clonal teak plantation. Forest Science and Technology 18: 67–75. - DOI: 10.1080/21580103.2022.2063952
Wirabuana PYAP, Mulyana B, Meinata A, Idris F, Sadono R. 2021a. Allometric equations for estimating merchantable wood and aboveground biomass

of community forest tree species in Jepara District. Forestry Ideas 27: 496–515.
Wirabuana PYAP, Sadono R, Juniarso S, Idris F. 2020. Interaction of fertilization and weed control influences on growth , biomass , and carbon in eucalyptus hybrid (*E. pellita* × *E. brassica*). Journal of Tropical Forest Management 26: 144–154. - DOI: 10.7226/jtfm.26.2.144
Wirabuana PYAP, Sadono R, Matatula J. 2022b. Competition influences tree dimension, biomass distribution, and leaf area index of Eucalyptus Urophylla in dryland ecosystems at East Nusa Tenggara. Agriculture and Forestry 68: 191–206. - doi: 10.17707/AgricultForest.68.1.12
Wirabuana PYAP, Setiahadi R, Sadono R, Lukito M, Martono DS. 2021b. The influence of stand density and species diversity into timber production and carbon stock in community forest. Indonesian Journal of Forestry Research 8: 13–22. - doi: 10.20886/ijfr.2021.8.1.13-22
Yang XZ, Zhang WH, He QY. 2019. Effects of intraspecific competition on growth, architecture and biomass allocation of *Quercus Liaotungensis*. Journal of Plant Interactions 14: 284–294. - DOI: 10.1080/17429145.2019.1629656
Yue JW, Guan JH, Deng L, Zhang JG, Li G, Du S. 2018. Allocation pattern and accumulation potential of carbon stock in natural spruce forests in northwest China. PeerJ 2018: 1–21. - doi: 10.7717/peerj.4859
Zambiazi DC, Fantini AC, Piotto D, Siminski A, Vibrans AC, Oller DC, Piazza GE, Peña-Claros M. 2021. Timber stock recovery in a chronosequence of secondary forests in Southern Brazil: Adding value to restored landscapes. Forest Ecology and Management 495: 1–11. - DOI: 10.1016/j.foreco.2021.119352

Pandu Yudha Adi Putra Wirabuana <pandu.yudha.a.p@ugm.ac.id>

[biodiv] Editor Decision

1 message

Nor Liza <smujo.id@gmail.com> Fri, Nov 11, 2022 at 9:09 AM
To: Pandu Wirabuana <pandu.yudha.a.p@ugm.ac.id>

Pandu Wirabuana:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Spatial distribution of vegetation diversity, timber production, and carbon storage in secondary tropical rainforest at South Borneo".

Our decision is: Revisions Required

Reviewer A:

Dear Editor-in-Chief,

The article is an interesting and comprehensive analysis to link species diversity, timber production, and carbon stock. However, I suggest to the author make some revisions to make more clear on the materials and method section. Please find the comments in the attached file. Overall, the article should be considered to be published in this journal.

Best regards

Recommendation: Revisions Required

Reviewer J:

My comments on how the manuscript can be improved are in the word document. There are major information gaps in the manuscript, but more fundamentally I am not seeing how the sampling sites were selected. Are the samples representative of the landscape? If not, then the results are not meaningful for management.

Recommendation: Resubmit for Review

Biodiversitas Journal of Biological Diversity

2 attachments

J-12632-Article Text-1064804-1-4-20221026_KMN.doc
425K

A-12632-Article Text-1064804-1-4-20221026_Reviewer.doc
425K

Spatial distribution of vegetation diversity, timber production, and carbon storage in secondary tropical rainforest at South Borneo

SUYANTO[1], YUSANTO NUGROHO[1], MOEHAR MARAGHIY HARAHAP[2], LIA KUSUMANINGRUM[4], PANDU YUDHA ADI PUTRA WIRABUANA[5,♥]

[1]Faculty of Forestry, Universitas Lambung Mangkurat, Jln. Ahmad Yani km 36 Banjarbaru, South Kalimantan, Indonesia
[2]Faculty of Forestry, Universitas Sumatera Utara, Jln. Tri Dharma Ujung No. 1 Medan, North Sumatra, Indonesia
[3]Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Jln. Jend. Urip Sumoharjo No.116 Surakarta, Central Java, Indonesia
[4]Faculty of Forestry, Universitas Gadjah Mada, Jln. Agro No. 1 Bulaksumur, Yogyakarta, Indonesia.
[♥]email: pandu.yudha.a.p@ugm.ac.id

Abstract. Sustainable management in secondary tropical rainforests requires basic information about stand characteristics, mainly related to productivity and biodiversity. This study aimed to quantify vegetation diversity, timber production, and carbon storage from various sites of secondary forests in South Borneo. Forest inventory was conducted using a census method at seven different natural forest management unit compartments. Four parameters were measured from each tree, including the type of species, commercial categories, tree diameter, and tree height. Individual tree volume and biomass were estimated using allometric equations, while carbon storage was determined using a conversion factor from biomass. Three indicators were used to evaluate vegetation diversity: richness, heterogeneity, and evenness. The analysis of correlations was applied to examine the relationship between vegetation diversity and stand productivity with a significant level of 5%. Results found that there were 41 tree species in the study site comprising 20 commercial and 21 non-commercial species. The highest richness (*R′*) was recorded in compartment 18X by approximately 4.0, while the most increased heterogeneity (*H′*) and evenness (*E′*) were observed in compartment 18Y by around 2.4 and 0.7, respectively. The accumulation of timber production varied in each site, with a range of 45.46−68.32 m^3 ha^{-1}. The highest carbon storage was noted in compartment 19Y (38.74±1.79t ha^{-1}), while the lowest was found in compartment 18W (20.76±0.93 t ha^{-1}). The relative contribution of commercial species to timber production and carbon storage was substantially higher than non-commercial species at all sites. However, there was not a significant correlation between vegetation diversity and stand productivity (*P>0.05*). Overall, our study concluded that the secondary tropical forest ecosystems in the site had good vegetation diversity, timber production, and carbon storage.

Commented [A1]: Timber production may or may not lead to long-term carbon storage.

Keywords: biodiversity, ecosystems, inventory, natural forest, productivity

Running title: Spatial distribution of vegetation diversity

INTRODUCTION

Biodiversity conservation, climate change mitigation, and economic development are essential issues in sustainable forest management, particularly in Indonesia. In this context, the management of forests is expected to stabilize wood supplies for commercial industries, support species conservation, and reduce carbon emissions in the atmosphere (Wirabuana et al. 2021b). To tackle these challenges, information about stand dynamics is required as baseline considerations to determine alternative forest management strategies (Pretzsch et al. 2014). It is related to timber production and includes vegetation diversity and carbon storage.

In general, the quantity of timber production will provide adequate information about the economic value of the forest and its capacity for supporting industry viability (Simmons et al. 2021). It also determines the maximum annual allowable cutting from the forest ecosystem (Asamoah et al., 2020). The number of timber production also describes the regeneration stock from different life stages of trees to maintain business sustainability (Zambiazi et al. 2021). Meanwhile, vegetation diversity information indicates the stability of environmental health and forest ecosystems (Pan et al. 2018). It also shows how many species live in the forest and their relative contribution to ecological functions (Matatula et al. 2021). The vegetation diversity can also be used to understand the natural competition in the ecosystems (Duan et al. 2021). On another side, the accumulation of carbon storage indicates the ability of the forest ecosystem to support climate change mitigation, primarily for reducing carbon emissions (Sadono et al. 2021a). Many studies explain forest vegetation generally absorbs CO_2 through the photosynthesis process. First, it converts it into biomass (Sasaki et al. 2016, Ma et al. 2017, Kocurek et al. 2020, Wirabuana et al. 2020, Sadono et al. 2021b, Setiahadi 2021). Then, the biomass will be distributed in components like roots, stems, branches, and foliage (Poorter et al. 2012, Yue et al. 2018, Altanzagas et al. 2019, Wirabuana et al. 2021a). Higher biomass indicates excellent carbon storage wherein the carbon absorption in forests will increase along with vegetation age (Arora et al. 2014). Another study report the critical role of vegetation on carbon absorption is also a part of the balance in biogeochemical cycles (Taillardat et al. 2018). To collect this information, forest

inventory is necessary to support forest managers in monitoring the stand dynamics in each forest ecosystem, including secondary tropical rainforest (STR).

Before the 1990s, STR played an essential role in economic development. It provided wood materials for forest industries like furniture, veneer, and plywood. STR also occupied the second position of important sectors contributing to country revenue. However, the occurrence of deforestation has declined its contribution significantly to the gross domestic product. Most STR currently have low productivity and high biodiversity loss (Gaveau et al. 2014). To anticipate this condition, the government has conducted the effort of reforestation to recover forest productivity and prevent vegetation extinction. However, this program is not easy to implement because STR commonly has high variation in land configuration with low accessibility (Wardhana et al. 2020).

Moreover, soil quality in these sites is also dominated by mature soil with low fertility, like oxisols and ultisols (Fujii et al. 2018). Therefore, it causes the low survival rate of vegetation generated from the reforestation program. Nevertheless, several concession areas of STR still exist and maintain their functions for economic development, biodiversity conservation, and climate change mitigation. One of them is a secondary tropical rainforest area managed by PT Aya Yayang Indonesia (AYI) located in South Borneo. Although it has been managed for over 30 years, the information about forest dynamics in this location is still limited, mainly related to vegetation diversity and carbon storage. Therefore, it is essential to provide more comprehensive details on stand dynamics in this area to support better forest management efforts.

This study aims to document vegetation diversity, timber production, and carbon storage from several compartments of secondary tropical rainforests managed by AYI. This information will help forest manager to determine the forest planning strategy, mainly related to yield regulation and harvesting schedules. Thus, even though it is managed as a production zone, forest regeneration is still maintained and minimizes the risk of biodiversity loss. We hypothesize that: Every compartment has a different value for vegetation diversity, timber production, and carbon storage (i). Higher vegetation diversity significantly increases timber production and carbon storage (ii). The contribution of non-commercial species on stand productivity is higher than commercial species (iii).

MATERIALS AND METHODS

Study area

This study was conducted in the secondary tropical rainforest concession area managed by PT Aya Yayang Indonesia. It is situated in Tabalong District, approximately 270 km from Banjarmasin, the capital city of South Borneo province. The geographic coordinates of this area are located in S1°39'−1°40' and E115°29'−115°30'. Altitude ranges from 225 to 470 m above sea level. Land configuration is dominated by hills with a slope level of 15−40%. The average daily temperature is 27.6°C with a minimum of 25.7°C and a maximum of 30.3°C. The mean annual rainfall during the past ten years is 2,589 mm $year^{-1}$, with an average air humidity of 87.6%. The highest rainfall is recorded in November. Dry periods are relatively short, only around two months from July to August. Oxisols and ultisols dominate soil types with high acidity levels.

> **Commented [A2]:** What is the history of the site? How long ago was it last logged? Logged for how many times? How was it logged?

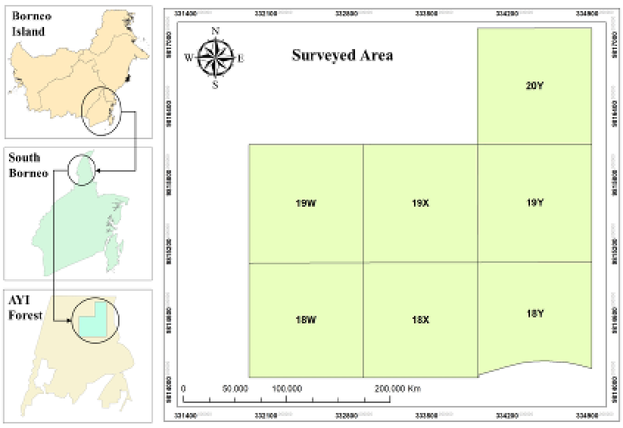


Figure 1. The study area of secondary tropical rainforest in South Borneo

Data collection

Forest inventory was conducted using a census method at seven compartments of the secondary tropical rainforest management unit, namely 18W, 18X, 18Y, 19W, 19X, 19Y, and 20Y. The total surveyed area reached 700 ha, with each site 100 ha. To facilitate the measurement process, the field survey was conducted step by step using sub-plots of 20 m x 20 m. These sub-plots were arranged systematically; all trees in compartments could be covered and measured correctly. Four parameters were measured from each tree, i.e., type of species, commercial categories, tree diameter, and tree height. The determination of commercial and non-commercial species was undertaken, referring to the guidance from the company. Tree diameter was measured using a phi band at 1.3 m aboveground, while tree height was quantified using a haga altimeter from aboveground to the top crown. Moreover, the coordinate of trees was also recorded using a global positioning system (GPS).

Commented [A3]: Why only these compartments? What are the operations happening in these compartments?

Commented [A4]: What is the minimum tree size measured?

Data analysis

Three indicators were selected to describe vegetation diversity, i.e., richness, heterogeneity, and evenness. Vegetation richness was determined by Margalef Index (*R′*), while its heterogeneity was quantified using Shannon-Wiener Index (*H′*). On another side, the evenness of vegetation was assessed by Pielou Evenness Index (*E′*). Detail equations for calculating those indicators are expressed below (Nugroho et al. 2022):

$$R' = S\text{-}1/\ln(N) \quad (1)$$

$$H' = -\sum (n_i/N)\,(\ln n_i/N) \quad (2)$$

$$E' = H'/\ln(S) \quad (3)$$

where S was the number of species observed, N represented the total tree population in each compartment, and n_i described the sum of trees for each species.

To determine the quantity of timber production, individual tree volume was calculated using the following equation:

$$V = 0.25\,\pi\,dbh^2\,h\,f \quad (4)$$

where V was tree volume (m^3), *dbh* indicated tree diameter (cm), h represented tree height (m), and f showed a constant of form factor (0.6) (Akossou et al. 2013). Then, the timber production degree was assumed to be the mean stand volume in hectare units. This value could be derived by dividing the total tree volume in a compartment by its area.

The quantification of carbon storage and CO_2 absorption were also calculated using a similar principle to timber production. However, we used biomass accumulation as a conversion to compute both parameters. In this context, the individual tree biomass was estimated using a generalized allometric model for secondary tropical rainforest as given (Krisnawati et al. 2012):

$$B = 0.047454dbh^{2.078} \quad (4)$$

B was aboveground biomass (kg), and *dbh* indicated tree diameter (cm). Next, the carbon stock of each tree was computed by multiplying its biomass with a conversion factor of 0.46 (Latifah et al. 2018), while CO_2 absorption was estimated by multiplying carbon stock with a constant of 3.67 (Latifah & Sulistiyono 2013). Then, the result was converted into a hectare unit.

Descriptive analysis was selected to compare the value of vegetation diversity, timber production, and carbon storage among different compartments based on the trend of the histogram and the summarized information from the table. Meanwhile, the spatial distribution of three parameters was processed using QGIS. Finally, to evaluate the relationship between vegetation diversity and stand productivity, both in timber production and carbon storage, Pearson correlation analysis was applied with a significant level of 5%.

RESULTS AND DISCUSSION

Vegetation diversity

Commented [A5]: I would like to see the species list, density, and basal area contribution

Results found that vegetation diversity among compartments was substantially different (Table 1). The highest species abundance was recorded in the compartment of 18Y, while the lowest number of species was observed in the compartment of 20Y. Similar trends were also discovered in the richness, heterogeneity, and evenness, wherein the highest value of those indicators was noted in compartment 18Y. These findings directly confirmed our first hypothesis that assumed there was different vegetation diversity between compartments in the study site.

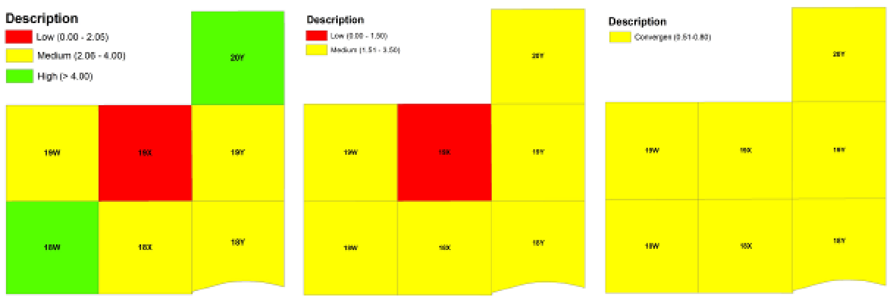
The diversity of vegetation in secondary tropical rainforests was generally caused by the interaction between vegetation and the environment. This process generated natural competition wherein trees compete with each other to obtain sufficient resources to support their survival (Wirabuana et al. 2022b). On another side, environmental variation also became a limiting factor for certain species; thus, it could inhibit several vegetation from growing well (Wang et al. 2019). Consequently, the regeneration capacity of each species in this ecosystem was highly dynamic depending on their adaptation to environmental conditions. Several previous studies also reported similar results wherein the natural regeneration in secondary tropical rainforests was exceptionally dynamics due to the impact of intraspecific and

interspecific competition between trees for obtaining light, water, nutrients, and space (Barabás et al. 2016, Adler et al. 2018, Yang et al. 2019).

Table 1. Comparison of species abundance, richness, heterogeneity, and evenness among compartments

Compartment	N species	Richness	Heterogeneity	Evenness
18W	32	4.01	1.91	0.55
18X	31	3.79	2.10	0.61
18Y	36	4.43	2.42	0.68
19W	32	3.99	1.96	0.57
19X	30	3.59	1.84	0.54
19Y	31	3.89	1.86	0.54
20Y	4	0.38	0.81	0.58

This study recorded that the heterogeneity of vegetation in the study location was dominated by medium classes with a range of 1.51−3.50 (Table 1) (Hidayat 2013). It was similar to previous studies that documented the secondary tropical rainforests commonly had medium vegetation biodiversity (Siregar and Undaharta 2018, Murdjoko et al. 2021, Tawer et al. 2021). This condition could happen because this site was managed using a selective cutting system; thus, only certain species were maintained to support the ecological function of the forest (Butarbutar 2014). In addition, most trees with a limit diameter of more than 50 cm and having commercial values were harvested to provide better-growing space for younger trees (Matangaran et al. 2019). Therefore, this scheme was expected to stabilize the regeneration capacity of secondary forests without sacrificing its economic benefits.



(a) Richness (b) Heterogeneity (c) Evenness

Figure 2. Spatial distribution of vegetation diversity in the study site

Our results also indicated that species distribution in the study site was not evenly distributed. It was shown by the evenness index value ranging from 0.54 to 0.68 (Table 1). These outcomes signified that most species in this location grew in groups (Hussain et al. 2012). It was not surprising since Dipterocarpaceae families dominated most species in secondary tropical rainforests. Many studies explained that these families naturally live in groups and have a specific preference for their habitat (Purwaningsih 2004, Hadi et al. 2019, Sari et al. 2019).

According to the results, it was seen that vegetation diversity in the study site was still maintained well. It also implied that the forest management activity in this area fulfills the principle of sustainability by minimizing the risk of biodiversity loss. However, the effort of enrichment planting is required to improve biodiversity in the compartment with low diversity level. This scheme will also facilitate the conservation of native species from the secondary tropical rainforests.

Commented [A6]: Without a baseline, without a reference to primary forest, it is hard to see if this statement is true.

Timber production

Summarized observation results documented that timber production in the study area ranged from 44.49±1.72 m^3 ha^{-1} to 68.32±2.69 m^3 ha^{-1} (Table 2). These values were substantially higher than the average productivity of Borneo's natural forests, ranging from 30 m^3 ha^{-1} (KLHK, 2019). Therefore, it indicated that the secondary tropical rainforest in this area had high productivity and could still support industry development. Moreover, this study recorded that the average timber production in each compartment was relatively different, wherein the most increased timber production was found in the compartment of 19Y. These findings also confirmed our first hypothesis that timber production was highly varied between compartments in secondary tropical rainforests.

Table 2. Comparison of timber production, biomass accumulation, carbon storage, and CO_2 absorption among compartments

Compartment	Timber production (m^3 ha^{-1})	Biomass accumulation (t ha^{-1})	Carbon stock (t ha^{-1})	CO_2 absorption (t ha^{-1})
18W	44.49±1.72	45.13±2.02	20.76±0.93	76.18±3.40
18X	56.05±2.05	68.35±2.85	31.44±1.31	115.38±4.81
18Y	54.3±2.43	69.25±3.74	31.86±1.73	116.92±6.32
19W	45.56±1.86	48.83±2.42	22.46±1.12	82.44±4.08
19X	54.96±1.55	67.11±2.44	30.87±1.12	113.29±4.11
19Y	68.32±2.69	84.22±3.89	38.74±1.79	142.17±6.56
20Y	50.57±2.30	46.37±2.36	21.33±1.09	78.29±3.98

Interestingly, the compartment of 18Y only occupied the fourth position of the most productivity compartments, even though it had the highest vegetation diversity (Table 2). Our study also did not find a significant correlation between vegetation diversity and timber production (Table 3). It was in contrast to previous studies that documented a substantial effect of vegetation diversity on stand productivity in tropical rainforest ecosystems (Cai et al. 2016, Gevaña et al. 2017, McNicol et al. 2018). These findings rejected our second hypothesis that higher vegetation diversity significantly increases timber production in the study site. However, several kinds of literature also found a similar outcome to ours wherein there was no significant relationship between vegetation diversity and forest productivity (Belote et al. 2011, Bravo-Oviedo et al. 2021). In this context, forest ecosystems may have diverse patterns regarding the connection between biodiversity and productivity.

