ASIAN JOURNAL OF FORESTRY
Volume 10, Number 1, June 2026
Pages: 6
E-ISSN: 2580-2844
https://doi.org/10.13057/asianjfor/r100132

Diversity and potential carbon storage of tree and pole vegetation in Mount Merapi National Park, Indonesia

MUHAMMAD ADIB AL-DZAHABI[1], MUHAMMAD BONDAN MARDIYANTO[1], MARETTA PATRICIA BERNADETTA[1], MARTINA PUTRI MAHARANI[1], RINOA SALSABILA IZDIHAR[1], AHMAD DWI SETYAWAN[1,2,♥]

[1]Department of Environmental Science, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia. Tel./fax.: +62-271-663375, ♥email: volatileoils@gmail.com
[2]Biodiversity Research Group, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia

Manuscript received: 11 July 2024. Revision accepted: 12 April 2026.

Abstract. *Al-Dzahabi MA, Mardiyanto MB, Bernadetta MP, Maharani MP, Izdihar RS, Setyawan AD. 2026. Diversity and potential carbon storage of tree and pole vegetation in Mount Merapi National Park, Indonesia. Asian J For 10 (1): r100132. https://doi.org/10.13057/asianjfor/r100132.* Forests are complex terrestrial ecosystems essential for life on Earth. They harbor high biodiversity and provide broad benefits for life, with various plants, animals, and microorganisms interacting. Forests can become national parks, where forest areas are protected and managed for conservation, research, education, and recreation. Mount Merapi National Park (MMNP) Resort Kemalang, Klaten, Central Java, Indonesia, exhibits a high diversity of tree vegetation. This study examines the diversity of tree vegetation and carbon storage potential at MMNP Resort Kemalang. The methodology used is a vegetation survey using purposive sampling. The data collected includes tree type, stem diameter, and tree height; the carbon storage potential was also calculated. The diversity index, a measure of species richness and evenness, is used to assess the variety of tree species in the area. The vegetation at Deles Station has a low diversity index for both trees and poles, indicating a less varied and balanced ecosystem. Meanwhile, the vegetation at Sapuangin Station has a low diversity index to a medium tree diversity index, suggesting a more diverse and balanced ecosystem. The tree vegetation at MMNP Resort Kemalang plays an important role in absorbing carbon dioxide and mitigating climate change. The vegetation biomass capacity at Sapuangin Station is 1,067.99 tonnes/ha for poles and 22,154.61 tonnes/ha for trees. Moreover, at Deles Station, it was 477.66 tonnes/ha for poles and 173,459.94 tonnes/ha for trees. The average carbon storage at Sapuangin Station is 501.96 kg/plot for poles and 10,381.01 kg/plot for tree plots. The average carbon storage at Deles Station is 243.01 kg/plot for poles and 81,526.17 kg/plot for tree plots. This study highlights the importance of tree diversity in maintaining ecosystem balance and carbon sequestration potential in MMNP. Future research should explore the impact of environmental factors on tree growth and investigate strategies for enhancing carbon storage through sustainable forest management.

Keywords: Biodiversity, carbon stock, Kemalang Resort, Mount Merapi National Park (MMNP)

INTRODUCTION

Indonesia, with its remarkable natural wealth, has long been recognized as one of the countries with the largest tropical forests in the world. Indonesian forests serve as habitats for various rare endemic plant and animal species and play a crucial role in maintaining ecological balance and addressing the challenges of global climate change (Ahada and Zuhri 2020). One of their key roles is as significant carbon sinks (Lupembe and Munishi 2019; Nunes et al. 2020; Larasati et al. 2024; Rakib et al. 2024; Fadhilah et al. 2025; Ha et al. 2025; Wibowo et al. 2025). With abundant vegetation, Indonesian forests play a crucial role in carbon storage in tree biomass and soil.