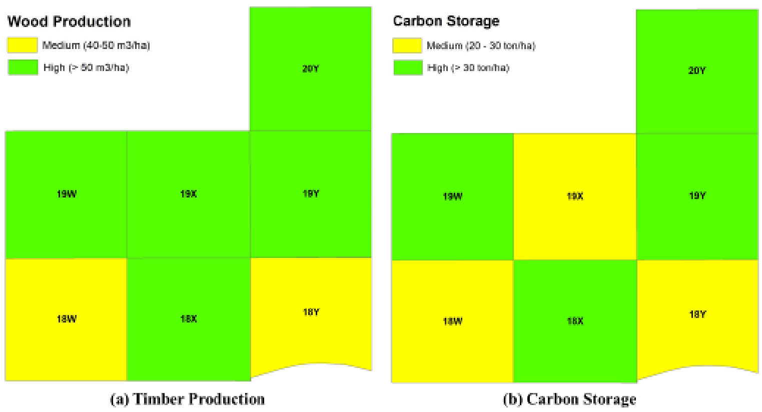


Figure 3. Spatial distribution of timber production and carbon storage in the study site

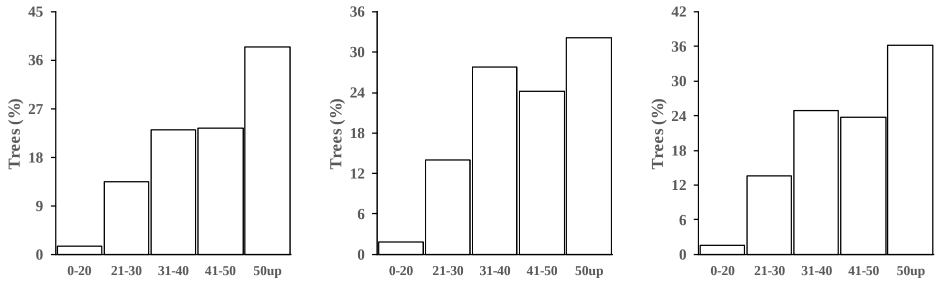
Table 3. Correlation between diversity indicators and stand productivity parameters

Diversity parameter	Productivity parameter	
	Timber production	Carbon Storage
Richness	0.123^{ns}	0.420^{ns}
Heterogeneity	0.116^{ns}	0.442^{ns}
Evenness	-0.056^{ns}	0.098^{ns}

ns: non-significant based on correlation test

Forest ecosystems in the study site had high productivity since their vegetation was dominated by trees with a diameter of more than 50 cm (Figure 4). On another side, the frequency of trees with a diameter lower than 20 cm was only around 2%. These indicated there was sufficient stock of timber production for selective cutting. Moreover, the relative contribution of non-commercial species to total timber production was considerably lower than commercial species (Figure 4). It demonstrated that the current standing stock had high economic value. These results confirmed our third hypothesis that commercial species' relative contribution to stand productivity was higher than non-commercial species. Although this site had increased productivity, forest managers should be careful to determine the quantity of annual allowable cutting (AAC) since the implementation of timber extraction can be impacted young trees' regeneration. Most importantly, the process of timber extraction should not harvest trees that generate seeds for maintaining natural regeneration.

Commented [A7]: How does this translate into rotation cycles?



(a) Commercial (b) Non Commercial (c) All Species

Figure 4. Diameter distribution of tree species in the study site

Carbon storage

Carbon storage in each compartment varied, wherein the carbon stock in the study site ranged from 20.76±0.93 t ha^{-1} to 38.74±1.79 t ha^{-1} (Table 3). The highest CO_2 absorption was recorded in the compartment of 19Y by around 142.17±6.56 t ha^{-1}. In addition, the relative contribution of commercial species on carbons stock was considerably higher than species non-commercial (Figure 4). These findings directly verified our first and third hypotheses in this study. However, similarly to timber production, our study did not find a significant effect of vegetation diversity on carbon storage in this area (Table 3).

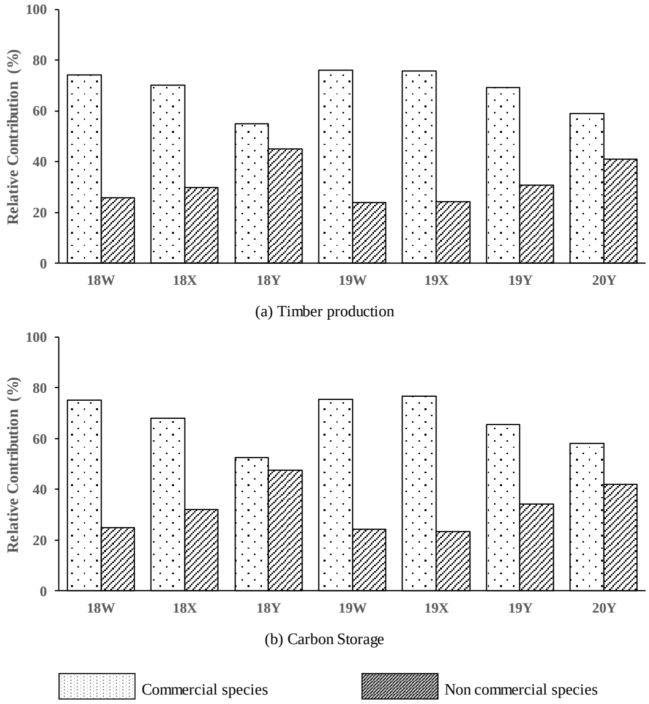


Figure 4. The relative contribution of commercial and non-commercial species on timber production and carbon storage

The accumulation of carbon storage in forest ecosystems has a positive relationship with stand productivity. Higher stand productivity increases carbon stock since it was generated from photosynthesis (Cai et al. 2016, Brancalion et al. 2019, Alam et al. 2022, Wirabuana et al. 2022a). A study reported the average carbon stock in tropical rainforest ecosystems was 51.18 t ha^{-1} (Butarbutar et al. 2019). This value is higher than carbon storage in the study site. However, this study's carbon stock measurement is still limited to the tree level. We still have not quantified the carbon stock in other life stages like poles, saplings, seedlings, and understorey. Thereby, the actual carbon storage in the study area may be higher than the current estimation. It is also essential for forest managers in the study location to consider the quantity of carbon stock as the additional value of sustainable natural resources management.

Implication results

This study concluded that the secondary tropical rainforest ecosystems in the study site had good vegetation diversity, timber production, and carbon storage. Furthermore, it indicated that forest managers had applied sustainability principles in the context of operation scale. Nevertheless, some improvements are still required to increase the value of forest management on this site. Besides conducting enrichment planting in the compartment with low biodiversity levels, we also suggest forest managers determine the scheme of yield regulation to minimize forest disturbance due to the impact of harvesting operations. Furthermore, the cutting process has a high potential to decline regeneration capacity since the felled trees will override the younger plants like seedlings and saplings.

We also suggest forest managers identify the distribution of mother trees in their concession area for obtaining seed as plant material in artificial regeneration. The seed collection is also essential to maintain the genetic diversity in this area. On another side, it is also necessary to document the carbon dynamics during the rotation periods, including loss and increment, since it will provide comprehensive information about forest management's effectiveness in tackling the climate change mitigation issue. We also encourage forest managers in this area to share their knowledge with other natural resources managers who fail to manage the secondary tropical rainforest ecosystems. It is highly required since forest ecosystems play an essential role in economic development, climate change mitigation, and biodiversity conservation. They have a strategic position in hydrological cycles related to food security and natural disaster.

ACKNOWLEDGEMENTS

The authors address our appreciation to the management of PT Aya Yayang Indonesia, who allows us to conduct this study in their concession forest area. We are also grateful to the Faculty of Forestry, Lambung Mangkurat University, which provides a surveyor team to help with forest inventory. Finally, the authors also thank the anonymous reviewer who offers suggestions to improve this article.

REFERENCES

Adler PB, Smull D, Beard KH, Choi RT, Furniss T, Kulmatiski A, Meiners JM, Tredennick AT, Veblen KE. 2018. Competition and coexistence in plant communities: intraspecific competition is stronger than interspecific competition. Ecology Letters 21: 1319–1329. - DOI: 10.1111/ele.13098
Akossou AYJ, Arzouma S, Attakpa EY, Fonton NH, Kokou K. 2013. Scaling of teak (*Tectona grandis*) logs by the xylometer technique: accuracy of volume equations and influence of the log length. Diversity 5: 99–113. - DOI: 10.3390/d5010099
Alam S, Ginting S, Hemon MT, Leomo S, Kilowasid LMH, Karim J, Nugroho Y, Matatula J, Wirabuana PYAP. 2022. Influence of land cover types on soil quality and carbon storage in Moramo Education Estate, Southeast Sulawesi, Indonesia. Biodiversitas Journal of Biological Diversity 23: 4371–4376. - doi: 10.13057/biodiv/d230901
Altanzagas B, Luo Y, Altansukh B, Dorjsuren C, Fang J, Hu H. 2019. Allometric equations for estimating the aboveground biomass of five forest tree species in Khangai, Mongolia. Forests 10: 1–17. - DOI: 10.3390/f10080661
Arora G, Chaturvedi S, Kaushal R, Nain A, Tewari S. 2014. Growth , biomass , carbon stocks , and sequestration in an age series of Populus deltoides plantations in Tarai region of central Himalaya. Turkish Journal of Agriculture and Forestry 38: 550–560. - DOI: 10.3906/tar-1307-94
Asamoah O, Kuittinen S, Danquah JA, Quartey ET, Bamwesigye D, Boateng CM, Pappinen A. 2020. Assessing wood waste by timber industry as a contributing factor to deforestation in Ghana. Forests 11: 1–15. - DOI: 10.3390/f11090939
Barabás G, Michalska-Smith MJ, Allesina S. 2016. The effect of intra- and interspecific competition on coexistence in multispecies communities. American Naturalist 188: 1–12. - DOI: 10.1086/686901
Belote RT, Prisley S, Jones RH, Fitzpatrick M, de Beurs K. 2011. Forest productivity and tree diversity relationships depend on ecological context within mid-Atlantic and Appalachian forests (USA). Forest Ecology and Management 261: 1315–1324. - DOI: 10.1016/j.foreco.2011.01.010
Brancalion PHS, Campoe O, Mendes JCT, Noel C, Moreira GG, van Melis J, Stape JL, Guillemot J. 2019. Intensive silviculture enhances biomass accumulation and tree diversity recovery in tropical forest restoration. Ecological Applications 29. - DOI: 10.1002/eap.1847
Bravo-Oviedo A, Kastendick DN, Alberdi I, Woodall CW. 2021. Similar tree species richness-productivity response but differing effects on carbon stocks and timber production in eastern US and continental Spain. Science of the Total Environment 793: 1–10. - doi: 10.1016/j.scitotenv.2021.148399
Butarbutar T. 2014. Silviculture system of Indonesia selective cutting for mitigation on climate change in the perspective of REDD+. Jurnal Analisis Kebijakan Kehutanan 11: 163–173. - doi: 10.20886/jakk.2014.11.2.163-173
Butarbutar T, Soedirman S, Neupane PR, Köhl M. 2019. Carbon recovery following selective logging in tropical rainforests in Kalimantan, Indonesia. Forest Ecosystems 6: 1–14. - doi: 10.1186/s40663-019-0195-x
Cai H, Di X, Chang SX, Jin G. 2016. Stand density and species richness affect carbon storage and net primary productivity in early and late successional temperate forests differently. Ecological Research 31: 525–533. - doi: 10.1007/s11284-016-1361-z
Duan T, Zhang J, Wang Z. 2021. Responses and indicators of composition, diversity, and productivity of plant communities at different levels of disturbance in a wetland ecosystem. Diversity 13: 13–16. - DOI: 10.3390/d13060252
Fujii K, Shibata M, Kitajima K, Ichie T, Kitayama K, Turner BL. 2018. Plant–soil interactions maintain biodiversity and functions of tropical forest ecosystems. Ecological Research 33: 149–160. - DOI: 10.1007/s11284-017-1511-y
Gaveau DLA, Sloan S, Molidena E, Yaen H, Sheil D, Abram NK, Ancrenaz M, Nasi R, Quinones M, Wielaard N, Meijaard E. 2014. Four decades of forest persistence, clearance and logging on Borneo. PLoS ONE 9: 1–11. - DOI: 10.1371/journal.pone.0101654
Gevaña DT, Camacho LD, Camacho SC. 2017. Stand density management and blue carbon stock of monospecific mangrove plantation in Bohol, Philippines. Forestry Studies 66: 75–83. - doi: 10.1515/fsmu-2017-0008
Hadi S, Rafdinal R, Linda R. 2019. Density and distribution pattern of *Shorea Leprosula* Miq. in Panti branch research station Gunung Palung National Park South Borneo. Jurnal Protobiont 8: 229–235. - doi: 10.26418/protobiont.v8i3.36877
Hidayat O. 2013. Diversity avifauna species in KHDTK Hambal, East Nusa Tenggara Timur. Journal of Forestry Research Wallacea 2: 12. - DOI: 10.18330/jwallacea.2013.vol2iss1pp12-25
Hussain NA, Ali AH, Lazem LF. 2012. Ecological indices of key biological groups in Southern Iraqi marshland during 2005-2007. Mesopotamian Journal of Marine Science 27: 112–125.
Kementerian Lingkungan Hidup dan Kehutanan (KLHK). 2019. Public press release: improving productivity of natural forest using intensive silviculture. SP. 028/HUMAS/PP/HMS.3/01/2019
Kocurek M, Kornas A, Wierzchnicki R, Lüttge U, Miszalski Z. 2020. Importance of stem photosynthesis in plant carbon allocation of Clusia minor. Trees - Structure and Function 34: 1009–1020. - DOI: 10.1007/s00468-020-01977-w
Krisnawati H, Imanuddin R, Adinugroho WC. 2012. Monograph allometric models for estimating tree biomass at various forest ecosystems types in Indonesia. Ministry of Forestry, Center for research and development of conservation and rehabilitation, Bogor, pp. 1–141. - DOI: 10.13140/RG.2.1.4139.2161
Latifah S, Muhdi M, Purwoko A, Tanjung E. 2018. Estimation of aboveground tree biomass Toona sureni and Coffea arabica in agroforestry system of Simalungun, North Sumatra, Indonesia. Biodiversitas Journal of Biological Diversity 19: 620–625. - doi: 10.13057/biodiv/d190239
Latifah S, Sulistiyono N. 2013. Carbon Sequestration Potential in Aboveground Biomass of Hybrid Eucalyptus Plantation Forest. Journal of Tropical Forest Management 19: 54–62. - doi: 10.7226/jtfm.19.1.54
Ma L, Shen C, Lou D, Fu S, Guan D. 2017. Ecosystem carbon storage in forest fragments of differing patch size. Scientific Reports 7: 1–8. - DOI: 10.1038/s41598-017-13598-4
Matangaran JR, Putra EI, Diatin I, Mujahid M, Adlan Q. 2019. Residual stand damage from selective logging of tropical forests: A comparative case study in central Kalimantan and West Sumatra, Indonesia. Global Ecology and Conservation 19: 1–9. - DOI: 10.1016/j.gecco.2019.e00688
Matatula J, Afandi AY, Wirabuana PYAP. 2021. A comparison of stand structure, species diversity, and aboveground biomass between natural and planted mangroves in Sikka, East Nusa Tenggara, Indonesia. Biodiversitas Journal of Biological Diversity 22: 1098–1103. - doi: 10.13057/biodiv/d220303
McNicol IM, Ryan CM, Dexter KG, Ball SMJ, Williams M. 2018. Aboveground carbon storage and its links to stand structure, tree diversity and floristic composition in South-Eastern Tanzania. Ecosystems 21: 740–754. - DOI: 10.1007/s10021-017-0180-6

Murdjoko A, Djitmau DA, Ungirwalu A, Sinery AS, Siburian RHS, Mardiyadi Z, Wanma AO, Wanma JF, Rumatora A, Mofu WY, Worabai D, May NL, Jitmau MM, Mentansan GAF, Krey K, Musaad I, Manaf M, Abdullah Y, Mamboai H, Pamuji KE, Raharjo S, Kilmaskossu A, Bachri S, Nur-Alzair NA, Benu NMH, Tambing J, Kuswandi R, Khayati L, Lekitoo K. 2021. Pattern of tree diversity in lowland tropical forest in Nikiwar, West Papua, Indonesia. Dendrobiology 85: 78–91. - doi: 10.12657/denbio.085.008

Nugroho Y, Suyanto, Makinudin D, Aditia S, Yulimasita DD, Afandi AY, Harahap MM, Matatula J, Wirabuana PYAP. 2022. Vegetation diversity, structure and composition of three forest ecosystems in Angsana coastal area, South Kalimantan, Indonesia. Biodiversitas Journal of Biological Diversity 23: 2640–2647. - doi: 10.13057/biodiv/d230547

Pan Y, McCullough K, Hollinger DY. 2018. Forest biodiversity, relationships to structural and functional attributes, and stability in New England forests. Forest Ecosystems 5: 1–12. - DOI: 10.1186/s40663-018-0132-4

Poorter H, Niklas KJ, Reich PB, Oleksyn J, Poot P, Mommer L. 2012. Biomass allocation to leaves, stems and roots: Meta-analyses of interspecific variation and environmental control. New Phytologist 193: 30–50. - doi: 10.1111/j.1469-8137.2011.03952.x

Pretzsch H, Biber P, Schütze G, Uhl E, Rötzer T. 2014. Forest stand growth dynamics in Central Europe have accelerated since 1870. Nature Communications 5: 1–10. - DOI: 10.1038/ncomms5967

Purwaningsih. 2004. Ecological distribution of Dipterocarpaceae species in Indonesia. Biodiversitas Journal of Biological Diversity 5: 89–95. - doi: 10.13057/biodiv/d050210

Sadono R, Wardhana W, Idris F, Wirabuana PYAP. 2021a. Carbon storage and energy production of *Eucalyptus urophylla* developed in dryland ecosystems at East Nusa Tenggara. Journal of Degraded and Mining Lands Management 9: 3107–3114. - DOI: 10.15243/JDMLM.2021.091.3107

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021b. Allometric equations for estimating aboveground biomass of Eucalyptus urophylla S.T. Blake in East Nusa Tenggara. Journal of Tropical Forest Management 27: 24–31. - DOI: 10.7226/jtfm.27.1.24

Sari VM, Manurung TF, Iskandar AM. 2019. Identification of tree species in the Dipterocarpaceae Family at Sambas Botanical Gardens Sambas Regency West Kalimantan. Jurnal Hutan Lestari 10: 370–386.

Sasaki N, Asner GP, Pan Y, Knorr W, Durst PB, Ma HO, Abe I, Lowe AJ, Koh LP, Putz FE. 2016. Sustainable management of tropical forests can reduce carbon emissions and stabilize timber production. Frontiers in Environmental Science 4: 1–13. - doi: 10.3389/fenvs.2016.00050

Setiahadi R. 2021. Comparison of individual tree aboveground biomass estimation in community forests using allometric equation and expansion factor in magetan, east java, Indonesia. Biodiversitas Journal of Biological Diversity 22: 3899–3909. - doi: 10.13057/biodiv/d220936

Simmons EA, Morgan TA, Hayes SW, Ng K, Berg EC. 2021. Timber use, processing capacity, and capability within the USDA forest service, rocky mountain region timber-processing area. Journal of Forestry 118: 233–243. - doi: 10.1093/JOFORE/FVAA011

Siregar M, Undaharta NKE. 2018. Tree standing dynamics after 30 years in a secondary forest of Bali, Indonesia. Biodiversitas Journal of Biological Diversity 19: 22–30. - doi: 10.13057/biodiv/d190104

Taillardat P, Friess DA, Lupascu M. 2018. Mangrove blue carbon strategies for climate change mitigation are most effective at the national scale. Biology Letters 14: 1–7. - doi: 10.1098/rsbl.2018.0251

Tawer P, Maturbongs R, Murdjoko A, Jitmau M, Djitmau D, Siburian R, Ungirwalu A, Wanma A, Mardiyadi Z, Wanma J, Rumatora A, Mofu W, Sinery A, Fatem S, Benu N, Kuswandi R, Lekitoo K, Khayati L, Tambing J. 2021. Vegetation dynamic post-disturbance in tropical rain forest of bird's head peninsula of west Papua, Indonesia. Annals of Silvicultural Research 46. - doi: 10.12899/ASR-2145

Wang Z, Du A, Xu Y, Zhu W, Zhang J. 2019. Factors limiting the growth of eucalyptus and the characteristics of growth and water use underwater and fertilizer management in the dry season of Leizhou Peninsula, China. Agronomy. 9: 1–17. - DOI: 10.3390/agronomy9100590

Wardhana W, Widyatmanti W, Soraya E, Soeprijadi D, Larasati B, Umarhadi DA, Hutomo YHT, Idris F, Wirabuana PYAP. 2020. A hybrid approach of remote sensing for mapping vegetation biodiversity in a tropical rainforest. Biodiversitas Journal of Biological Diversity. 21: 3946–3953. - doi: 10.13057/biodiv/d210904

Wirabuana PYAP, Hendrati RL, Baskorowati L, Susanto M, Mashudi M, Budi Santoso Sulistiadi H, Setiadi D, Sumardi D, Alam S. 2022a. Growth performance, biomass accumulation, and energy production in age series of clonal teak plantation. Forest Science and Technology 18: 67–75. - DOI: 10.1080/21580103.2022.2063952

Wirabuana PYAP, Mulyana B, Meinata A, Idris F, Sadono R. 2021a. Allometric equations for estimating merchantable wood and aboveground biomass of community forest tree species in Jepara District. Forestry Ideas 27: 496–515.