Carbon dioxide is a greenhouse gas that raises concerns due to its impact on global climate patterns. Human activities like industrialization, deforestation, forest degradation, and the use of fossil fuels contribute to the accumulation of carbon gases in the atmosphere, which disrupts the carbon cycle (Drexler et al. 2021; Lestari et al. 2023; Ningtyas et al. 2023). Carbon stock refers to the total amount of carbon stored in or from an ecosystem, such as forests, soils, and wetlands, including carbon in living biomass (trees, plants, microorganisms), carbon trapped in dead organic matter (e.g., trash, waste plant, food waste), and carbon in the soil. The terrestrial vegetation is crucial in the global carbon cycle (Rawal and Subedi 2022; Sha et al. 2022). Trees play a significant role in storing carbon, as they store carbon in their biomass (stems, branches, and leaves) during photosynthesis, reducing carbon dioxide in the atmosphere. This helps minimize global warming by providing shade, lowering air temperature through evapotranspiration, and supporting the continuation of the global carbon cycle.

Land and forests have enormous potential as storage sources and are called natural scrubbers or "carbon sinks". Forests play an important role in CO_2 mitigation by absorbing and storing it in the form of biomass through the process of photosynthesis. In addition, plants also naturally provide extra benefits by releasing oxygen into the air through the same process so that forests can be a good buffer against air pollution (Nedhisa and Tjahjaningrum 2020). Terrestrial and most trees (plants) store the most carbon due to their large volume and long-lived storage. Plant parts such as stems, leaves, wood, roots, and the soil in which the plant remains without decaying or burning store atmospheric carbon. Plants of all categories and uncultivated land and grasslands are carbon sinks and stores, thus storing organic matter carbon in the soil. At a global level, soil carbon sequestration may offset as much as 15 percent of fossil fuel emissions (Toochi 2018). In general, the rate of carbon sequestration depends on the plant growth characteristics of a particular tree species, the wood density of the tree, and the growing conditions and stage of the plant, meaning that the largest sequestration stage is in the younger stages of tree growth, between 20 and 50 years (Yuniawati and Andini 2022). One hectare of green leaves can absorb 8 kg CO_2/hour or 0.8 g/m^2/hour, equivalent to the CO_2 exhaled by 200 people simultaneously (Astuti et al. 2020). These findings underscore the significant role of green leaves in carbon absorption. Carbon stock measurements are then carried out to determine the accumulation of carbon stored at that location, providing crucial data for understanding the forest's carbon absorption capacity (Irundu et al. 2020).

Mount Merapi was designated as a National Park based on the Indonesian Ministry of Forestry Decree Number: 134/MENHUT-II/2004 with a total area of 6,410 hectares. This Mountain National Park is divided into 2 *Seksi Pengelolaan Taman Nasional* (SPTN), namely SPTN Region I, which consists of the Cangkringan, Pakem Turi, Srumbung, and Dukun Resorts, and SPTN Region II, which consists of the Selo, Musuk Cepogo, and Kemalang Resorts. Merapi is a water catchment area that is utilized by the surrounding community (Rahmayanti 2022). Apart from that, MMNP's potential in the form of biodiversity includes *saninten* (*Castanopsis argentea* (Blume) A.DC.), vanda tricolor orchid, and Javanese eagle (*Spizaetus bartelsi* Stresemann, 1924). National parks are crucial for storing and absorbing CO_2 and reducing climate change's impact. They support environmental sustainability by acting as carbon sinks and maintaining ecosystem balance and biodiversity. This research aimed to determine the diversity and carbon storage of pole and tree-level vegetation in the Mount Merapi National Park, Kemalang Resort, Klaten, Central Java.

MATERIALS AND METHODS

Study area

Mount Merapi National Park (MMNP) is a conservation area located on Mount Merapi, which is the most active volcano in Indonesia and has quite a diverse flora (Figure 1). MMNP is geographically located at the coordinates 07°22'33"-07°52'30" south latitude and 110°15'00"-110°37'30" east longitude. The area of MMNP covers 5,126 hectares of Central Java and 1,283.99 hectares of Yogyakarta. Administratively, the MMNP area is included in the districts of Magelang, Boyolali, and Klaten in Central Java, and Sleman in Yogyakarta. It can also be concluded that the MMNP borders 23 villages in Central Java and 7 villages in Yogyakarta. The MMNP area is between 600-2,968 meters above sea level. The topography of this area is different, ranging from sloping, hilly, and mountainous. Based on the results of determining the current Schmidt-Ferguson climate type (period II: 1989-2018), there are 3 climate types, namely A, B, and C. The climate type in the MMNP area based on Schmidt-Ferguson is type C, a rather wet description with a Q value between 33.3-66%. The amount of rainfall varies between 875 and 2,527 mm/year. The average temperature at Sapuangin Station is 25.8°C, and at Deles Station is 25.3°C. The research data was taken at 2 stations, namely Sidorejo Village (Deles) and Tegalmulyo Village (Sapuangin), located in the Kemalang Resort, Mount Merapi National Park, Klaten. The data collection was carried out in March 2024, ensuring the most accurate and valuable information for the research and conservation efforts.