Wirabuana PYAP, Sadono R, Juniarso S, Idris F. 2020. Interaction of fertilization and weed control influences on growth , biomass , and carbon in eucalyptus hybrid (*E. pellita* × *E. brassica*). Journal of Tropical Forest Management 26: 144–154. - DOI: 10.7226/jtfm.26.2.144

Wirabuana PYAP, Sadono R, Matatula J. 2022b. Competition influences tree dimension, biomass distribution, and leaf area index of Eucalyptus Urophylla in dryland ecosystems at East Nusa Tenggara. Agriculture and Forestry 68: 191–206. - doi: 10.17707/AgricultForest.68.1.12

Wirabuana PYAP, Setiahadi R, Sadono R, Lukito M, Martono DS. 2021b. The influence of stand density and species diversity into timber production and carbon stock in community forest. Indonesian Journal of Forestry Research 8: 13–22. - doi: 10.20886/ijfr.2021.8.1.13-22

Yang XZ, Zhang WH, He QY. 2019. Effects of intraspecific competition on growth, architecture and biomass allocation of *Quercus Liaotungensis*. Journal of Plant Interactions 14: 284–294. - DOI: 10.1080/17429145.2019.1629656

Yue JW, Guan JH, Deng L, Zhang JG, Li G, Du S. 2018. Allocation pattern and accumulation potential of carbon stock in natural spruce forests in northwest China. PeerJ 2018: 1–21. - doi: 10.7717/peerj.4859

Zambiazi DC, Fantini AC, Piotto D, Siminski A, Vibrans AC, Oller DC, Piazza GE, Peña-Claros M. 2021. Timber stock recovery in a chronosequence of secondary forests in Southern Brazil: Adding value to restored landscapes. Forest Ecology and Management 495: 1–11. - DOI: 10.1016/j.foreco.2021.119352

Spatial distribution of vegetation diversity, timber production, and carbon storage in secondary tropical rainforest at South Borneo

Abstract. Sustainable management in secondary tropical rainforests requires basic information about stand characteristics, mainly related to productivity and biodiversity. This study aimed to quantify vegetation diversity, timber production, and carbon storage from various sites of secondary forests in South Borneo. Forest inventory was conducted using a census method at seven different natural forest management unit compartments. Four parameters were measured from each tree, including the type of species, commercial categories, tree diameter, and tree height. Individual tree volume and biomass were estimated using allometric equations, while carbon storage was determined using a conversion factor from biomass. Three indicators were used to evaluate vegetation diversity: richness, heterogeneity, and evenness. The analysis of correlations was applied to examine the relationship between vegetation diversity and stand productivity with a significant level of 5%. Results found that there were 41 tree species in the study site comprising 20 commercial and 21 non-commercial species. The highest richness (*R′*) was recorded in compartment 18X by approximately 4.0, while the most increased heterogeneity (*H′*) and evenness (*E′*) were observed in compartment 18Y by around 2.4 and 0.7, respectively. The accumulation of timber production varied in each site, with a range of 45.46−68.32 m^3 ha^{-1}. The highest carbon storage was noted in compartment 19Y (38.74±1.79t ha^{-1}), while the lowest was found in compartment 18W (20.76±0.93 t ha^{-1}). The relative contribution of commercial species to timber production and carbon storage was substantially higher than non-commercial species at all sites. However, there was not a significant correlation between vegetation diversity and stand productivity (*P>0.05*). Overall, our study concluded that the secondary tropical forest ecosystems in the site had good vegetation diversity, timber production, and carbon storage.

Commented [A1]: I suggest to use the unit for carbon storage is t C/ha. If you calculate the biomass, the unit is t/ha

Commented [A2]: I suggest to use the unit for carbon storage is t C/ha. If you calculate the biomass, the unit is t/ha

Keywords: biodiversity, ecosystems, inventory, natural forest, productivity

Running title: Spatial distribution of vegetation diversity

INTRODUCTION

Biodiversity conservation, climate change mitigation, and economic development are essential issues in sustainable forest management, particularly in Indonesia. In this context, the management of forests is expected to stabilize wood supplies for commercial industries, support species conservation, and reduce carbon emissions in the atmosphere (Wirabuana et al. 2021b). To tackle these challenges, information about stand dynamics is required as baseline considerations to determine alternative forest management strategies (Pretzsch et al. 2014). It is related to timber production and includes vegetation diversity and carbon storage.

In general, the quantity of timber production will provide adequate information about the economic value of the forest and its capacity for supporting industry viability (Simmons et al. 2021). It also determines the maximum annual allowable cutting from the forest ecosystem (Asamoah et al., 2020). The number of timber production also describes the regeneration stock from different life stages of trees to maintain business sustainability (Zambiazi et al. 2021). Meanwhile, vegetation diversity information indicates the stability of environmental health and forest ecosystems (Pan et al. 2018). It also shows how many species live in the forest and their relative contribution to ecological functions (Matatula et al. 2021). The vegetation diversity can also be used to understand the natural competition in the ecosystems (Duan et al. 2021). On another side, the accumulation of carbon storage indicates the ability of the forest ecosystem to support climate change mitigation, primarily for reducing carbon emissions (Sadono et al. 2021a). Many studies explain forest vegetation generally absorbs CO_2 through the photosynthesis process. First, it converts it into biomass (Sasaki et al. 2016, Ma et al. 2017, Kocurek et al. 2020, Wirabuana et al. 2020, Sadono et al. 2021b, Setiahadi 2021). Then, the biomass will be distributed in components like roots, stems, branches, and foliage (Poorter et al. 2012, Yue et al. 2018, Altanzagas et al. 2019, Wirabuana et al. 2021a). Higher biomass indicates excellent carbon storage wherein the carbon absorption in forests will increase along with vegetation age (Arora et al. 2014). Another study report the critical role of vegetation on carbon absorption is also a part of the balance in biogeochemical cycles (Taillardat et al. 2018). To collect this information, forest

inventory is necessary to support forest managers in monitoring the stand dynamics in each forest ecosystem, including secondary tropical rainforest (STR).

Before the 1990s, STR played an essential role in economic development. It provided wood materials for forest industries like furniture, veneer, and plywood. STR also occupied the second position of important sectors contributing to country revenue. However, the occurrence of deforestation has declined its contribution significantly to the gross domestic product. Most STR currently have low productivity and high biodiversity loss (Gaveau et al. 2014). To anticipate this condition, the government has conducted the effort of reforestation to recover forest productivity and prevent vegetation extinction. However, this program is not easy to implement because STR commonly has high variation in land configuration with low accessibility (Wardhana et al. 2020).

Commented [A3]: Please add the citation

Moreover, soil quality in these sites is also dominated by mature soil with low fertility, like oxisols and ultisols (Fujii et al. 2018). Therefore, it causes the low survival rate of vegetation generated from the reforestation program. Nevertheless, several concession areas of STR still exist and maintain their functions for economic development, biodiversity conservation, and climate change mitigation. One of them is a secondary tropical rainforest area managed by PT Aya Yayang Indonesia (AYI) located in South Borneo. Although it has been managed for over 30 years, the information about forest dynamics in this location is still limited, mainly related to vegetation diversity and carbon storage. Therefore, it is essential to provide more comprehensive details on stand dynamics in this area to support better forest management efforts.

This study aims to document vegetation diversity, timber production, and carbon storage from several compartments of secondary tropical rainforests managed by AYI. This information will help forest manager to determine the forest planning strategy, mainly related to yield regulation and harvesting schedules. Thus, even though it is managed as a production zone, forest regeneration is still maintained and minimizes the risk of biodiversity loss. We hypothesize that: Every compartment has a different value for vegetation diversity, timber production, and carbon storage (i). Higher vegetation diversity significantly increases timber production and carbon storage (ii). The contribution of non-commercial species on stand productivity is higher than commercial species (iii).

Commented [A4]: Authors should explain clearly in the materials and methods section on how to test these hypothesis

MATERIALS AND METHODS

Study area

This study was conducted in the secondary tropical rainforest concession area managed by PT Aya Yayang Indonesia. It is situated in Tabalong District, approximately 270 km from Banjarmasin, the capital city of South Borneo province. The geographic coordinates of this area are located in S1°39'−1°40' and E115°29'−115°30'. Altitude ranges from 225 to 470 m above sea level. Land configuration is dominated by hills with a slope level of 15−40%. The average daily temperature is 27.6°C with a minimum of 25.7°C and a maximum of 30.3°C. The mean annual rainfall during the past ten years is 2,589 mm year^{-1}, with an average air humidity of 87.6%. The highest rainfall is recorded in November. Dry periods are relatively short, only around two months from July to August. Oxisols and ultisols dominate soil types with high acidity levels.

Commented [A5]: When was the data collection conducted?

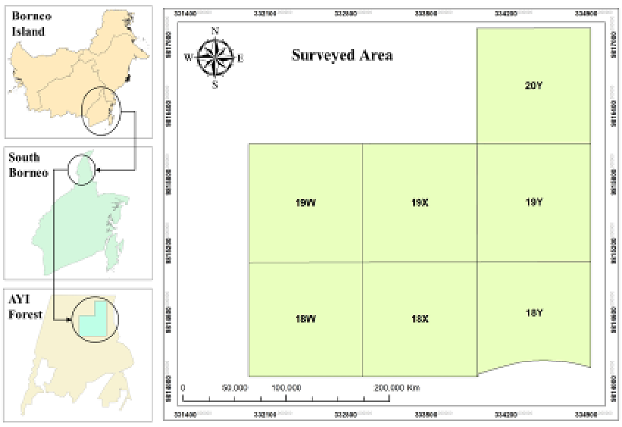


Figure 1. The study area of secondary tropical rainforest in South Borneo

Commented [A6]: Please use contras color to show the research site map

Data collection

Forest inventory was conducted using a census method at seven compartments of the secondary tropical rainforest management unit, namely 18W, 18X, 18Y, 19W, 19X, 19Y, and 20Y. The total surveyed area reached 700 ha, with each site 100 ha. To facilitate the measurement process, the field survey was conducted step by step using sub-plots of 20 m x 20 m. These sub-plots were arranged systematically; all trees in compartments could be covered and measured correctly. Four parameters were measured from each tree, i.e., type of species, commercial categories, tree diameter, and tree height. The determination of commercial and non-commercial species was undertaken, referring to the guidance from the company. Tree diameter was measured using a phi band at 1.3 m aboveground, while tree height was quantified using a haga altimeter from aboveground to the top crown. Moreover, the coordinate of trees was also recorded using a global positioning system (GPS).

> **Commented [A7]:** Census method but authors used sub-plots 20 m x 20 m.
> What the authors did, census method or sampling method?
>
> Or the authors used sampling method but in each sampling plot used census to measure all vegetation in the sampling plot?

> **Commented [A8R7]:**

> **Commented [A9]:** Census method but authors used sub-plots 20 m x 20 m.
> What the authors did, census method or sampling method?
>
> Or the authors used sampling method but in each sampling plot used census to measure all vegetation in the sampling plot?

> **Commented [A10]:** I guess, the author have used the uniform systematic distribution sampling and measured the unit sample using census method. Please, state clearly on the data collection method

Data analysis

Three indicators were selected to describe vegetation diversity, i.e., richness, heterogeneity, and evenness. Vegetation richness was determined by Margalef Index (R'), while its heterogeneity was quantified using Shannon-Wiener Index (H'). On another side, the evenness of vegetation was assessed by Pielou Evenness Index (E'). Detail equations for calculating those indicators are expressed below (Nugroho et al. 2022):

$$R' = S\text{-}1/ln(N) \quad (1)$$

$$H' = -\sum (n_i/N)\ (ln\ n_i/N) \quad (2)$$

$$E' = H'/ln(S) \quad (3)$$

where S was the number of species observed, N represented the total tree population in each compartment, and n_i described the sum of trees for each species.

To determine the quantity of timber production, individual tree volume was calculated using the following equation:

$$V = 0.25\ \pi\ dbh^2\ h\ f \quad (4)$$

where V was tree volume (m^3), *dbh* indicated tree diameter (cm), *h* represented tree height (m), and *f* showed a constant of form factor (0.6) (Akossou et al. 2013). Then, the timber production degree was assumed to be the mean stand volume in hectare units. This value could be derived by dividing the total tree volume in a compartment by its area.

> **Commented [A11]:** Is it total tree height or commercial height?

The quantification of carbon storage and CO_2 absorption were also calculated using a similar principle to timber production. However, we used biomass accumulation as a conversion to compute both parameters. In this context, the individual tree biomass was estimated using a generalized allometric model for secondary tropical rainforest as given (Krisnawati et al. 2012):

$$B = 0.047454dbh^{2.078} \quad (4)$$

B was aboveground biomass (kg), and *dbh* indicated tree diameter (cm). Next, the carbon stock of each tree was computed by multiplying its biomass with a conversion factor of 0.46 (Latifah et al. 2018), while CO_2 absorption was estimated by multiplying carbon stock with a constant of 3.67 (Latifah & Sulistiyono 2013). Then, the result was converted into a hectare unit.

> **Commented [A12]:** I suggest to use the terminology of percentage carbon content (PCC) than conversion factor. In general, the total carbon is dry-weight biomass multiply with percentage carbon content.

Descriptive analysis was selected to compare the value of vegetation diversity, timber production, and carbon storage among different compartments based on the trend of the histogram and the summarized information from the table. Meanwhile, the spatial distribution of three parameters was processed using QGIS. Finally, to evaluate the relationship between vegetation diversity and stand productivity, both in timber production and carbon storage, Pearson correlation analysis was applied with a significant level of 5%.

RESULTS AND DISCUSSION

Vegetation diversity

Results found that vegetation diversity among compartments was substantially different (Table 1). The highest species abundance was recorded in the compartment of 18Y, while the lowest number of species was observed in the compartment of 20Y. Similar trends were also discovered in the richness, heterogeneity, and evenness, wherein the highest value of those indicators was noted in compartment 18Y. These findings directly confirmed our first hypothesis that assumed there was different vegetation diversity between compartments in the study site.

> **Commented [A13]:** I suggest the authors to pay attention on compartment 20Y. Why the number of species is 4? While in other compartments the species more than 30

The diversity of vegetation in secondary tropical rainforests was generally caused by the interaction between vegetation and the environment. This process generated natural competition wherein trees compete with each other to obtain sufficient resources to support their survival (Wirabuana et al. 2022b). On another side, environmental variation also became a limiting factor for certain species; thus, it could inhibit several vegetation from growing well (Wang et al. 2019). Consequently, the regeneration capacity of each species in this ecosystem was highly dynamic depending on their adaptation to environmental conditions. Several previous studies also reported similar results wherein the natural regeneration in secondary tropical rainforests was exceptionally dynamics due to the impact of intraspecific and

interspecific competition between trees for obtaining light, water, nutrients, and space (Barabás et al. 2016, Adler et al. 2018, Yang et al. 2019).

Table 1. Comparison of species abundance, richness, heterogeneity, and evenness among compartments

Compartment	N species	Richness	Heterogeneity	Evenness
18W	32	4.01	1.91	0.55
18X	31	3.79	2.10	0.61
18Y	36	4.43	2.42	0.68
19W	32	3.99	1.96	0.57
19X	30	3.59	1.84	0.54
19Y	31	3.89	1.86	0.54
20Y	4	0.38	0.81	0.58

This study recorded that the heterogeneity of vegetation in the study location was dominated by medium classes with a range of 1.51−3.50 (Table 1) (Hidayat 2013). It was similar to previous studies that documented the secondary tropical rainforests commonly had medium vegetation biodiversity (Siregar and Undaharta 2018, Murdjoko et al. 2021, Tawer et al. 2021). This condition could happen because this site was managed using a selective cutting system; thus, only certain species were maintained to support the ecological function of the forest (Butarbutar 2014). In addition, most trees with a limit diameter of more than 50 cm and having commercial values were harvested to provide better-growing space for younger trees (Matangaran et al. 2019). Therefore, this scheme was expected to stabilize the regeneration capacity of secondary forests without sacrificing its economic benefits.

Commented [A14]: Please state in the data analysis section on how authors classified biodiversity indices into low, medium, high.

It also will useful to explain the figure 2. whree the authors have made classification also

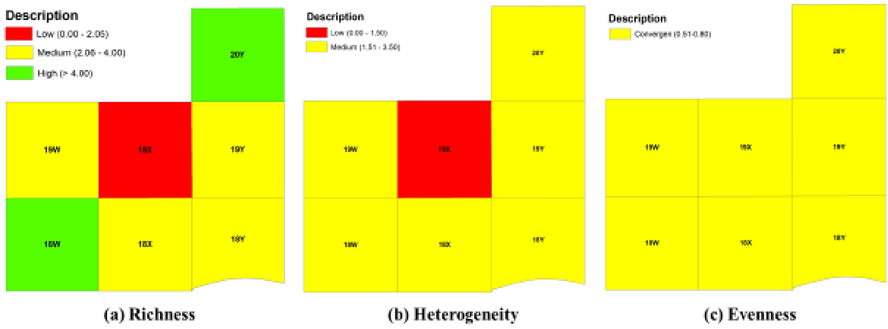


Figure 2. Spatial distribution of vegetation diversity in the study site

Our results also indicated that species distribution in the study site was not evenly distributed. It was shown by the evenness index value ranging from 0.54 to 0.68 (Table 1). These outcomes signified that most species in this location grew in groups (Hussain et al. 2012). It was not surprising since Dipterocarpaceae families dominated most species in secondary tropical rainforests. Many studies explained that these families naturally live in groups and have a specific preference for their habitat (Purwaningsih 2004, Hadi et al. 2019, Sari et al. 2019).

According to the results, it was seen that vegetation diversity in the study site was still maintained well. It also implied that the forest management activity in this area fulfills the principle of sustainability by minimizing the risk of biodiversity loss. However, the effort of enrichment planting is required to improve biodiversity in the compartment with low diversity level. This scheme will also facilitate the conservation of native species from the secondary tropical rainforests.

Timber production

Summarized observation results documented that timber production in the study area ranged from 44.49±1.72 m^3 ha^{-1} to 68.32±2.69 m^3 ha^{-1} (Table 2). These values were substantially higher than the average productivity of Borneo's natural forests, ranging from 30 m^3 ha^{-1} (KLHK, 2019). Therefore, it indicated that the secondary tropical rainforest in this area had high productivity and could still support industry development. Moreover, this study recorded that the average timber production in each compartment was relatively different, wherein the most increased timber production was found in the compartment of 19Y. These findings also confirmed our first hypothesis that timber production was highly varied between compartments in secondary tropical rainforests.

Table 2. Comparison of timber production, biomass accumulation, carbon storage, and CO_2 absorption among compartments

Compartment	Timber production (m^3 ha^{-1})	Biomass accumulation (t ha^{-1})	Carbon stock (t ha^{-1})	CO_2 absorption (t ha^{-1})
18W	44.49±1.72	45.13±2.02	20.76±0.93	76.18±3.40
18X	56.05±2.05	68.35±2.85	31.44±1.31	115.38±4.81
18Y	54.3±2.43	69.25±3.74	31.86±1.73	116.92±6.32
19W	45.56±1.86	48.83±2.42	22.46±1.12	82.44±4.08
19X	54.96±1.55	67.11±2.44	30.87±1.12	113.29±4.11
19Y	68.32±2.69	84.22±3.89	38.74±1.79	142.17±6.56
20Y	50.57±2.30	46.37±2.36	21.33±1.09	78.29±3.98

Interestingly, the compartment of 18Y only occupied the fourth position of the most productivity compartments, even though it had the highest vegetation diversity (Table 2). Our study also did not find a significant correlation between vegetation diversity and timber production (Table 3). It was in contrast to previous studies that documented a substantial effect of vegetation diversity on stand productivity in tropical rainforest ecosystems (Cai et al. 2016, Gevaña et al. 2017, McNicol et al. 2018). These findings rejected our second hypothesis that higher vegetation diversity significantly increases timber production in the study site. However, several kinds of literature also found a similar outcome to ours wherein there was no significant relationship between vegetation diversity and forest productivity (Belote et al. 2011, Bravo-Oviedo et al. 2021). In this context, forest ecosystems may have diverse patterns regarding the connection between biodiversity and productivity.

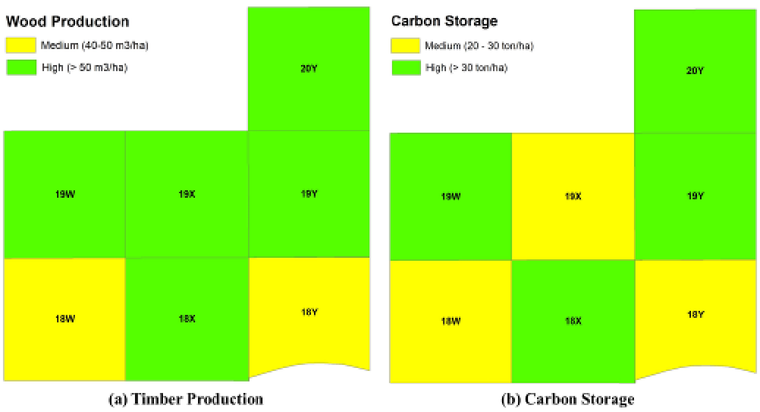


Figure 3. Spatial distribution of timber production and carbon storage in the study site

Commented [A15]: How you classifying the wood production and carbon storage into medium and high?

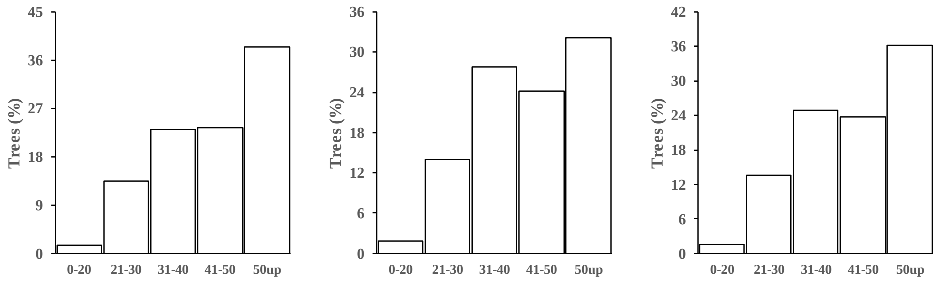
Please state your approach on data analysis section to classification the wood production and carbon storage

Table 3. Correlation between diversity indicators and stand productivity parameters

Diversity parameter	Productivity parameter	
	Timber production	Carbon Storage
Richness	0.123^{ns}	0.420^{ns}
Heterogeneity	0.116^{ns}	0.442^{ns}
Evenness	-0.056^{ns}	0.098^{ns}

ns: non-significant based on correlation test

Forest ecosystems in the study site had high productivity since their vegetation was dominated by trees with a diameter of more than 50 cm (Figure 4). On another side, the frequency of trees with a diameter lower than 20 cm was only around 2%. These indicated there was sufficient stock of timber production for selective cutting. Moreover, the relative contribution of non-commercial species to total timber production was considerably lower than commercial species (Figure 4). It demonstrated that the current standing stock had high economic value. These results confirmed our third hypothesis that commercial species' relative contribution to stand productivity was higher than non-commercial species. Although this site had increased productivity, forest managers should be careful to determine the quantity of annual allowable cutting (AAC) since the implementation of timber extraction can be impacted young trees' regeneration. Most importantly, the process of timber extraction should not harvest trees that generate seeds for maintaining natural regeneration.



(a) Commercial (b) Non Commercial (c) All Species

Figure 4. Diameter distribution of tree species in the study site

Carbon storage

Carbon storage in each compartment varied, wherein the carbon stock in the study site ranged from 20.76±0.93 t ha^{-1} to 38.74±1.79 t ha^{-1} (Table 3). The highest CO_2 absorption was recorded in the compartment of 19Y by around 142.17±6.56 t ha^{-1}. In addition, the relative contribution of commercial species on carbons stock was considerably higher than species non-commercial (Figure 4). These findings directly verified our first and third hypotheses in this study. However, similarly to timber production, our study did not find a significant effect of vegetation diversity on carbon storage in this area (Table 3).

Commented [A16]: I suggest to add an explanation for figure 5 that relative contribution of commercial species on carbon storage higher than non-commercial species based on your finding on diameter distribution in the figure 4.

Commented [A17]: Please re-check, table 3 or table 2?

Table 3 is correlation between diversity indicators and stand productivity parameters.

Commented [A18]: Please check again.
Figure 4 is diameter distribution of tree species in the study site.

Figure 4 does not explain about relative contribution of commercial species on carbon stock

Commented [A19]: How author test the hypotheses 1?
Refer to table 2, I can not see the difference on timber production and carbon storage for each compartment.

How author analyze the table 2 to get the conclusion that your findings have been verified for the first hypotheses?

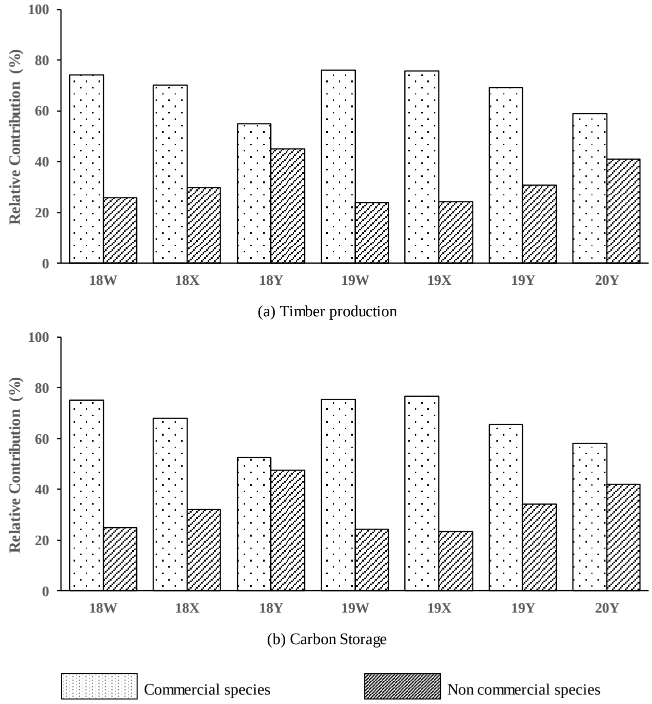


Figure 4. The relative contribution of commercial and non-commercial species on timber production and carbon storage

Commented [A20]: It should be figure 5 not figure 4

The accumulation of carbon storage in forest ecosystems has a positive relationship with stand productivity. Higher stand productivity increases carbon stock since it was generated from photosynthesis (Cai et al. 2016, Brancalion et al. 2019, Alam et al. 2022, Wirabuana et al. 2022a). A study reported the average carbon stock in tropical rainforest ecosystems was 51.18 t ha^{-1} (Butarbutar et al. 2019). This value is higher than carbon storage in the study site. However, this study's carbon stock measurement is still limited to the tree level. We still have not quantified the carbon stock in other life stages like poles, saplings, seedlings, and understorey. Thereby, the actual carbon storage in the study area may be higher than the current estimation. It is also essential for forest managers in the study location to consider the quantity of carbon stock as the additional value of sustainable natural resources management.

Implication results

This study concluded that the secondary tropical rainforest ecosystems in the study site had good vegetation diversity, timber production, and carbon storage. Furthermore, it indicated that forest managers had applied sustainability principles in the context of operation scale. Nevertheless, some improvements are still required to increase the value of forest management on this site. Besides conducting enrichment planting in the compartment with low biodiversity levels, we also suggest forest managers determine the scheme of yield regulation to minimize forest disturbance due to the impact of harvesting operations. Furthermore, the cutting process has a high potential to decline regeneration capacity since the felled trees will override the younger plants like seedlings and saplings.

We also suggest forest managers identify the distribution of mother trees in their concession area for obtaining seed as plant material in artificial regeneration. The seed collection is also essential to maintain the genetic diversity in this area. On another side, it is also necessary to document the carbon dynamics during the rotation periods, including loss and increment, since it will provide comprehensive information about forest management's effectiveness in tackling the climate change mitigation issue. We also encourage forest managers in this area to share their knowledge with other natural resources managers who fail to manage the secondary tropical rainforest ecosystems. It is highly required since forest ecosystems play an essential role in economic development, climate change mitigation, and biodiversity conservation. They have a strategic position in hydrological cycles related to food security and natural disaster.

ACKNOWLEDGEMENTS

The authors address our appreciation to the management of PT Aya Yayang Indonesia, who allows us to conduct this study in their concession forest area. We are also grateful to the Faculty of Forestry, Lambung Mangkurat University, which provides a surveyor team to help with forest inventory. Finally, the authors also thank the anonymous reviewer who offers suggestions to improve this article.

REFERENCES

Adler PB, Smull D, Beard KH, Choi RT, Furniss T, Kulmatiski A, Meiners JM, Tredennick AT, Veblen KE. 2018. Competition and coexistence in plant communities: intraspecific competition is stronger than interspecific competition. Ecology Letters 21: 1319–1329. - DOI: 10.1111/ele.13098

Akossou AYJ, Arzouma S, Attakpa EY, Fonton NH, Kokou K. 2013. Scaling of teak (*Tectona grandis*) logs by the xylometer technique: accuracy of volume equations and influence of the log length. Diversity 5: 99–113. - DOI: 10.3390/d5010099

Alam S, Ginting S, Hemon MT, Leomo S, Kilowasid LMH, Karim J, Nugroho Y, Matatula J, Wirabuana PYAP. 2022. Influence of land cover types on soil quality and carbon storage in Moramo Education Estate, Southeast Sulawesi, Indonesia. Biodiversitas Journal of Biological Diversity 23: 4371–4376. - doi: 10.13057/biodiv/d230901

Altanzagas B, Luo Y, Altansukh B, Dorjsuren C, Fang J, Hu H. 2019. Allometric equations for estimating the aboveground biomass of five forest tree species in Khangai, Mongolia. Forests 10: 1–17. - DOI: 10.3390/f10080661

Arora G, Chaturvedi S, Kaushal R, Nain A, Tewari S. 2014. Growth , biomass , carbon stocks , and sequestration in an age series of Populus deltoides plantations in Tarai region of central Himalaya. Turkish Journal of Agriculture and Forestry 38: 550–560. - DOI: 10.3906/tar-1307-94

Asamoah O, Kuittinen S, Danquah JA, Quartey ET, Bamwesigye D, Boateng CM, Pappinen A. 2020. Assessing wood waste by timber industry as a contributing factor to deforestation in Ghana. Forests 11: 1–15. - DOI: 10.3390/f11090939

Barabás G, Michalska-Smith MJ, Allesina S. 2016. The effect of intra- and interspecific competition on coexistence in multispecies communities. American Naturalist 188: 1–12. - DOI: 10.1086/686901

Belote RT, Prisley S, Jones RH, Fitzpatrick M, de Beurs K. 2011. Forest productivity and tree diversity relationships depend on ecological context within mid-Atlantic and Appalachian forests (USA). Forest Ecology and Management 261: 1315–1324. - DOI: 10.1016/j.foreco.2011.01.010

Brancalion PHS, Campoe O, Mendes JCT, Noel C, Moreira GG, van Melis J, Stape JL, Guillemot J. 2019. Intensive silviculture enhances biomass accumulation and tree diversity recovery in tropical forest restoration. Ecological Applications 29. - DOI: 10.1002/eap.1847

Bravo-Oviedo A, Kastendick DN, Alberdi I, Woodall CW. 2021. Similar tree species richness-productivity response but differing effects on carbon stocks and timber production in eastern US and continental Spain. Science of the Total Environment 793: 1–10. - doi: 10.1016/j.scitotenv.2021.148399

Butarbutar T. 2014. Silviculture system of Indonesia selective cutting for mitigation on climate change in the perspective of REDD+. Jurnal Analisis Kebijakan Kehutanan 11: 163–173. - doi: 10.20886/jakk.2014.11.2.163-173

Butarbutar T, Soedirman S, Neupane PR, Köhl M. 2019. Carbon recovery following selective logging in tropical rainforests in Kalimantan, Indonesia. Forest Ecosystems 6: 1–14. - doi: 10.1186/s40663-019-0195-x

Cai H, Di X, Chang SX, Jin G. 2016. Stand density and species richness affect carbon storage and net primary productivity in early and late successional temperate forests differently. Ecological Research 31: 525–533. - doi: 10.1007/s11284-016-1361-z

Duan T, Zhang J, Wang Z. 2021. Responses and indicators of composition, diversity, and productivity of plant communities at different levels of disturbance in a wetland ecosystem. Diversity 13: 13–16. - DOI: 10.3390/d13060252

Fujii K, Shibata M, Kitajima K, Ichie T, Kitayama K, Turner BL. 2018. Plant–soil interactions maintain biodiversity and functions of tropical forest ecosystems. Ecological Research 33: 149–160. - DOI: 10.1007/s11284-017-1511-y

Gaveau DLA, Sloan S, Molidena E, Yaen H, Sheil D, Abram NK, Ancrenaz M, Nasi R, Quinones M, Wielaard N, Meijaard E. 2014. Four decades of forest persistence, clearance and logging on Borneo. PLoS ONE 9: 1–11. - DOI: 10.1371/journal.pone.0101654

Gevaña DT, Camacho LD, Camacho SC. 2017. Stand density management and blue carbon stock of monospecific mangrove plantation in Bohol, Philippines. Forestry Studies 66: 75–83. - doi: 10.1515/fsmu-2017-0008

Hadi S, Rafdinal R, Linda R. 2019. Density and distribution pattern of *Shorea Leprosula* Miq. in Panti branch research station Gunung Palung National Park South Borneo. Jurnal Protobiont 8: 229–235. - doi: 10.26418/protobiont.v8i3.36877

Hidayat O. 2013. Diversity avifauna species in KHDTK Hambal, East Nusa Tenggara Timur. Journal of Forestry Research Wallacea 2: 12. - DOI: 10.18330/jwallacea.2013.vol2iss1pp12-25

Hussain NA, Ali AH, Lazem LF. 2012. Ecological indices of key biological groups in Southern Iraqi marshland during 2005-2007. Mesopotamian Journal of Marine Science 27: 112–125.

Kementerian Lingkungan Hidup dan Kehutanan (KLHK). 2019. Public press release: improving productivity of natural forest using intensive silviculture. SP. 028/HUMAS/PP/HMS.3/01/2019

Kocurek M, Kornas A, Wierzchnicki R, Lüttge U, Miszalski Z. 2020. Importance of stem photosynthesis in plant carbon allocation of Clusia minor. Trees - Structure and Function 34: 1009–1020. - DOI: 10.1007/s00468-020-01977-w

Krisnawati H, Imanuddin R, Adinugroho WC. 2012. Monograph allometric models for estimating tree biomass at various forest ecosystems types in Indonesia. Ministry of Forestry, Center for research and development of conservation and rehabilitation, Bogor, pp. 1–141. - DOI: 10.13140/RG.2.1.4139.2161

Latifah S, Muhdi M, Purwoko A, Tanjung E. 2018. Estimation of aboveground tree biomass Toona sureni and Coffea arabica in agroforestry system of Simalungun, North Sumatra, Indonesia. Biodiversitas Journal of Biological Diversity 19: 620–625. - doi: 10.13057/biodiv/d190239

Latifah S, Sulistiyono N. 2013. Carbon Sequestration Potential in Aboveground Biomass of Hybrid Eucalyptus Plantation Forest. Journal of Tropical Forest Management 19: 54–62. - doi: 10.7226/jtfm.19.1.54

Ma L, Shen C, Lou D, Fu S, Guan D. 2017. Ecosystem carbon storage in forest fragments of differing patch size. Scientific Reports 7: 1–8. - DOI: 10.1038/s41598-017-13598-4

Matangaran JR, Putra EI, Diatin I, Mujahid M, Adlan Q. 2019. Residual stand damage from selective logging of tropical forests: A comparative case study in central Kalimantan and West Sumatra, Indonesia. Global Ecology and Conservation 19: 1–9. - DOI: 10.1016/j.gecco.2019.e00688

Matatula J, Afandi AY, Wirabuana PYAP. 2021. A comparison of stand structure, species diversity, and aboveground biomass between natural and planted mangroves in Sikka, East Nusa Tenggara, Indonesia. Biodiversitas Journal of Biological Diversity 22: 1098–1103. - doi: 10.13057/biodiv/d220303

McNicol IM, Ryan CM, Dexter KG, Ball SMJ, Williams M. 2018. Aboveground carbon storage and its links to stand structure, tree diversity and floristic composition in South-Eastern Tanzania. Ecosystems 21: 740–754. - DOI: 10.1007/s10021-017-0180-6

Murdjoko A, Djitmau DA, Ungirwalu A, Sinery AS, Siburian RHS, Mardiyadi Z, Wanma AO, Wanma JF, Rumatora A, Mofu WY, Worabai D, May NL, Jitmau MM, Mentansan GAF, Krey K, Musaad I, Manaf M, Abdullah Y, Mamboai H, Pamuji KE, Raharjo S, Kilmaskossu A, Bachri S, Nur-Alzair NA, Benu NMH, Tambing J, Kuswandi R, Khayati L, Lekitoo K. 2021. Pattern of tree diversity in lowland tropical forest in Nikiwar, West Papua, Indonesia. Dendrobiology 85: 78–91. - doi: 10.12657/denbio.085.008

Nugroho Y, Suyanto, Makinudin D, Aditia S, Yulimasita DD, Afandi AY, Harahap MM, Matatula J, Wirabuana PYAP. 2022. Vegetation diversity, structure and composition of three forest ecosystems in Angsana coastal area, South Kalimantan, Indonesia. Biodiversitas Journal of Biological Diversity 23: 2640–2647. - doi: 10.13057/biodiv/d230547

Pan Y, McCullough K, Hollinger DY. 2018. Forest biodiversity, relationships to structural and functional attributes, and stability in New England forests. Forest Ecosystems 5: 1–12. - DOI: 10.1186/s40663-018-0132-4

Poorter H, Niklas KJ, Reich PB, Oleksyn J, Poot P, Mommer L. 2012. Biomass allocation to leaves, stems and roots: Meta-analyses of interspecific variation and environmental control. New Phytologist 193: 30–50. - doi: 10.1111/j.1469-8137.2011.03952.x

Pretzsch H, Biber P, Schütze G, Uhl E, Rötzer T. 2014. Forest stand growth dynamics in Central Europe have accelerated since 1870. Nature Communications 5: 1–10. - DOI: 10.1038/ncomms5967

Purwaningsih. 2004. Ecological distribution of Dipterocarpaceae species in Indonesia. Biodiversitas Journal of Biological Diversity 5: 89–95. - doi: 10.13057/biodiv/d050210

Sadono R, Wardhana W, Idris F, Wirabuana PYAP. 2021a. Carbon storage and energy production of *Eucalyptus urophylla* developed in dryland ecosystems at East Nusa Tenggara. Journal of Degraded and Mining Lands Management 9: 3107–3114. - DOI: 10.15243/JDMLM.2021.091.3107

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021b. Allometric equations for estimating aboveground biomass of Eucalyptus urophylla S.T. Blake in East Nusa Tenggara. Journal of Tropical Forest Management 27: 24–31. - DOI: 10.7226/jtfm.27.1.24

Sari VM, Manurung TF, Iskandar AM. 2019. Identification of tree species in the Dipterocarpaceae Family at Sambas Botanical Gardens Sambas Regency West Kalimantan. Jurnal Hutan Lestari 10: 370–386.

Sasaki N, Asner GP, Pan Y, Knorr W, Durst PB, Ma HO, Abe I, Lowe AJ, Koh LP, Putz FE. 2016. Sustainable management of tropical forests can reduce carbon emissions and stabilize timber production. Frontiers in Environmental Science 4: 1–13. - doi: 10.3389/fenvs.2016.00050

Setiahadi R. 2021. Comparison of individual tree aboveground biomass estimation in community forests using allometric equation and expansion factor in magetan, east java, Indonesia. Biodiversitas Journal of Biological Diversity 22: 3899–3909. - doi: 10.13057/biodiv/d220936

Simmons EA, Morgan TA, Hayes SW, Ng K, Berg EC. 2021. Timber use, processing capacity, and capability within the USDA forest service, rocky mountain region timber-processing area. Journal of Forestry 118: 233–243. - doi: 10.1093/JOFORE/FVAA011

Siregar M, Undaharta NKE. 2018. Tree standing dynamics after 30 years in a secondary forest of Bali, Indonesia. Biodiversitas Journal of Biological Diversity 19: 22–30. - doi: 10.13057/biodiv/d190104

Taillardat P, Friess DA, Lupascu M. 2018. Mangrove blue carbon strategies for climate change mitigation are most effective at the national scale. Biology Letters 14: 1–7. - doi: 10.1098/rsbl.2018.0251

Tawer P, Maturbongs R, Murdjoko A, Jitmau M, Djitmau D, Siburian R, Ungirwalu A, Wanma A, Mardiyadi Z, Wanma J, Rumatora A, Mofu W, Sinery A, Fatem S, Benu N, Kuswandi R, Lekitoo K, Khayati L, Tambing J. 2021. Vegetation dynamic post-disturbance in tropical rain forest of bird's head peninsula of west Papua, Indonesia. Annals of Silvicultural Research 46. - doi: 10.12899/ASR-2145

Wang Z, Du A, Xu Y, Zhu W, Zhang J. 2019. Factors limiting the growth of eucalyptus and the characteristics of growth and water use underwater and fertilizer management in the dry season of Leizhou Peninsula, China. Agronomy. 9: 1–17. - DOI: 10.3390/agronomy9100590

Wardhana W, Widyatmanti W, Soraya E, Soeprijadi D, Larasati B, Umarhadi DA, Hutomo YHT, Idris F, Wirabuana PYAP. 2020. A hybrid approach of remote sensing for mapping vegetation biodiversity in a tropical rainforest. Biodiversitas Journal of Biological Diversity. 21: 3946–3953. - doi: 10.13057/biodiv/d210904

Wirabuana PYAP, Hendrati RL, Baskorowati L, Susanto M, Mashudi M, Budi Santoso Sulistiadi H, Setiadi D, Sumardi D, Alam S. 2022a. Growth performance, biomass accumulation, and energy production in age series of clonal teak plantation. Forest Science and Technology 18: 67–75. - DOI: 10.1080/21580103.2022.2063952

Wirabuana PYAP, Mulyana B, Meinata A, Idris F, Sadono R. 2021a. Allometric equations for estimating merchantable wood and aboveground biomass of community forest tree species in Jepara District. Forestry Ideas 27: 496–515.

Wirabuana PYAP, Sadono R, Juniarso S, Idris F. 2020. Interaction of fertilization and weed control influences on growth , biomass , and carbon in eucalyptus hybrid (*E. pellita* × *E. brassica*). Journal of Tropical Forest Management 26: 144–154. - DOI: 10.7226/jtfm.26.2.144

Wirabuana PYAP, Sadono R, Matatula J. 2022b. Competition influences tree dimension, biomass distribution, and leaf area index of Eucalyptus Urophylla in dryland ecosystems at East Nusa Tenggara. Agriculture and Forestry 68: 191–206. - doi: 10.17707/AgricultForest.68.1.12

Wirabuana PYAP, Setiahadi R, Sadono R, Lukito M, Martono DS. 2021b. The influence of stand density and species diversity into timber production and carbon stock in community forest. Indonesian Journal of Forestry Research 8: 13–22. - doi: 10.20886/ijfr.2021.8.1.13-22

Yang XZ, Zhang WH, He QY. 2019. Effects of intraspecific competition on growth, architecture and biomass allocation of *Quercus Liaotungensis*. Journal of Plant Interactions 14: 284–294. - DOI: 10.1080/17429145.2019.1629656

Yue JW, Guan JH, Deng L, Zhang JG, Li G, Du S. 2018. Allocation pattern and accumulation potential of carbon stock in natural spruce forests in northwest China. PeerJ 2018: 1–21. - doi: 10.7717/peerj.4859

Zambiazi DC, Fantini AC, Piotto D, Siminski A, Vibrans AC, Oller DC, Piazza GE, Peña-Claros M. 2021. Timber stock recovery in a chronosequence of secondary forests in Southern Brazil: Adding value to restored landscapes. Forest Ecology and Management 495: 1–11. - DOI: 10.1016/j.foreco.2021.119352

November 26, 2022

Subject: Revision and re-submission of manuscript ID 12632

Dear Editor Biodiversitas,
Thank you for your decision e-mail and the opportunity to revise our manuscript entitled "**Spatial distribution of vegetation diversity, timber production, and carbon storage in secondary tropical rainforest at South Borneo**". The suggestions offered by the reviewers have immensely helpful to improve our manuscript.