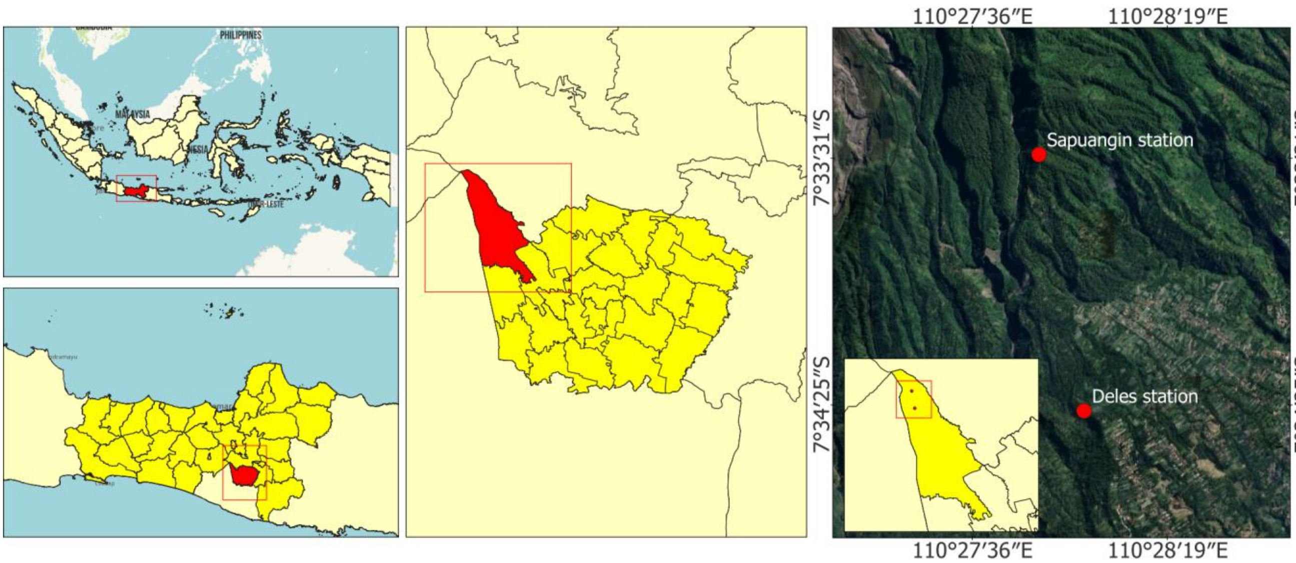

Figure 1. Location of data collection: Deles Station and Sapuangin Station, Kemalang, Klaten, Central Java, Indonesia

Data collection

This research uses a quantitative description method with a non-destructive approach. The samples used were vegetation with a pole or tree habitus. A plot of 20 x 20 meters will be created for tree habitus plants with a minimum circumference of 68 cm, and a plot of 10 meters x 10 meters for pole habitus plants with a maximum circumference of 68 cm. Each village will be given 20 plots. This research utilizes a random sampling method for data collection. This technique, which involves determining the sample area and selecting samples within it (Suriani et al. 2023), is particularly useful for managing large and dispersed populations. Its implementation is also relatively straightforward and cost-effective.

Data analysis

The Shannon-Wiener Diversity Index (*H')* was used to calculate the tree species diversity at each station (Magurran 1988).

$$H' = \sum_{i=1}^{S} (pi)(ln\ pi)$$

Where, Pi = ∑ni/N, H' is the Shannon-Wiener Diversity Index, Pi is the number of individuals within a species/ the total number of species, Ni is the number of individuals in the i -th species, N is the total number of individuals

Shannon-Wiener Diversity Index values range from 1-3 and are classified as follows (Indriani et al. 2009; Anjani et al. 2022):

H' = < 1 Low-level of diversity; H' = 1-3 Medium-level of diversity; H' = > 3 High-level of diversity

Some species have varying allometric equations. Table 1 shows the allometric equations for several species at these research locations.