The revisions have been approved by all authors. The changes are demonstrated by green highlight in MS Word. Our response to reviewer's comments have been enclosed below.

We hope the revised manuscript will be better suit to Biodiversitas, but are pleased to consider further revisions. Thank you for your interest in our research.

Sincerely yours,
Pandu Yudha Adi Putra Wirabuana

Department of Forest Management
Faculty of Forestry
Universitas Gadjah Mada
Jln. Agro No.1 Kampus Bulaksumur, Yogyakarta, Indonesia 55281
e-mail: pandu.yudha.a.p@ugm.ac.id

Response to Reviewer A

Part of Article	**Reviewer's Comments**	**Authors's Response**
Abtract	I suggest to use the unit for carbon storage is t C/ha. If you calculate the biomass, the unit is t/ha (Line 22)	The unit of carbon storage has been changed into t C ha^{-1} (Line 22)
Introduction	- Please add the citation (Line 54) - Authors should explain clearly in the materials and methods section on how to test these hypothesis (Line 70-73)	- The citation has been added (Line 54) - The hypothesis test not always uses inferential statistics to examine it. The descriptive test is also possible to apply. We use descriptive test to answer the first and last hypothesis while the analysis of pearson correlation is utilized to answer the second hypothesis. We have described a clear method how to test the hypothesis in the section of data analysis. Please see "Descriptive analysis was selected to compare the value of vegetation diversity, timber production….." (Line 117-118)..
Methods	- When was the data collection conducted? (Line 76) - Please use contras color to show the research site map (Line 86) - Census method but authors used sub-plots 20 m x 20 m. What the authors did, census method or sampling method? Or the authors used sampling method but in each sampling plot used census to measure all vegetation in the sampling plot? (Line 88) - I guess, the author have used the uniform systematic distribution sampling and measured the unit sample using census method. Please, state clearly on the data collection method (Line 91)	- Data collection was conducted from 2021 to 2022. Forest inventory was undertaken with the intensity sampling of 100% in 700 ha area - We think the color for site map is sufficient because it only uses to ilustrate the position of study area - Forest inventory was carried out using census method. We has clearly stated in the first statement. However, since the study area is too large, the process of tree measurement was done step by step with a subplot 20 m x 20 m. There is no distance between subplot. To avoid missunderstanding we have deleted the statement. (Line 90-91)

	- Is it total tree height or commercial height? (Line 105) - I suggest to use the terminology of percentage carbon content (PCC) than conversion factor. In general, the total carbon is dry-weight biomass multiply with percentage carbon content (Line 114)	- No, this research used a cencus method. We have deleted a confusing statement about forest inventory method (Line 90-91) - It is total tree height (Line 103) - We have changed into a percentage carbon content (Line 112)
Results and Discussion	- I suggest the authors to pay attention on compartment 20Y. Why the number of species is 4? While in other compartments the species more than 30 (Line 124-128) - Please state in the data analysis section on how authors classified biodiversity indices into low, medium, high. It also will useful to explain the figure 2. whree the authors have made classification also (Line 144-145) - How you classifying the wood production and carbon storage into medium and high? Please state your approach on data analysis section to classification the wood production and carbon storage (Line 194) - I suggest to add an explanation for figure 5 that relative contribution of commercial species on carbon storage higher than non-commercial species based on your finding on diameter distribution in the figure 4 (Line 215) - Please re-check, table 3 or table 2? Table 3 is correlation between diversity indicators	- Yes, we also still curious about this compartment. Further investigation will be planned to explore this information (Line 124-128) - We classify the value of biodiversity parameters referring to the literatures. This explanation has been added in the article (Line 118-121) - The classification of wood production and carbon storage was determined referring to the literatures. We also add the explanation in the method (Line 118-121) - We have add the explanation about the relative contribution of commercial and non commercial species based on the information from Figure 4 and Figure 4 (Line 221-222) - We have re-checked it and make a revision (Line 219) - We have re-checked it and make revision (Line 221) - We test the hypothesis based on the trend of value obtained from the descriptive test. The analysis of table 2 was calculated by dividing the productivity with the area of compartment. We did not use

	and stand productivity parameters. (Line 217) - Please check again. Figure 4 is diameter distribution of tree species in the study site. Figure 4 does not explain about relative contribution of commercial species on carbon stock (Line 219) - How author test the hypotheses 1? Refer to table 2, I can not see the difference on timber production and carbon storage for each compartment. How author analyze the table 2 to get the conclusion that your findings have been verified for the first hypotheses? (Line 219) - It should be figure 5 not figure 4 (Line 223)	an inferential statistic since our hypothesis did not state a significant different but only different value. - We have changed it for Figure 5 (Line 221)

Response to Reviewer J

Part of Article	**Reviewer's Comments**	**Authors's Response**
Abtract	Timber production may or may not lead to long-term carbon storage (Line 25)	Yes, it is also become a good question for the next research about stand dynamics. We have placed permanent sampling plots here to monitor the change of forest stand in long-term periods
Methods	- What is the history of the site? How long ago was it last logged? Logged for how many times? How was it logged? (Line 75) - Why only these compartments? What are the operations happening in these compartments? (Line 89) - What is the minimum tree size measured? (Line 94)	- We highly apologize there is not sufficient information about this question. We have tried to ask with forest manager but they also did not about it because there are many staff rotation since the company has been operating. - We only have a permission to survey in these compartments since it will be managed for 10 years based on the forest planning strategies from the company. - The most minimum tree size is 15 cm in diameter at breast

		height and 15 cm at total tree height
Results and Discussion	- I would like to see the species list, density, and basal area contribution (Line 123) - Without a baseline, without a reference to primary forest, it is hard to see if this statement is true (Line 164) - How does this translate into rotation cycles? (Line 206-207)	- We have used those data to write other manuscripts that still considered, so that it can not be added here. - It is also difficult to find the baseline since there is not sufficient information about the stand characteristics of primary forest in this area - Annual Allowable Cutting refers to the sum of stand volume that can be harvested in each year. Therefore, change this term to rotation cylces is not correct

Spatial distribution of vegetation diversity, timber production, and carbon storage in secondary tropical rainforest at South Borneo

Abstract. Sustainable management in secondary tropical rainforests requires basic information about stand characteristics, mainly related to productivity and biodiversity. This study aimed to quantify vegetation diversity, timber production, and carbon storage from various sites of secondary forests in South Borneo. Forest inventory was conducted using a census method at seven different natural forest management unit compartments. Four parameters were measured from each tree, including the type of species, commercial categories, tree diameter, and tree height. Individual tree volume and biomass were estimated using allometric equations, while carbon storage was determined using a conversion factor from biomass. Three indicators were used to evaluate vegetation diversity: richness, heterogeneity, and evenness. The analysis of correlations was applied to examine the relationship between vegetation diversity and stand productivity with a significant level of 5%. Results found that there were 41 tree species in the study site comprising 20 commercial and 21 non-commercial species. The highest richness (*R′*) was recorded in compartment 18X by approximately 4.0, while the most increased heterogeneity (*H′*) and evenness (*E′*) were observed in compartment 18Y by around 2.4 and 0.7, respectively. The accumulation of timber production varied in each site, with a range of 45.46−68.32 m^3 ha^{-1}. The highest carbon storage was noted in compartment 19Y (38.74±1.79 t C ha^{-1}), while the lowest was found in compartment 18W (20.76±0.93 t C ha^{-1}). The relative contribution of commercial species to timber production and carbon storage was substantially higher than non-commercial species at all sites. However, there was not a significant correlation between vegetation diversity and stand productivity ($P>0.05$). Overall, our study concluded that the secondary tropical forest ecosystems in the site had good vegetation diversity, timber production, and carbon storage.

Keywords: biodiversity, ecosystems, inventory, natural forest, productivity

Running title: Spatial distribution of vegetation diversity

INTRODUCTION

Biodiversity conservation, climate change mitigation, and economic development are essential issues in sustainable forest management, particularly in Indonesia. In this context, the management of forests is expected to stabilize wood supplies for commercial industries, support species conservation, and reduce carbon emissions in the atmosphere (Wirabuana et al. 2021b). To tackle these challenges, information about stand dynamics is required as baseline considerations to determine alternative forest management strategies (Pretzsch et al. 2014). It is related to timber production and includes vegetation diversity and carbon storage.

In general, the quantity of timber production will provide adequate information about the economic value of the forest and its capacity for supporting industry viability (Simmons et al. 2021). It also determines the maximum annual allowable cutting from the forest ecosystem (Asamoah et al., 2020). The number of timber production also describes the regeneration stock from different life stages of trees to maintain business sustainability (Zambiazi et al. 2021). Meanwhile, vegetation diversity information indicates the stability of environmental health and forest ecosystems (Pan et al. 2018). It also shows how many species live in the forest and their relative contribution to ecological functions (Matatula et al. 2021). The vegetation diversity can also be used to understand the natural competition in the ecosystems (Duan et al. 2021). On another side, the accumulation of carbon storage indicates the ability of the forest ecosystem to support climate change mitigation, primarily for reducing carbon emissions (Sadono et al. 2021a). Many studies explain forest vegetation generally absorbs CO_2 through the photosynthesis process. First, it converts it into biomass (Sasaki et al. 2016, Ma et al. 2017, Kocurek et al. 2020, Wirabuana et al. 2020, Sadono et al. 2021b, Setiahadi 2021). Then, the biomass will be distributed in components like roots, stems, branches, and foliage (Poorter et al. 2012, Yue et al. 2018, Altanzagas et al. 2019, Wirabuana et al. 2021a). Higher biomass indicates excellent carbon storage wherein the carbon absorption in forests will increase along with vegetation age (Arora et al. 2014). Another study report the critical role of vegetation on carbon absorption is also a part of the balance in biogeochemical cycles (Taillardat et al. 2018). To collect this information, forest

inventory is necessary to support forest managers in monitoring the stand dynamics in each forest ecosystem, including secondary tropical rainforest (STR).

Before the 1990s, STR played an essential role in economic development. It provided wood materials for forest industries like furniture, veneer, and plywood. STR also occupied the second position of important sectors contributing to country revenue (KLHK, 2015). However, the occurrence of deforestation has declined its contribution significantly to the gross domestic product. Most STR currently have low productivity and high biodiversity loss (Gaveau et al. 2014). To anticipate this condition, the government has conducted the effort of reforestation to recover forest productivity and prevent vegetation extinction. However, this program is not easy to implement because STR commonly has high variation in land configuration with low accessibility (Wardhana et al. 2020).

Moreover, soil quality in these sites is also dominated by mature soil with low fertility, like oxisols and ultisols (Fujii et al. 2018). Therefore, it causes the low survival rate of vegetation generated from the reforestation program. Nevertheless, several concession areas of STR still exist and maintain their functions for economic development, biodiversity conservation, and climate change mitigation. One of them is a secondary tropical rainforest area managed by PT Aya Yayang Indonesia (AYI) located in South Borneo. Although it has been managed for over 30 years, the information about forest dynamics in this location is still limited, mainly related to vegetation diversity and carbon storage. Therefore, it is essential to provide more comprehensive details on stand dynamics in this area to support better forest management efforts.

This study aims to document vegetation diversity, timber production, and carbon storage from several compartments of secondary tropical rainforests managed by AYI. This information will help forest manager to determine the forest planning strategy, mainly related to yield regulation and harvesting schedules. Thus, even though it is managed as a production zone, forest regeneration is still maintained and minimizes the risk of biodiversity loss. We hypothesize that: Every compartment has a different value for vegetation diversity, timber production, and carbon storage (i). Higher vegetation diversity significantly increases timber production and carbon storage (ii). The contribution of non-commercial species on stand productivity is higher than commercial species (iii).

MATERIALS AND METHODS

Study area

This study was conducted in the secondary tropical rainforest concession area managed by PT Aya Yayang Indonesia. It is situated in Tabalong District, approximately 270 km from Banjarmasin, the capital city of South Borneo province. The geographic coordinates of this area are located in S1°39'−1°40' and E115°29'−115°30'. Altitude ranges from 225 to 470 m above sea level. Land configuration is dominated by hills with a slope level of 15−40%. The average daily temperature is 27.6°C with a minimum of 25.7°C and a maximum of 30.3°C. The mean annual rainfall during the past ten years is 2,589 mm year^{-1}, with an average air humidity of 87.6%. The highest rainfall is recorded in November. Dry periods are relatively short, only around two months from July to August. Oxisols and ultisols dominate soil types with high acidity levels.

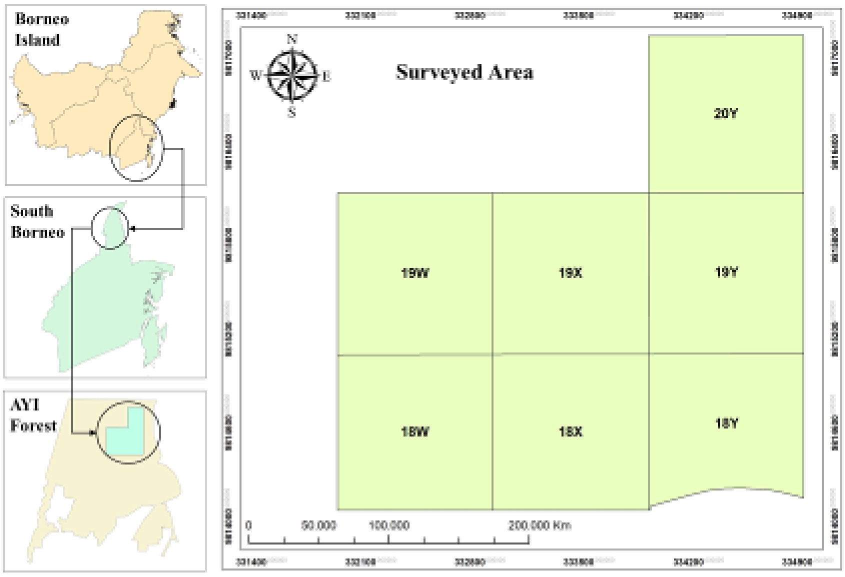


Figure 1. The study area of secondary tropical rainforest in South Borneo

Data collection

Forest inventory was conducted using a census method at seven compartments of the secondary tropical rainforest management unit, namely 18W, 18X, 18Y, 19W, 19X, 19Y, and 20Y. The total surveyed area reached 700 ha, with each site 100 ha. All trees in compartments could be covered and measured correctly. Four parameters were measured from each tree, i.e., type of species, commercial categories, tree diameter, and tree height. The determination of commercial and non-commercial species was undertaken, referring to the guidance from the company. Tree diameter was measured using a phi band at 1.3 m aboveground, while tree height was quantified using a haga altimeter from aboveground to the top crown. Moreover, the coordinate of trees was also recorded using a global positioning system (GPS).

Data analysis

Three indicators were selected to describe vegetation diversity, i.e., richness, heterogeneity, and evenness. Vegetation richness was determined by Margalef Index (*R′*), while its heterogeneity was quantified using Shannon-Wiener Index (*H′*). On another side, the evenness of vegetation was assessed by Pielou Evenness Index (*E′*). Detail equations for calculating those indicators are expressed below (Nugroho et al. 2022):

$$R' = S\text{-}1/ln(N) \quad (1)$$

$$H' = -\sum (n_i/N)\ (ln\ n_i/N) \quad (2)$$

$$E' = H'/ln(S) \quad (3)$$

where *S* was the number of species observed, *N* represented the total tree population in each compartment, and n_i described the sum of trees for each species.

To determine the quantity of timber production, individual tree volume was calculated using the following equation:

$$V = 0.25\ \pi\ dbh^2\ h\ f \quad (4)$$

where *V* was tree volume (m^3), *dbh* indicated tree diameter (cm), *h* represented total tree height (m), and *f* showed a constant of form factor (0.6) (Akossou et al. 2013). Then, the timber production degree was assumed to be the mean stand volume in hectare units. This value could be derived by dividing the total tree volume in a compartment by its area.

The quantification of carbon storage and CO_2 absorption were also calculated using a similar principle to timber production. However, we used biomass accumulation as a conversion to compute both parameters. In this context, the individual tree biomass was estimated using a generalized allometric model for secondary tropical rainforest as given (Krisnawati et al. 2012):

$$B = 0.047454dbh^{2.078} \quad (4)$$

B was aboveground biomass (kg), and *dbh* indicated tree diameter (cm). Next, the carbon stock of each tree was computed by multiplying its biomass with a percentage carbon content of 0.46 (Latifah et al. 2018), while CO_2 absorption was estimated by multiplying carbon stock with a constant of 3.67 (Latifah & Sulistiyono 2013). Then, the result was converted into a hectare unit.

Descriptive analysis was selected to compare the value of vegetation diversity, timber production, and carbon storage among different compartments based on the trend of the histogram and the summarized information from the table. Meanwhile, the spatial distribution of three parameters was processed using QGIS. The diversity of vegetation including richness, heteogeneity, and evenness was categorized referring to the classification of ecological indices by Hussain et al (2012). The quantity of timber production was classified into three categories, i.e. low (< 40 m^3 ha^{-1}), medium (40-50 m^3 ha^{-1}), and high (> 50 m^3 ha^{-1}). We also stratified the carbon storage into three classes, namely low (< 20 t C ha^{-1}), medium (20-30 t C ha^{-1}), and high (> 30 t C ha^{-1}). Finally, to evaluate the relationship between vegetation diversity and stand productivity, both in timber production and carbon storage, Pearson correlation analysis was applied with a significant level of 5%.

RESULTS AND DISCUSSION

Vegetation diversity

Results found that vegetation diversity among compartments was substantially different (Table 1). The highest species abundance was recorded in the compartment of 18Y, while the lowest number of species was observed in the compartment of 20Y. Similar trends were also discovered in the richness, heterogeneity, and evenness, wherein the highest value of those indicators was noted in compartment 18Y. These findings directly confirmed our first hypothesis that assumed there was different vegetation diversity between compartments in the study site.

The diversity of vegetation in secondary tropical rainforests was generally caused by the interaction between vegetation and the environment. This process generated natural competition wherein trees compete with each other to obtain sufficient resources to support their survival (Wirabuana et al. 2022b). On another side, environmental variation also became a limiting factor for certain species; thus, it could inhibit several vegetation from growing well (Wang et al. 2019). Consequently, the regeneration capacity of each species in this ecosystem was highly dynamic depending on their adaptation to environmental conditions. Several previous studies also reported similar results wherein the natural regeneration in secondary tropical rainforests was exceptionally dynamics due to the impact of intraspecific and interspecific competition between trees for obtaining light, water, nutrients, and space (Barabás et al. 2016, Adler et al. 2018, Yang et al. 2019).

Table 1. Comparison of species abundance, richness, heterogeneity, and evenness among compartments

Compartment	N species	Richness	Heterogeneity	Evenness
18W	32	4.01	1.91	0.55
18X	31	3.79	2.10	0.61
18Y	36	4.43	2.42	0.68
19W	32	3.99	1.96	0.57
19X	30	3.59	1.84	0.54
19Y	31	3.89	1.86	0.54
20Y	4	0.38	0.81	0.58

This study recorded that the heterogeneity of vegetation in the study location was dominated by medium classes with a range of 1.51–3.50 (Table 1) (Hidayat 2013). It was similar to previous studies that documented the secondary tropical rainforests commonly had medium vegetation biodiversity (Siregar and Undaharta 2018, Murdjoko et al. 2021, Tawer et al. 2021). This condition could happen because this site was managed using a selective cutting system; thus, only certain species were maintained to support the ecological function of the forest (Butarbutar 2014). In addition, most trees with a limit diameter of more than 50 cm and having commercial values were harvested to provide better-growing space for younger trees (Matangaran et al. 2019). Therefore, this scheme was expected to stabilize the regeneration capacity of secondary forests without sacrificing its economic benefits.

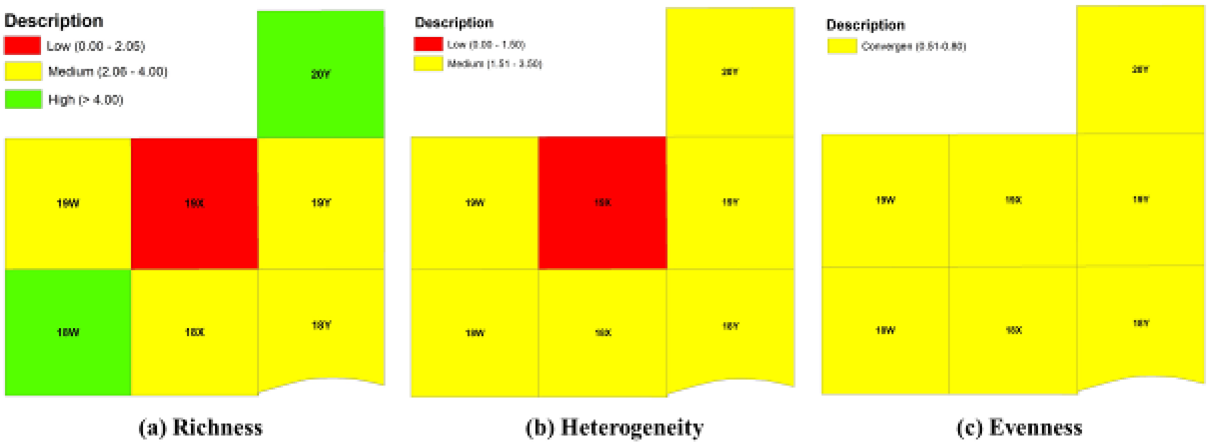


Figure 2. Spatial distribution of vegetation diversity in the study site

Our results also indicated that species distribution in the study site was not evenly distributed. It was shown by the evenness index value ranging from 0.54 to 0.68 (Table 1). These outcomes signified that most species in this location grew in groups (Hussain et al. 2012). It was not surprising since Dipterocarpaceae families dominated most species in secondary tropical rainforests. Many studies explained that these families naturally live in groups and have a specific preference for their habitat (Purwaningsih 2004, Hadi et al. 2019, Sari et al. 2019).

According to the results, it was seen that vegetation diversity in the study site was still maintained well. It also implied that the forest management activity in this area fulfills the principle of sustainability by minimizing the risk of biodiversity loss. However, the effort of enrichment planting is required to improve biodiversity in the compartment with low diversity level. This scheme will also facilitate the conservation of native species from the secondary tropical rainforests.

Timber production

Summarized observation results documented that timber production in the study area ranged from 44.49±1.72 m^3 ha^{-1} to 68.32±2.69 m^3 ha^{-1} (Table 2). These values were substantially higher than the average productivity of Borneo's natural forests, ranging from 30 m^3 ha^{-1} (KLHK, 2019). Therefore, it indicated that the secondary tropical rainforest in this area had high productivity and could still support industry development. Moreover, this study recorded that the average timber production in each compartment was relatively different, wherein the most increased timber production was found in the compartment of 19Y. These findings also confirmed our first hypothesis that timber production was highly varied between compartments in secondary tropical rainforests.

Table 2. Comparison of timber production, biomass accumulation, carbon storage, and CO_2 absorption among compartments

Compartment	Timber production (m^3 ha^{-1})	Biomass accumulation (t ha^{-1})	Carbon stock (t ha^{-1})	CO_2 absorption (t ha^{-1})
18W	44.49±1.72	45.13±2.02	20.76±0.93	76.18±3.40
18X	56.05±2.05	68.35±2.85	31.44±1.31	115.38±4.81
18Y	54.3±2.43	69.25±3.74	31.86±1.73	116.92±6.32
19W	45.56±1.86	48.83±2.42	22.46±1.12	82.44±4.08
19X	54.96±1.55	67.11±2.44	30.87±1.12	113.29±4.11
19Y	68.32±2.69	84.22±3.89	38.74±1.79	142.17±6.56
20Y	50.57±2.30	46.37±2.36	21.33±1.09	78.29±3.98

Interestingly, the compartment of 18Y only occupied the fourth position of the most productivity compartments, even though it had the highest vegetation diversity (Table 2). Our study also did not find a significant correlation between vegetation diversity and timber production (Table 3). It was in contrast to previous studies that documented a substantial effect of vegetation diversity on stand productivity in tropical rainforest ecosystems (Cai et al. 2016, Gevaña et al. 2017, McNicol et al. 2018). These findings rejected our second hypothesis that higher vegetation diversity significantly increases timber production in the study site. However, several kinds of literature also found a similar outcome to ours wherein there was no significant relationship between vegetation diversity and forest productivity (Belote et al. 2011, Bravo-Oviedo et al. 2021). In this context, forest ecosystems may have diverse patterns regarding the connection between biodiversity and productivity.

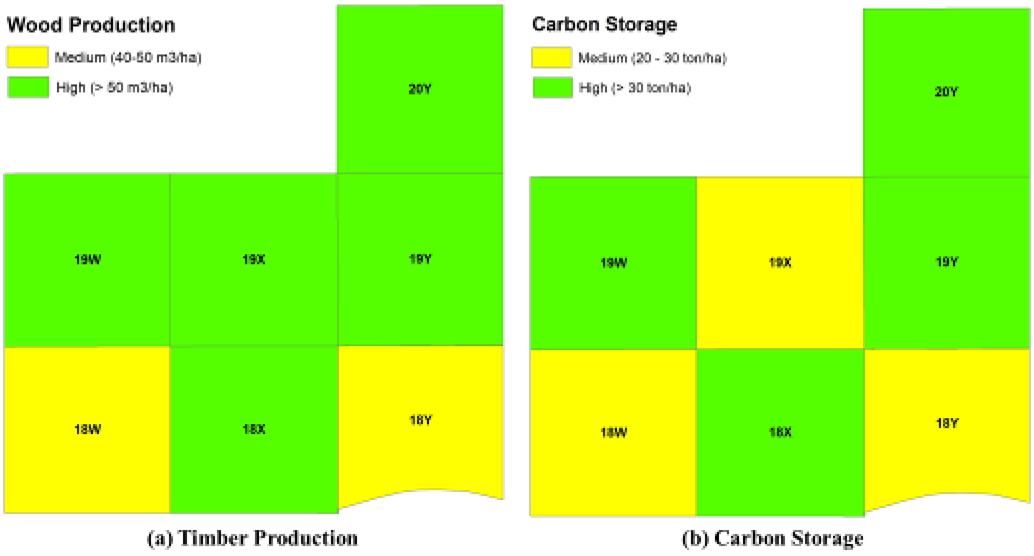


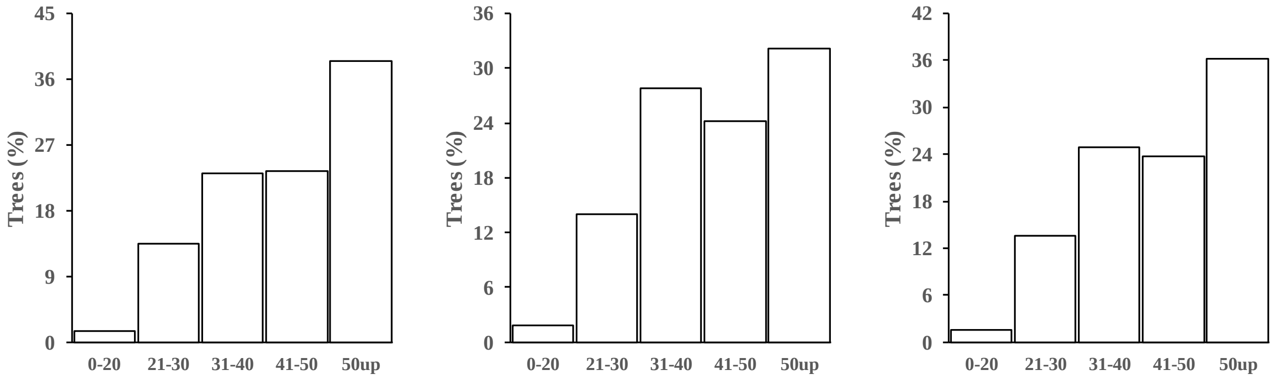
Figure 3. Spatial distribution of timber production and carbon storage in the study site

Table 3. Correlation between diversity indicators and stand productivity parameters

Diversity parameter	Productivity parameter	
	Timber production	Carbon Storage
Richness	0.123^{ns}	0.420^{ns}
Heterogeneity	0.116^{ns}	0.442^{ns}
Evenness	-0.056^{ns}	0.098^{ns}

ns: non-significant based on correlation test

Forest ecosystems in the study site had high productivity since their vegetation was dominated by trees with a diameter of more than 50 cm (Figure 4). On another side, the frequency of trees with a diameter lower than 20 cm was only around 2%. These indicated there was sufficient stock of timber production for selective cutting. Moreover, the relative contribution of non-commercial species to total timber production was considerably lower than commercial species (Figure 4). It demonstrated that the current standing stock had high economic value. These results confirmed our third hypothesis that commercial species' relative contribution to stand productivity was higher than non-commercial species. Although this site had increased productivity, forest managers should be careful to determine the quantity of annual allowable cutting (AAC) since the implementation of timber extraction can be impacted young trees' regeneration. Most importantly, the process of timber extraction should not harvest trees that generate seeds for maintaining natural regeneration.



(a) Commercial (b) Non Commercial (c) All Species

Figure 4. Diameter distribution of tree species in the study site

Carbon storage

Carbon storage in each compartment varied, wherein the carbon stock in the study site ranged from 20.76±0.93 t ha^{-1} to 38.74±1.79 t ha^{-1} (Table 2). The highest CO_2 absorption was recorded in the compartment of 19Y by around 142.17±6.56 t ha^{-1}. In addition, the relative contribution of commercial species on carbons stock was considerably higher than species non-commercial (Figure 5). It was possible since the percentage of trees with diameter more than 50 cm in commercial species higher than species non-commercial (Figure 4). These findings directly verified our first and third hypotheses in this study. However, similarly to timber production, our study did not find a significant effect of vegetation diversity on carbon storage in this area (Table 3).

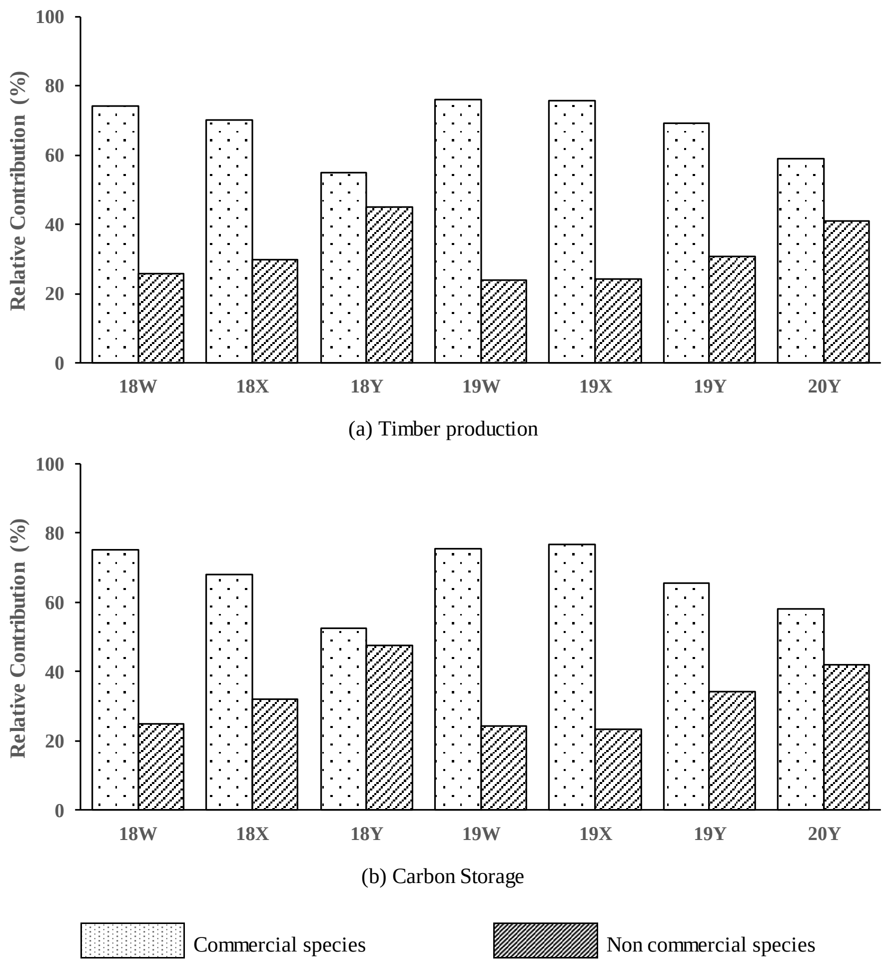


Figure 5. The relative contribution of commercial and non-commercial species on timber production and carbon storage

The accumulation of carbon storage in forest ecosystems has a positive relationship with stand productivity. Higher stand productivity increases carbon stock since it was generated from photosynthesis (Cai et al. 2016, Brancalion et al. 2019, Alam et al. 2022, Wirabuana et al. 2022a). A study reported the average carbon stock in tropical rainforest ecosystems was 51.18 t ha^{-1} (Butarbutar et al. 2019). This value is higher than carbon storage in the study site. However, this study's carbon stock measurement is still limited to the tree level. We still have not quantified the carbon stock in other life stages like poles, saplings, seedlings, and understorey. Thereby, the actual carbon storage in the study area may be higher than the current estimation. It is also essential for forest managers in the study location to consider the quantity of carbon stock as the additional value of sustainable natural resources management.

Implication results

This study concluded that the secondary tropical rainforest ecosystems in the study site had good vegetation diversity, timber production, and carbon storage. Furthermore, it indicated that forest managers had applied sustainability principles in the context of operation scale. Nevertheless, some improvements are still required to increase the value of forest management on this site. Besides conducting enrichment planting in the compartment with low biodiversity levels, we also suggest forest managers determine the scheme of yield regulation to minimize forest disturbance due to the impact of harvesting operations. Furthermore, the cutting process has a high potential to decline regeneration capacity since the felled trees will override the younger plants like seedlings and saplings.

We also suggest forest managers identify the distribution of mother trees in their concession area for obtaining seed as plant material in artificial regeneration. The seed collection is also essential to maintain the genetic diversity in this area. On another side, it is also necessary to document the carbon dynamics during the rotation periods, including loss and increment, since it will provide comprehensive information about forest management's effectiveness in tackling the climate change mitigation issue. We also encourage forest managers in this area to share their knowledge with other natural resources managers who fail to manage the secondary tropical rainforest ecosystems. It is highly required since forest ecosystems play an essential role in economic development, climate change mitigation, and biodiversity conservation. They have a strategic position in hydrological cycles related to food security and natural disaster.

ACKNOWLEDGEMENTS

The authors address our appreciation to the management of PT Aya Yayang Indonesia, who allows us to conduct this study in their concession forest area. We are also grateful to the Faculty of Forestry, Lambung Mangkurat University, which provides a surveyor team to help with forest inventory. Finally, the authors also thank the anonymous reviewer who offers suggestions to improve this article.

REFERENCES

Adler PB, Smull D, Beard KH, Choi RT, Furniss T, Kulmatiski A, Meiners JM, Tredennick AT, Veblen KE. 2018. Competition and coexistence in plant communities: intraspecific competition is stronger than interspecific competition. Ecology Letters 21: 1319–1329. - DOI: 10.1111/ele.13098

Akossou AYJ, Arzouma S, Attakpa EY, Fonton NH, Kokou K. 2013. Scaling of teak (*Tectona grandis*) logs by the xylometer technique: accuracy of volume equations and influence of the log length. Diversity 5: 99–113. - DOI: 10.3390/d5010099

Alam S, Ginting S, Hemon MT, Leomo S, Kilowasid LMH, Karim J, Nugroho Y, Matatula J, Wirabuana PYAP. 2022. Influence of land cover types on soil quality and carbon storage in Moramo Education Estate, Southeast Sulawesi, Indonesia. Biodiversitas Journal of Biological Diversity 23: 4371–4376. - doi: 10.13057/biodiv/d230901

Altanzagas B, Luo Y, Altansukh B, Dorjsuren C, Fang J, Hu H. 2019. Allometric equations for estimating the aboveground biomass of five forest tree species in Khangai, Mongolia. Forests 10: 1–17. - DOI: 10.3390/f10080661

Arora G, Chaturvedi S, Kaushal R, Nain A, Tewari S. 2014. Growth , biomass , carbon stocks , and sequestration in an age series of Populus deltoides plantations in Tarai region of central Himalaya. Turkish Journal of Agriculture and Forestry 38: 550–560. - DOI: 10.3906/tar-1307-94

Asamoah O, Kuittinen S, Danquah JA, Quartey ET, Bamwesigye D, Boateng CM, Pappinen A. 2020. Assessing wood waste by timber industry as a contributing factor to deforestation in Ghana. Forests 11: 1–15. - DOI: 10.3390/f11090939

Barabás G, Michalska-Smith MJ, Allesina S. 2016. The effect of intra- and interspecific competition on coexistence in multispecies communities. American Naturalist 188: 1–12. - DOI: 10.1086/686901

Belote RT, Prisley S, Jones RH, Fitzpatrick M, de Beurs K. 2011. Forest productivity and tree diversity relationships depend on ecological context within mid-Atlantic and Appalachian forests (USA). Forest Ecology and Management 261: 1315–1324. - DOI: 10.1016/j.foreco.2011.01.010

Brancalion PHS, Campoe O, Mendes JCT, Noel C, Moreira GG, van Melis J, Stape JL, Guillemot J. 2019. Intensive silviculture enhances biomass accumulation and tree diversity recovery in tropical forest restoration. Ecological Applications 29. - DOI: 10.1002/eap.1847

Bravo-Oviedo A, Kastendick DN, Alberdi I, Woodall CW. 2021. Similar tree species richness-productivity response but differing effects on carbon stocks and timber production in eastern US and continental Spain. Science of the Total Environment 793: 1–10. - doi: 10.1016/j.scitotenv.2021.148399

Butarbutar T. 2014. Silviculture system of Indonesia selective cutting for mitigation on climate change in the perspective of REDD+. Jurnal Analisis Kebijakan Kehutanan 11: 163–173. - doi: 10.20886/jakk.2014.11.2.163-173

Butarbutar T, Soedirman S, Neupane PR, Köhl M. 2019. Carbon recovery following selective logging in tropical rainforests in Kalimantan, Indonesia. Forest Ecosystems 6: 1–14. - doi: 10.1186/s40663-019-0195-x

Cai H, Di X, Chang SX, Jin G. 2016. Stand density and species richness affect carbon storage and net primary productivity in early and late successional temperate forests differently. Ecological Research 31: 525–533. - doi: 10.1007/s11284-016-1361-z

Duan T, Zhang J, Wang Z. 2021. Responses and indicators of composition, diversity, and productivity of plant communities at different levels of disturbance in a wetland ecosystem. Diversity 13: 13–16. - DOI: 10.3390/d13060252

Fujii K, Shibata M, Kitajima K, Ichie T, Kitayama K, Turner BL. 2018. Plant–soil interactions maintain biodiversity and functions of tropical forest ecosystems. Ecological Research 33: 149–160. - DOI: 10.1007/s11284-017-1511-y

Gaveau DLA, Sloan S, Molidena E, Yaen H, Sheil D, Abram NK, Ancrenaz M, Nasi R, Quinones M, Wielaard N, Meijaard E. 2014. Four decades of forest persistence, clearance and logging on Borneo. PLoS ONE 9: 1–11. - DOI: 10.1371/journal.pone.0101654

Gevaña DT, Camacho LD, Camacho SC. 2017. Stand density management and blue carbon stock of monospecific mangrove plantation in Bohol, Philippines. Forestry Studies 66: 75–83. - doi: 10.1515/fsmu-2017-0008

Hadi S, Rafdinal R, Linda R. 2019. Density and distribution pattern of *Shorea Leprosula* Miq. in Panti branch research station Gunung Palung National Park South Borneo. Jurnal Protobiont 8: 229–235. - doi: 10.26418/protobiont.v8i3.36877

Hidayat O. 2013. Diversity avifauna species in KHDTK Hambal, East Nusa Tenggara Timur. Journal of Forestry Research Wallacea 2: 12. - DOI: 10.18330/jwallacea.2013.vol2iss1pp12-25

Hussain NA, Ali AH, Lazem LF. 2012. Ecological indices of key biological groups in Southern Iraqi marshland during 2005-2007. Mesopotamian Journal of Marine Science 27: 112–125.

Kementerian Lingkugan Hidup dan Kehutanan (KLHK). 2015. Public press release: the gap supply of legal timber and its implications for the capacity building of Indonesian forestry industry.

Kementerian Lingkungan Hidup dan Kehutanan (KLHK). 2019. Public press release: improving productivity of natural forest using intensive silviculture. SP. 028/HUMAS/PP/HMS.3/01/2019

Kocurek M, Kornas A, Wierzchnicki R, Lüttge U, Miszalski Z. 2020. Importance of stem photosynthesis in plant carbon allocation of Clusia minor. Trees - Structure and Function 34: 1009–1020. - DOI: 10.1007/s00468-020-01977-w

Krisnawati H, Imanuddin R, Adinugroho WC. 2012. Monograph allometric models for estimating tree biomass at various forest ecosystems types in Indonesia. Ministry of Forestry, Center for research and development of conservation and rehabilitation, Bogor, pp. 1–141. - DOI: 10.13140/RG.2.1.4139.2161

Latifah S, Muhdi M, Purwoko A, Tanjung E. 2018. Estimation of aboveground tree biomass Toona sureni and Coffea arabica in agroforestry system of Simalungun, North Sumatra, Indonesia. Biodiversitas Journal of Biological Diversity 19: 620–625. - doi: 10.13057/biodiv/d190239

Latifah S, Sulistiyono N. 2013. Carbon Sequestration Potential in Aboveground Biomass of Hybrid Eucalyptus Plantation Forest. Journal of Tropical Forest Management 19: 54–62. - doi: 10.7226/jtfm.19.1.54

Ma L, Shen C, Lou D, Fu S, Guan D. 2017. Ecosystem carbon storage in forest fragments of differing patch size. Scientific Reports 7: 1–8. - DOI: 10.1038/s41598-017-13598-4

Matangaran JR, Putra EI, Diatin I, Mujahid M, Adlan Q. 2019. Residual stand damage from selective logging of tropical forests: A comparative case study in central Kalimantan and West Sumatra, Indonesia. Global Ecology and Conservation 19: 1–9. - DOI: 10.1016/j.gecco.2019.e00688

Matatula J, Afandi AY, Wirabuana PYAP. 2021. A comparison of stand structure, species diversity, and aboveground biomass between natural and planted mangroves in Sikka, East Nusa Tenggara, Indonesia. Biodiversitas Journal of Biological Diversity 22: 1098–1103. - doi: 10.13057/biodiv/d220303

McNicol IM, Ryan CM, Dexter KG, Ball SMJ, Williams M. 2018. Aboveground carbon storage and its links to stand structure, tree diversity and floristic composition in South-Eastern Tanzania. Ecosystems 21: 740–754. - DOI: 10.1007/s10021-017-0180-6

Murdjoko A, Djitmau DA, Ungirwalu A, Sinery AS, Siburian RHS, Mardiyadi Z, Wanma AO, Wanma JF, Rumatora A, Mofu WY, Worabai D, May NL, Jitmau MM, Mentansan GAF, Krey K, Musaad I, Manaf M, Abdullah Y, Mamboai H, Pamuji KE, Raharjo S, Kilmaskossu A, Bachri S, Nur-Alzair NA, Benu NMH, Tambing J, Kuswandi R, Khayati L, Lekitoo K. 2021. Pattern of tree diversity in lowland tropical forest in Nikiwar, West Papua, Indonesia. Dendrobiology 85: 78–91. - doi: 10.12657/denbio.085.008

Nugroho Y, Suyanto, Makinudin D, Aditia S, Yulimasita DD, Afandi AY, Harahap MM, Matatula J, Wirabuana PYAP. 2022. Vegetation diversity, structure and composition of three forest ecosystems in Angsana coastal area, South Kalimantan, Indonesia. Biodiversitas Journal of Biological Diversity 23: 2640–2647. - doi: 10.13057/biodiv/d230547

Pan Y, McCullough K, Hollinger DY. 2018. Forest biodiversity, relationships to structural and functional attributes, and stability in New England forests. Forest Ecosystems 5: 1–12. - DOI: 10.1186/s40663-018-0132-4

Poorter H, Niklas KJ, Reich PB, Oleksyn J, Poot P, Mommer L. 2012. Biomass allocation to leaves, stems and roots: Meta-analyses of interspecific variation and environmental control. New Phytologist 193: 30–50. - doi: 10.1111/j.1469-8137.2011.03952.x

Pretzsch H, Biber P, Schütze G, Uhl E, Rötzer T. 2014. Forest stand growth dynamics in Central Europe have accelerated since 1870. Nature Communications 5: 1–10. - DOI: 10.1038/ncomms5967

Purwaningsih. 2004. Ecological distribution of Dipterocarpaceae species in Indonesia. Biodiversitas Journal of Biological Diversity 5: 89–95. - doi: 10.13057/biodiv/d050210

Sadono R, Wardhana W, Idris F, Wirabuana PYAP. 2021a. Carbon storage and energy production of *Eucalyptus urophylla* developed in dryland ecosystems at East Nusa Tenggara. Journal of Degraded and Mining Lands Management 9: 3107–3114. - DOI: 10.15243/JDMLM.2021.091.3107

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021b. Allometric equations for estimating aboveground biomass of Eucalyptus urophylla S.T. Blake in East Nusa Tenggara. Journal of Tropical Forest Management 27: 24–31. - DOI: 10.7226/jtfm.27.1.24

Sari VM, Manurung TF, Iskandar AM. 2019. Identification of tree species in the Dipterocarpaceae Family at Sambas Botanical Gardens Sambas Regency West Kalimantan. Jurnal Hutan Lestari 10: 370–386.

Sasaki N, Asner GP, Pan Y, Knorr W, Durst PB, Ma HO, Abe I, Lowe AJ, Koh LP, Putz FE. 2016. Sustainable management of tropical forests can reduce carbon emissions and stabilize timber production. Frontiers in Environmental Science 4: 1–13. - doi: 10.3389/fenvs.2016.00050

Setiahadi R. 2021. Comparison of individual tree aboveground biomass estimation in community forests using allometric equation and expansion factor in magetan, east java, Indonesia. Biodiversitas Journal of Biological Diversity 22: 3899–3909. - doi: 10.13057/biodiv/d220936

Simmons EA, Morgan TA, Hayes SW, Ng K, Berg EC. 2021. Timber use, processing capacity, and capability within the USDA forest service, rocky mountain region timber-processing area. Journal of Forestry 118: 233–243. - doi: 10.1093/JOFORE/FVAA011

Siregar M, Undaharta NKE. 2018. Tree standing dynamics after 30 years in a secondary forest of Bali, Indonesia. Biodiversitas Journal of Biological Diversity 19: 22–30. - doi: 10.13057/biodiv/d190104

Taillardat P, Friess DA, Lupascu M. 2018. Mangrove blue carbon strategies for climate change mitigation are most effective at the national scale. Biology Letters 14: 1–7. - doi: 10.1098/rsbl.2018.0251

Tawer P, Maturbongs R, Murdjoko A, Jitmau M, Djitmau D, Siburian R, Ungirwalu A, Wanma A, Mardiyadi Z, Wanma J, Rumatora A, Mofu W, Sinery A, Fatem S, Benu N, Kuswandi R, Lekitoo K, Khayati L, Tambing J. 2021. Vegetation dynamic post-disturbance in tropical rain forest of bird's head peninsula of west Papua, Indonesia. Annals of Silvicultural Research 46. - doi: 10.12899/ASR-2145

Wang Z, Du A, Xu Y, Zhu W, Zhang J. 2019. Factors limiting the growth of eucalyptus and the characteristics of growth and water use underwater and fertilizer management in the dry season of Leizhou Peninsula, China. Agronomy. 9: 1–17. - DOI: 10.3390/agronomy9100590

Wardhana W, Widyatmanti W, Soraya E, Soeprijadi D, Larasati B, Umarhadi DA, Hutomo YHT, Idris F, Wirabuana PYAP. 2020. A hybrid approach of remote sensing for mapping vegetation biodiversity in a tropical rainforest. Biodiversitas Journal of Biological Diversity. 21: 3946–3953. - doi: 10.13057/biodiv/d210904

Wirabuana PYAP, Hendrati RL, Baskorowati L, Susanto M, Mashudi M, Budi Santoso Sulistiadi H, Setiadi D, Sumardi D, Alam S. 2022a. Growth performance, biomass accumulation, and energy production in age series of clonal teak plantation. Forest Science and Technology 18: 67–75. - DOI: 10.1080/21580103.2022.2063952

Wirabuana PYAP, Mulyana B, Meinata A, Idris F, Sadono R. 2021a. Allometric equations for estimating merchantable wood and aboveground biomass of community forest tree species in Jepara District. Forestry Ideas 27: 496–515.

Wirabuana PYAP, Sadono R, Juniarso S, Idris F. 2020. Interaction of fertilization and weed control influences on growth , biomass , and carbon in eucalyptus hybrid (*E. pellita* × *E. brassica*). Journal of Tropical Forest Management 26: 144–154. - DOI: 10.7226/jtfm.26.2.144

Wirabuana PYAP, Sadono R, Matatula J. 2022b. Competition influences tree dimension, biomass distribution, and leaf area index of Eucalyptus Urophylla in dryland ecosystems at East Nusa Tenggara. Agriculture and Forestry 68: 191–206. - doi: 10.17707/AgricultForest.68.1.12

Wirabuana PYAP, Setiahadi R, Sadono R, Lukito M, Martono DS. 2021b. The influence of stand density and species diversity into timber production and carbon stock in community forest. Indonesian Journal of Forestry Research 8: 13–22. - doi: 10.20886/ijfr.2021.8.1.13-22

Yang XZ, Zhang WH, He QY. 2019. Effects of intraspecific competition on growth, architecture and biomass allocation of *Quercus Liaotungensis*. Journal of Plant Interactions 14: 284–294. - DOI: 10.1080/17429145.2019.1629656

Yue JW, Guan JH, Deng L, Zhang JG, Li G, Du S. 2018. Allocation pattern and accumulation potential of carbon stock in natural spruce forests in northwest China. PeerJ 2018: 1–21. - doi: 10.7717/peerj.4859

Zambiazi DC, Fantini AC, Piotto D, Siminski A, Vibrans AC, Oller DC, Piazza GE, Peña-Claros M. 2021. Timber stock recovery in a chronosequence of secondary forests in Southern Brazil: Adding value to restored landscapes. Forest Ecology and Management 495: 1–11. - DOI: 10.1016/j.foreco.2021.119352

Pandu Yudha Adi Putra Wirabuana <pandu.yudha.a.p@ugm.ac.id>

[biodiv] Editor Decision

1 message

Nor Liza <support@mail.smujo.id> Tue, Dec 6, 2022 at 12:37 PM
To: SUYANTO <author@smujo.id>, PANDU YUDHA ADI PUTRA WIRABUANA <pandu.yudha.a.p@ugm.ac.id>

SUYANTO, YUSANTO NUGROHO, MOEHAR MARAGHIY HARAHAP, LIA KUSUMANINGRUM, PANDU YUDHA ADI PUTRA WIRABUANA:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Spatial distribution of vegetation diversity, timber production, and carbon storage in secondary tropical rainforest at South Kalimantan, Indonesia".

Our decision is to: Accept Submission

Biodiversitas Journal of Biological Diversity

Source details

Biodiversitas

Open Access

Scopus coverage years: from 2014 to Present

Publisher: Biology department, Sebelas Maret University Surakarta

ISSN: 1412-033X E-ISSN: 2085-4722

Subject area: Agricultural and Biological Sciences: Animal Science and Zoology; Agricultural and Biological Sciences: Plant Science; Biochemistry, Genetics and Molecular Biology: Molecular Biology

Source type: Journal

View all documents > | Set document alert | Save to source list | Source Homepage

CiteScore 2021
1.7

SJR 2021
0.290

SNIP 2021
0.945

CiteScore | CiteScore rank & trend | Scopus content coverage

Export content for category

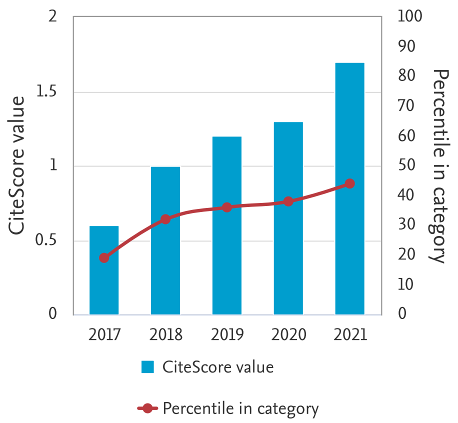
CiteScore rank

2021 — In category: Plant Science

#266/482	Biodiversitas	1.7	44th percentile

Rank	Source title	CiteScore 2021	Percentile
#1	Annual Review of Plant Biology	38.3	99th percentile
#2	Trends in Plant Science	28.4	99th percentile
#3	Annual Review of Phytopathology	23.7	99th percentile
#4	Nature Plants	20.8	99th percentile
#5	Molecular Plant	19.5	99th percentile
#6	Plant Biotechnology Journal	16.6	98th percentile
#7	Plant Cell	16.5	98th percentile
#8	New Phytologist	15.7	98th percentile
#9	Current Opinion in Plant Biology	14.7	98th percentile
#10	Mycosphere	13.9	98th percentile
#11	NJAS - Wageningen Journal of Life Sciences	13.4	97th percentile
#12	Plant Physiology	12.7	97th percentile
#13	Plant, Cell and Environment	12.5	97th percentile
#14	Journal of Integrative Plant Biology	11.8	97th percentile

CiteScore trend



☆	Rank	Source title	CiteScore 2021	Percentile
☆	#15	Phytochemistry Reviews	11.6	96th percentile
☆	#16	Molecular Plant Pathology	11.0	96th percentile
☆	#17	Journal of Experimental Botany	10.9	96th percentile
☆	#18	Plant Journal	10.4	96th percentile
☆	#19	Journal of Pest Science	10.1	96th percentile
☆	#20	Journal of Ecology	9.9	95th percentile
☆	#21	Plant and Cell Physiology	9.2	95th percentile
☆	#22	European Journal of Agronomy	9.1	95th percentile
☆	#23	Environmental and Experimental Botany	9.1	95th percentile
☆	#24	Plant Methods	8.9	95th percentile
☆	#25	Annals of Botany	8.6	94th percentile
☆	#26	Horticulture Research	8.5	94th percentile
☆	#27	BMC Biology	8.4	94th percentile
☆	#28	Plant Reproduction	8.3	94th percentile
☆	#29	Critical Reviews in Plant Sciences	8.2	94th percentile
☆	#30	Harmful Algae	8.1	93rd percentile
☆	#31	Plant Science	8.0	93rd percentile
☆	#32	Frontiers in Plant Science	8.0	93rd percentile
☆	#33	Metabarcoding and Metagenomics	7.9	93rd percentile
☆	#34	Rice	7.9	93rd percentile
☆	#35	Plant Cell Reports	7.8	92nd percentile
☆	#36	Plant Communications	7.6	92nd percentile
☆	#37	Plant Molecular Biology	7.4	92nd percentile
☆	#38	Journal of Plant Interactions	7.4	92nd percentile
☆	#39	Annals of Agricultural Sciences	7.4	92nd percentile
☆	#40	Plant Physiology and Biochemistry	7.3	91st percentile
☆	#41	Plant and Soil	7.3	91st percentile
☆	#42	Tree Physiology	7.1	91st percentile
☆	#43	Physiologia Plantarum	7.1	91st percentile
☆	#44	Journal of Plant Growth Regulation	7.0	90th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#45	Journal of Plant Physiology	6.9	90th percentile
☆	#46	BMC Plant Biology	6.9	90th percentile
☆	#47	Crop Journal	6.9	90th percentile
☆	#48	Planta	6.9	90th percentile
☆	#49	Perspectives in Plant Ecology, Evolution and Systematics	6.7	89th percentile
☆	#50	Protoplasma	6.7	89th percentile
☆	#51	Fungal Ecology	6.6	89th percentile
☆	#52	Journal of Systematics and Evolution	6.6	89th percentile
☆	#53	Life Science Alliance	6.5	89th percentile
☆	#54	Photosynthesis Research	6.4	88th percentile
☆	#55	Photosynthetica	6.3	88th percentile
☆	#56	Phytochemistry	6.2	88th percentile
☆	#57	Phytobiomes Journal	6.2	88th percentile
☆	#58	Journal of Agronomy and Crop Science	6.1	88th percentile
☆	#59	Mycorrhiza	6.1	87th percentile
☆	#60	Phytopathology	6.0	87th percentile
☆	#61	Plant Growth Regulation	6.0	87th percentile
☆	#61	Rice Science	6.0	87th percentile
☆	#63	Preslia	6.0	87th percentile
☆	#64	NeoBiota	5.8	86th percentile
☆	#65	Horticultural Plant Journal	5.8	86th percentile
☆	#66	Plant Biology	5.8	86th percentile
☆	#67	EFSA Journal	5.7	86th percentile
☆	#68	Plant Genome	5.7	85th percentile
☆	#69	Environmental Technology and Innovation	5.7	85th percentile
☆	#70	Phytocoenologia	5.6	85th percentile
☆	#71	International Journal of Phytoremediation	5.6	85th percentile
☆	#71	Natural Products and Bioprospecting	5.6	85th percentile
☆	#73	Journal of Integrative Agriculture	5.6	84th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#74	Journal of Applied Phycology	5.5	84th percentile
☆	#75	American Journal of Botany	5.5	84th percentile
☆	#76	Phytochemical Analysis	5.5	84th percentile
☆	#77	Molecular Breeding	5.4	84th percentile
☆	#78	Functional Plant Biology	5.3	83rd percentile
☆	#79	Fermentation	5.3	83rd percentile
☆	#80	Current Plant Biology	5.2	83rd percentile
☆	#81	Journal of Applied Research on Medicinal and Aromatic Plants	5.1	83rd percentile
☆	#82	Plant Biosystems	5.1	83rd percentile
☆	#83	Botanical Journal of the Linnean Society	5.1	82nd percentile
☆	#84	AoB PLANTS	5.1	82nd percentile
☆	#85	Plants People Planet	5.1	82nd percentile
☆	#86	The Botanical Review	5.0	82nd percentile
☆	#87	Botanical Studies	5.0	82nd percentile
☆	#88	Dendrochronologia	5.0	81st percentile
☆	#89	Plant Phenome Journal	4.9	81st percentile
☆	#90	Plant Pathology	4.9	81st percentile
☆	#91	Weed Science	4.9	81st percentile
☆	#92	Journal of Plant Nutrition and Soil Science	4.9	80th percentile
☆	#92	Vegetation History and Archaeobotany	4.9	80th percentile
☆	#94	Microbes and Environments	4.9	80th percentile
☆	#95	Phycologia	4.8	80th percentile
☆	#96	Plant Direct	4.7	80th percentile
☆	#97	Journal of Integrated Pest Management	4.7	79th percentile
☆	#98	Annual Plant Reviews Online	4.7	79th percentile
☆	#99	Applications in Plant Sciences	4.6	79th percentile
☆	#100	Journal of Plant Research	4.6	79th percentile
☆	#101	European Journal of Phycology	4.6	79th percentile
☆	#102	Plant Diversity	4.6	78th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#103	Plant Ecology and Diversity	4.6	78th percentile
☆	#104	Fottea	4.6	78th percentile
☆	#105	Italian Botanist	4.6	78th percentile
☆	#106	European Journal of Forest Research	4.5	78th percentile
☆	#107	Journal of Vegetation Science	4.5	77th percentile
☆	#108	Trees - Structure and Function	4.5	77th percentile
☆	#109	Wood Science and Technology	4.5	77th percentile
☆	#110	Journal of Phycology	4.4	77th percentile
☆	#111	Weed Research	4.4	77th percentile
☆	#112	Advances in Botanical Research	4.3	76th percentile
☆	#113	Acta Physiologiae Plantarum	4.3	76th percentile
☆	#114	South African Journal of Botany	4.3	76th percentile
☆	#115	Foods	4.1	76th percentile
☆	#116	Journal of Fungi	4.1	76th percentile
☆	#117	Physiological and Molecular Plant Pathology	4.0	75th percentile
☆	#118	Crop and Pasture Science	4.0	75th percentile
☆	#118	Current protocols in plant biology	4.0	75th percentile
☆	#120	Plant Disease	4.0	75th percentile
☆	#121	Alpine Botany	4.0	75th percentile
☆	#122	Canadian Journal of Plant Pathology	4.0	74th percentile
☆	#123	Natural Product Research	4.0	74th percentile
☆	#124	In Vitro Cellular and Developmental Biology - Plant	3.9	74th percentile
☆	#125	Journal of Soil Science and Plant Nutrition	3.9	74th percentile
☆	#126	Economic Botany	3.9	73rd percentile
☆	#127	Algae	3.9	73rd percentile
☆	#128	Opuscula Philolichenum	3.9	73rd percentile
☆	#129	Journal of Plant Biology	3.8	73rd percentile
☆	#130	Breeding Science	3.8	73rd percentile
☆	#131	International Journal of Plant Sciences	3.8	72nd percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#132	Physiology and Molecular Biology of Plants	3.8	72nd percentile
☆	#133	Systematics and Biodiversity	3.7	72nd percentile
☆	#134	Journal of Forestry	3.7	72nd percentile
☆	#135	Soil Science and Plant Nutrition	3.7	72nd percentile
☆	#136	Aerobiologia	3.7	71st percentile
☆	#137	European Journal of Plant Pathology	3.7	71st percentile
☆	#138	Phytopathologia Mediterranea	3.7	71st percentile
☆	#139	Aquatic Botany	3.6	71st percentile
☆	#140	Plants	3.6	71st percentile
☆	#141	Flora: Morphology, Distribution, Functional Ecology of Plants	3.6	70th percentile
☆	#142	New Zealand Journal of Agricultural Research	3.6	70th percentile
☆	#143	Integrative Organismal Biology	3.6	70th percentile
☆	#144	Horticulture Environment and Biotechnology	3.6	70th percentile
☆	#145	Records of Natural Products	3.5	70th percentile
☆	#146	IAWA Journal	3.5	69th percentile
☆	#147	Plant Breeding	3.5	69th percentile
☆	#148	Rhizosphere	3.5	69th percentile
☆	#149	Forest and Society	3.5	69th percentile
☆	#150	Euphytica	3.4	68th percentile
☆	#151	Plant Biotechnology Reports	3.4	68th percentile
☆	#152	Biologia Plantarum	3.4	68th percentile
☆	#153	Botany Letters	3.4	68th percentile
☆	#154	International Journal of Plant Production	3.4	68th percentile
☆	#155	Plant Signaling and Behavior	3.4	67th percentile
☆	#156	Australian Systematic Botany	3.3	67th percentile
☆	#157	Journal of Berry Research	3.3	67th percentile
☆	#158	Seed Science Research	3.3	67th percentile
☆	#159	Taxon	3.3	67th percentile
☆	#160	Egyptian Journal of Biological Pest Control	3.3	66th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#161	Phycological Research	3.3	66th percentile
☆	#162	Cryptogamie, Algologie	3.2	66th percentile
☆	#163	Journal of Plant Ecology	3.2	66th percentile
☆	#164	Plant Gene	3.2	66th percentile
☆	#165	Theoretical and Experimental Plant Physiology	3.1	65th percentile
☆	#166	Annals of the Missouri Botanical Garden	3.1	65th percentile
☆	#167	Plant Ecology	3.1	65th percentile
☆	#168	Journal of Bryology	3.1	65th percentile
☆	#169	Agriculture (Switzerland)	3.1	65th percentile
☆	#170	Phytochemistry Letters	3.1	64th percentile
☆	#171	In Silico Plants	3.1	64th percentile
☆	#172	California Agriculture	3.0	64th percentile
☆	#173	Journal of Phytopathology	3.0	64th percentile
☆	#174	Botanica Marina	3.0	64th percentile
☆	#175	Acta Botanica Brasilica	3.0	63rd percentile
☆	#176	Plant Molecular Biology Reporter	3.0	63rd percentile
☆	#177	Hacquetia	2.9	63rd percentile
☆	#178	Sydowia	2.9	63rd percentile
☆	#179	Tropical Plant Pathology	2.9	62nd percentile
☆	#180	Weed Technology	2.9	62nd percentile
☆	#181	Plant Systematics and Evolution	2.9	62nd percentile
☆	#182	Asian Pacific Journal of Reproduction	2.9	62nd percentile
☆	#183	aBIOTECH	2.9	62nd percentile
☆	#184	Bryologist	2.8	61st percentile
☆	#185	Legume Science	2.8	61st percentile
☆	#186	Turkish Journal of Botany	2.8	61st percentile
☆	#187	Genetic Resources and Crop Evolution	2.8	61st percentile
☆	#188	Journal of Crop Improvement	2.8	61st percentile
☆	#189	Folia Cryptogamica Estonica	2.8	60th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#190	Plant Genetic Resources: Characterisation and Utilisation	2.7	60th percentile
☆	#191	Australasian Plant Pathology	2.7	60th percentile
☆	#192	Archives Animal Breeding	2.7	60th percentile
☆	#193	Folia Geobotanica	2.7	60th percentile
☆	#194	Journal of Plant Diseases and Protection	2.7	59th percentile
☆	#195	Plant Sociology	2.7	59th percentile
☆	#196	New Zealand Journal of Forestry Science	2.6	59th percentile
☆	#197	Grassland Science	2.6	59th percentile
☆	#198	Australian Journal of Botany	2.6	59th percentile
☆	#199	Journal of Applied Botany and Food Quality	2.6	58th percentile
☆	#200	Annals of Forest Research	2.5	58th percentile
☆	#201	Phytopathology Research	2.5	58th percentile
☆	#202	Edinburgh Journal of Botany	2.5	58th percentile
☆	#203	Journal of Ethnobiology	2.5	57th percentile
☆	#204	Acta Agrobotanica	2.5	57th percentile
☆	#205	Acta Botanica Hungarica	2.5	57th percentile
☆	#206	Genetica	2.5	57th percentile
☆	#207	Tropical Plant Biology	2.4	57th percentile
☆	#208	Acta Societatis Botanicorum Poloniae	2.4	56th percentile
☆	#209	Lindbergia	2.4	56th percentile
☆	#210	Phytoparasitica	2.4	56th percentile
☆	#211	Tuexenia	2.4	56th percentile
☆	#212	Gayana - Botanica	2.3	56th percentile
☆	#213	Comparative Cytogenetics	2.3	55th percentile
☆	#214	International Journal of Vegetable Science	2.3	55th percentile
☆	#215	Botany	2.3	55th percentile
☆	#216	Russian Journal of Plant Physiology	2.3	55th percentile
☆	#217	Acta Botanica Croatica	2.3	55th percentile
☆	#218	Willdenowia	2.2	54th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#219	Horticulture Journal	2.2	54th percentile
☆	#220	Bulletin of the Peabody Museum of Natural History	2.2	54th percentile
☆	#221	Dendrobiology	2.2	54th percentile
☆	#222	PhytoKeys	2.1	54th percentile
☆	#223	Journal of Plant Biochemistry and Biotechnology	2.1	53rd percentile
☆	#224	Biotechnology, Agronomy and Society and Environment	2.1	53rd percentile
☆	#224	Plant Ecology and Evolution	2.1	53rd percentile
☆	#226	Journal of General Plant Pathology	2.1	53rd percentile
☆	#227	Agricultural Research	2.1	53rd percentile
☆	#228	Journal of Crop Science and Biotechnology	2.1	52nd percentile
☆	#229	Grana	2.1	52nd percentile
☆	#230	Plant Physiology Reports	2.1	52nd percentile
☆	#231	Acta Biologica Cracoviensia Series Botanica	2.1	52nd percentile
☆	#232	Revista Brasileira de Botanica	2.1	51st percentile
☆	#233	Biologia (Poland)	2.1	51st percentile
☆	#234	Plant Breeding and Biotechnology	2.1	51st percentile
☆	#235	Blumea: Journal of Plant Taxonomy and Plant Geography	2.0	51st percentile
☆	#236	Pakistan Journal of Botany	2.0	51st percentile
☆	#237	Mediterranean Botany	2.0	50th percentile
☆	#237	Urban Agriculture and Regional Food Systems	2.0	50th percentile
☆	#239	Nova Hedwigia	2.0	50th percentile
☆	#240	Natural Product Communications	2.0	50th percentile
☆	#241	Plant Species Biology	2.0	50th percentile
☆	#242	Czech Journal of Genetics and Plant Breeding	2.0	49th percentile
☆	#243	Ethnobiology and Conservation	2.0	49th percentile
☆	#244	Tropical Ecology	2.0	49th percentile
☆	#245	Eurasian Journal of Soil Science	1.9	49th percentile
☆	#246	Plant Biotechnology	1.9	49th percentile
☆	#247	New Zealand Journal of Botany	1.9	48th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#248	Invasive Plant Science and Management	1.9	48th percentile
☆	#249	Annali di Botanica	1.9	48th percentile
☆	#250	Tropical Grasslands - Forrajes Tropicales	1.9	48th percentile
☆	#251	Notulae Botanicae Horti Agrobotanici Cluj-Napoca	1.9	48th percentile
☆	#252	Systematic Botany	1.9	47th percentile
☆	#253	EPPO Bulletin	1.9	47th percentile
☆	#254	USDA Forest Service - General Technical Report RMRS-GTR	1.9	47th percentile
☆	#255	Phytotaxa	1.8	47th percentile
☆	#256	Horticulturae	1.8	46th percentile
☆	#257	Plant Health Progress	1.8	46th percentile
☆	#258	Journal of Plant Pathology	1.8	46th percentile
☆	#259	Reference Series in Phytochemistry	1.8	46th percentile
☆	#260	Journal of Biologically Active Products from Nature	1.8	46th percentile
☆	#261	International Journal of Fruit Science	1.8	45th percentile
☆	#262	Biodiversity Data Journal	1.8	45th percentile
☆	#263	Revista Brasileira de Fruticultura	1.8	45th percentile
☆	#264	Allelopathy Journal	1.8	45th percentile
☆	#265	Journal of Plant Protection Research	1.7	45th percentile
☆	#266	Biodiversitas	1.7	44th percentile
☆	#267	Agrosystems, Geosciences and Environment	1.7	44th percentile
☆	#267	Rodriguesia	1.7	44th percentile
☆	#269	Karstenia	1.7	44th percentile
☆	#270	Kew Bulletin	1.7	44th percentile
☆	#271	Journal of Plant Nutrition and Fertilizers	1.7	43rd percentile
☆	#272	Journal of Asia-Pacific Biodiversity	1.7	43rd percentile
☆	#273	Bothalia	1.7	43rd percentile
☆	#274	Chinese Journal of Eco-Agriculture	1.7	43rd percentile
☆	#275	Planta Daninha	1.7	43rd percentile
☆	#276	Ecologica Montenegrina	1.7	42nd percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#277	Chinese Journal of Plant Ecology	1.7	42nd percentile
☆	#278	Journal of the Indian Academy of Wood Science	1.6	42nd percentile
☆	#279	Canadian Journal of Plant Science	1.6	42nd percentile
☆	#280	Webbia	1.6	42nd percentile
☆	#281	Revista de la Facultad de Ciencias Agrarias	1.6	41st percentile
☆	#282	Agriculture	1.6	41st percentile
☆	#283	Forest Products Journal	1.6	41st percentile
☆	#284	South African Journal of Plant and Soil	1.6	41st percentile
☆	#285	Plant and Fungal Systematics	1.6	40th percentile
☆	#286	Nordic Journal of Botany	1.6	40th percentile
☆	#287	Acta Mycologica	1.6	40th percentile
☆	#288	Israel Journal of Plant Sciences	1.6	40th percentile
☆	#289	Chinese Journal of Rice Science	1.6	40th percentile
☆	#290	Brittonia	1.5	39th percentile
☆	#291	Ethnobotany Research and Applications	1.5	39th percentile
☆	#292	Journal of Apicultural Science	1.5	39th percentile
☆	#293	Cryptogamie, Bryologie	1.5	39th percentile
☆	#294	Journal of the Professional Association for Cactus Development	1.5	39th percentile
☆	#295	Herba Polonica	1.5	38th percentile
☆	#296	Ornamental Horticulture	1.5	38th percentile
☆	#297	Boletin Latinoamericano y del Caribe de Plantas Medicinales y Aromaticas	1.5	38th percentile
☆	#298	New Disease Reports	1.5	38th percentile
☆	#299	Haseltonia	1.5	38th percentile
☆	#300	Plant OMICS	1.4	37th percentile
☆	#301	Current Research in Environmental and Applied Mycology	1.4	37th percentile
☆	#302	Horticultura Brasileira	1.4	37th percentile
☆	#303	Cytologia	1.4	37th percentile
☆	#304	Botanica Pacifica	1.4	37th percentile
☆	#305	Hellenic Plant Protection Journal	1.4	36th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#306	Novosti Sistematiki Nizshikh Rastenii	1.4	36th percentile
☆	#307	Beitrage zur Tabakforschung International/ Contributions to Tobacco Research	1.4	36th percentile
☆	#308	Australasian Plant Disease Notes	1.4	36th percentile
☆	#309	Journal of Plant Biotechnology	1.4	35th percentile
☆	#310	Indian Journal of Genetics and Plant Breeding	1.4	35th percentile
☆	#311	Natural Sciences Education	1.3	35th percentile
☆	#312	Journal of Biological Research (Italy)	1.3	35th percentile
☆	#313	International Journal of Forestry Research	1.3	35th percentile
☆	#314	Acta Scientiarum Polonorum, Hortorum Cultus	1.3	34th percentile
☆	#315	Phyton	1.3	34th percentile
☆	#316	Acta Phytopathologica et Entomologica Hungarica	1.3	34th percentile
☆	#317	Flora Mediterranea	1.3	34th percentile
☆	#318	Journal of Horticultural Research	1.3	34th percentile
☆	#319	Genetika	1.3	33rd percentile
☆	#320	Botanical Sciences	1.3	33rd percentile
☆	#321	Chemistry of Natural Compounds	1.3	33rd percentile
☆	#322	Acta Agronomica Sinica(China)	1.3	33rd percentile
☆	#323	Egyptian Journal of Botany	1.3	33rd percentile
☆	#324	Acta Botanica Mexicana	1.3	32nd percentile
☆	#325	Annales Botanici Fennici	1.2	32nd percentile
☆	#326	Czech Mycology	1.2	32nd percentile
☆	#327	American Fern Journal	1.2	32nd percentile
☆	#328	Australian Journal of Crop Science	1.2	31st percentile
☆	#328	Legume Research	1.2	31st percentile
☆	#330	Feddes Repertorium	1.2	31st percentile
☆	#331	Seed Science and Technology	1.2	31st percentile
☆	#332	Biotechnologia	1.2	31st percentile
☆	#333	Pakistan Journal of Agricultural Sciences	1.2	31st percentile
☆	#334	International Journal of Plant Biology	1.2	30th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#335	Maydica	1.2	30th percentile
☆	#336	Novon	1.2	30th percentile
☆	#337	Iranian Journal of Plant Physiology	1.2	30th percentile
☆	#338	Darwiniana	1.2	29th percentile
☆	#339	Tarim Bilimleri Dergisi	1.2	29th percentile
☆	#340	USDA Forest Service - Research Papers PNW-RP	1.2	29th percentile
☆	#341	Iheringia - Serie Botanica	1.1	29th percentile
☆	#342	Korean Journal of Plant Taxonomy	1.1	29th percentile
☆	#343	Botanica	1.1	28th percentile
☆	#343	Journal of Crop Protection	1.1	28th percentile
☆	#345	Turczaninowia	1.1	28th percentile
☆	#346	Journal of the Torrey Botanical Society	1.1	28th percentile
☆	#347	Anales del Jardin Botanico de Madrid	1.1	28th percentile
☆	#348	Indian Phytopathology	1.1	27th percentile
☆	#349	Neotropical Biology and Conservation	1.1	27th percentile
☆	#350	Crop, Forage and Turfgrass Management	1.1	27th percentile
☆	#351	Natura Croatica	1.1	27th percentile
☆	#352	Coffee Science	1.1	26th percentile
☆	#352	Vegetos	1.1	26th percentile
☆	#354	Plant Science Today	1.1	26th percentile
☆	#355	Environmental Control in Biology	1.1	26th percentile
☆	#356	Nuytsia	1.1	26th percentile
☆	#357	Journal of Animal and Plant Sciences	1.1	26th percentile
☆	#358	Agriculture and Forestry	1.1	25th percentile
☆	#359	Collectanea Botanica	1.0	25th percentile
☆	#360	Telopea	1.0	25th percentile
☆	#361	Acta Prataculturae Sinica	1.0	25th percentile
☆	#362	Check List	1.0	25th percentile
☆	#363	Rastitel'nost' Rossii	1.0	24th percentile
☆	#364	Acta Phytotaxonomica et Geobotanica	1.0	24th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#365	Journal of Applied Biology and Biotechnology	1.0	24th percentile
☆	#366	Indian Journal of Biotechnology	1.0	23rd percentile
☆	#366	Italian Journal of Mycology	1.0	23rd percentile
☆	#366	Lankesteriana	1.0	23rd percentile
☆	#369	Revista Chapingo, Serie Horticultura	1.0	23rd percentile
☆	#370	Acta Horticulturae Sinica	1.0	23rd percentile
☆	#371	Plant Stress	1.0	23rd percentile
☆	#372	Journal of Advanced Biotechnology and Experimental Therapeutics	1.0	22nd percentile
☆	#373	Asian Journal of Plant Sciences	1.0	22nd percentile
☆	#374	Boletin de la Sociedad Argentina de Botanica	1.0	22nd percentile
☆	#375	Journal of the Botanical Research Institute of Texas	0.9	22nd percentile
☆	#376	Mycotaxon	0.9	22nd percentile
☆	#377	Linye Kexue/Scientia Silvae Sinicae	0.9	21st percentile
☆	#378	Italus Hortus	0.9	21st percentile
☆	#379	Journal of New Zealand Grasslands	0.9	21st percentile
☆	#380	Mikologiya I Fitopatologiya	0.9	21st percentile
☆	#381	Bulletin of the Iraq Natural History Museum	0.9	20th percentile
☆	#381	Frontiers in Agronomy	0.9	20th percentile
☆	#383	Thai Forest Bulletin (Botany)	0.9	20th percentile
☆	#384	Candollea	0.8	20th percentile
☆	#385	Botanica Serbica	0.8	20th percentile
☆	#386	Rhodora	0.8	20th percentile
☆	#387	Botanikai Kozlemenyek	0.8	19th percentile
☆	#388	South-Western Journal of Horticulture, Biology and Environment	0.8	19th percentile
☆	#389	Indian Journal of Agricultural Research	0.8	19th percentile
☆	#389	Indian Journal of Natural Products and Resources	0.8	19th percentile
☆	#391	Natural History Sciences	0.8	18th percentile
☆	#392	Wulfenia	0.8	18th percentile
☆	#393	Agrociencia	0.8	18th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#394	Acta Biologica Sibirica	0.8	18th percentile
☆	#395	Geobotany Studies	0.7	18th percentile
☆	#396	Annales, Series Historia Naturalis	0.7	17th percentile
☆	#397	Electronic Journal of Plant Breeding	0.7	17th percentile
☆	#397	Journal of Biopesticides	0.7	17th percentile
☆	#399	Summa Phytopathologica	0.7	17th percentile
☆	#400	Castanea	0.7	17th percentile
☆	#400	Thaiszia Journal of Botany	0.7	17th percentile
☆	#402	Journal of Nuts	0.7	16th percentile
☆	#403	Journal of the International Society for Southeast Asian Agricultural Sciences	0.7	16th percentile
☆	#404	Plant Root	0.7	16th percentile
☆	#405	Adansonia	0.7	16th percentile
☆	#406	Revista Fitotecnia Mexicana	0.7	15th percentile
☆	#407	Journal fur Kulturpflanzen	0.7	15th percentile
☆	#408	Gorteria: Tijdschrift voor Onderzoek aan de Wilde Flora	0.7	15th percentile
☆	#409	Bonplandia	0.7	15th percentile
☆	#410	Korean Journal of Mycology	0.7	15th percentile
☆	#411	International Journal on Algae	0.7	14th percentile
☆	#412	Khimiya Rastitel'nogo Syr'ya	0.6	14th percentile
☆	#413	Journal of Phytology	0.6	14th percentile
☆	#414	Harvard Papers in Botany	0.6	14th percentile
☆	#415	Rheedea	0.6	14th percentile
☆	#416	Revista de Ciencias Agroveterinarias	0.6	13th percentile
☆	#417	Biota Colombiana	0.6	13th percentile
☆	#418	Bangladesh Journal of Botany	0.6	13th percentile
☆	#419	Forest Research	0.6	13th percentile
☆	#420	Universal Journal of Agricultural Research	0.6	12th percentile
☆	#421	Asian Journal of Agriculture and Rural Development	0.6	12th percentile
☆	#422	Austrobaileya	0.6	12th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#423	Botanicheskii Zhurnal	0.5	12th percentile
☆	#424	Waldokologie Online	0.5	12th percentile
☆	#425	Trends in Phytochemical Research	0.5	11th percentile
☆	#426	Pakistan Journal of Phytopathology	0.5	11th percentile
☆	#427	Medicinal Plants - International Journal of Phytomedicines and Related Industries	0.5	11th percentile
☆	#428	Journal of Tropical Life Science	0.5	11th percentile
☆	#429	Biopesticides International	0.5	11th percentile
☆	#430	Contributii Botanice	0.5	10th percentile
☆	#431	Botanica Complutensis	0.4	10th percentile
☆	#432	Integrative Systematics	0.4	10th percentile
☆	#433	Flora Montiberica	0.4	10th percentile
☆	#434	Korean Journal of Medicinal Crop Science	0.4	9th percentile
☆	#434	Propagation of Ornamental Plants	0.4	9th percentile
☆	#436	Travaux du Museum National d'Histoire Naturelle Grigore Antipa	0.4	9th percentile
☆	#437	Analele Universitatii din Oradea, Fascicula Biologie	0.4	9th percentile
☆	#438	Proceedings on Applied Botany, Genetics and Breeding	0.4	9th percentile
☆	#439	US Department of Agriculture, Forest Service - Resource Bulletin	0.4	9th percentile
☆	#440	Indian Journal of Agricultural Biochemistry	0.4	8th percentile
☆	#441	Arab Journal of Plant Protection	0.4	8th percentile
☆	#442	Journal of Tea Science	0.4	8th percentile
☆	#443	ACS Agricultural Science and Technology	0.4	8th percentile
☆	#444	Neilreichia	0.4	7th percentile
☆	#445	Journal of Applied Horticulture	0.4	7th percentile
☆	#446	Revista de la Facultad de Agronomia	0.3	7th percentile
☆	#447	Journal of Plant Resources and Environment	0.3	7th percentile
☆	#448	Iranian Journal of Botany	0.3	7th percentile
☆	#449	Progress in Plant Protection	0.3	6th percentile
☆	#450	Journal of Pollination Ecology	0.3	6th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#451	Revista del Jardin Botanico Nacional	0.3	6th percentile
☆	#452	Arctoa	0.3	6th percentile
☆	#453	Revista de Investigaciones Agropecuarias	0.3	6th percentile
☆	#453	Studies in Fungi	0.3	6th percentile
☆	#455	Journal of Horticultural Sciences	0.3	5th percentile
☆	#456	Research in Plant Disease	0.3	5th percentile
☆	#457	British Wildlife	0.2	5th percentile
☆	#458	Revista Cubana de Plantas Medicinales	0.2	5th percentile
☆	#459	Reinwardtia	0.2	4th percentile
☆	#460	Field Mycology	0.2	4th percentile
☆	#461	Journal of Agricultural Sciences (Belgrade)	0.2	4th percentile
☆	#462	Indian Journal of Nematology	0.2	4th percentile
☆	#463	Novosti Sistematiki Vysshikh Rastenii	0.2	4th percentile
☆	#464	Notulae Scientia Biologicae	0.2	3rd percentile
☆	#465	Historia Naturalis Bulgarica	0.2	3rd percentile
☆	#466	Acta Botanica Venezuelica	0.2	3rd percentile
☆	#467	Bio-protocol	0.2	3rd percentile
☆	#468	Rostaniha	0.2	2nd percentile
☆	#468	USDA Forest Service - General Technical Report PNW	0.2	2nd percentile
☆	#470	Ratarstvo i Povrtarstvo	0.1	2nd percentile
☆	#471	International Journal of Phytopathology	0.1	2nd percentile
☆	#472	Advances in Weed Science	0.1	2nd percentile
☆	#473	Journal of Medicinal Plants for Economic Development	0.1	1st percentile
☆	#474	Journal of Food Legumes	0.1	1st percentile
☆	#475	Arabian Journal of Medicinal and Aromatic Plants	0.1	1st percentile
☆	#476	International Journal of Secondary Metabolite	0.1	1st percentile
☆	#477	Journal of Agriculture and Crops	0.0	1st percentile
☆	#478	Folia Amazonica	0.0	0th percentile
☆	#478	Hattoria	0.0	0th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#478	Kitaibelia	0.0	0th percentile
☆	#478	Lilloa	0.0	0th percentile
☆	#478	Revista de Biologia Neotropical / Journal of Neotropical Biology	0.0	0th percentile

BIODIVERSITAS
Journal of Biological Diversity

Contact Us FAQ Useful links

Editors-PDF

Home
Content and Archives
Aims and Scope
Editorial Board
Guidance for Authors
Ethical Guidelines
Charges
Membership
Previously Reviewers
Conference Events

ISSN 1412-033X | E-ISSN 2085-4722

PUBLISHER: Society for Indonesian Biodiversity

CO-PUBLISHER: Department of Biology, FMNS, Sebelas Maret University Surakarta

FIRST PUBLISHED: 2000

ADDRESS:

Sebelas Maret University
Jl. Ir. Sutami 36A Surakarta 57126. Tel. +62-271-7994097, Tel. & Fax.: +62-271-663375, email: editors@smujo.id

ONLINE: biodiversitas.mipa.uns.ac.id

Download the Editorial Boards.

Home | Archives | Contact Us