Plant biomass calculations for species for which no allometric equations have been found are calculated using Brown's (1997) allometric equation.

$$B = \exp[-2.134 + 2.53 \ln(D)]$$

Where, B is the tree biomass (kg), D is the Diameter at Breast Height (DBH) (cm)

Table 1. Allometrics equations of *Pinus merkusii, Toona sureni,* and *Schima wallichii*

Species	Allometric equations	References
Pinus merkusii Jungh. & de Vriese.	B = 0.0936 x D^2.4323	Siregar (2007)
Schima wallichii (DC.) Korth.	B = 0.134741 x D^2.38	Suhendang (2002)
Toona sureni (Blume) Merr.	B = VK x 390 kg/m^3 VK = 0.00013 x D^2.057	P3HH (2008)

The carbon stock calculation utilizes the results of calculating the average amount of biomass at each station using the following formula. The conversion factor is an average estimate of the amount of carbon stored per unit weight of plant biomass. Specifically, a conversion factor of 0.47 is used to convert plant biomass to the amount of carbon stored in carbon stocks, which is useful in forest carbon accounting and ecological research involving vegetation carbon stock estimation. The estimate of carbon storage refers to the Standar Nasional Indonesia 7724:

$$C = B \times 0.47$$

Where, C is the carbon (ton/ha), B is the biomassa (kg/tree); 0,47 is the carbon estimation conservation factor

RESULTS AND DISCUSSION

Composition of tree and pole vegetation

Based on the vegetation survey conducted in two areas of Gunung Merapi National Park, Kemalang Resort, an analysis of pole and tree vegetation in Gunung Merapi National Park Kemalang Resort found that there were 319 individuals in the pole category and 280 individuals in the tree category. In terms of species diversity, 14 different plant species were identified. The composition of plant families represented in the data is 12 families (Table 2).

Table 2 illustrates that the vegetation in the form of trees and poles in the two Mount Merapi National Park Resort areas in Kemalang has quite a large potential in efforts to mitigate climate change. Sapuangin Station has a higher abundance of vegetation, namely 242 individuals, while Deles Station has 357 individuals.

In Sapuangin Station, there are 158 poles which are dominated by *Acacia decurrens* Willd. species (132 individuals), followed by *Altingia excelsa* Noronha. (6 individuals), *Hibiscus tiliaceus* L. (2 individuals), *Pinus merkusii* Jungh. & de Vriese. (1 individuals), *Psidium guajava* L. (1 individuals), *Schima wallichii* (DC.) Korth. (12 individuals), *Syzygium polyanthum* (Wight) Walp. (2 individuals), and *Tarenna incerta* Koord. & Valeton. (2 individuals). The diversity of tree species in Sapuangin Station is also dominated by the *A. decurrens* species (42 individuals), followed by *A. excelsa* species (24 individuals). In the Deles Station, there are 161 poles dominated by the *A. decurrens* species with a total of 107 individuals. In addition, in Deles Station there are 196 trees dominated by *P. merkusii* with a total of 155 individuals.

From Table 2, it can be seen that the number of trees is less than the poles; this indicates an active vegetation growth stage. Regarding diversity, Sapuangin Station has 12 different vegetation types, while Deles Station only has 10 identified vegetation types. Sapuangin Station has more diverse and abundant vegetation, dominated by the *A. decurrens* type; this is because it is one of the areas affected by the eruption of Mount Merapi, where *A. decurrens* is a type of plant that grows quickly and is dominant in this area (Suryawan et al. 2015), while *P. merkusii* dominates Deles Station with vegetation still in the growth stage.

Table 2. Composition of tree and pole vegetation in Mount Merapi National Park, Kemalang Resort, Klaten, Central Java, Indonesia

Scientific name	Local name	Family	Amount of vegetation			
			Sapuangin Station		Deles Station	
			Pole	Tree	Pole	Tree
Acacia decurrens Willd.	*Akasia Gunung*	Fabaceae	132	42	107	17
Altingia excelsa Noronha.	*Rasamala*	Altingiaceae	6	24	5	2
Castanopsis argentea (Blume) A.DC.	*Saninten*	Fagaceae	0	5	0	2
Cinnamomum verum J.Presl.	*Kayu Manis*	Lauraceae	0	1	0	1
Cupressus lusitanica Mill.	*Bintami*	Cupressaceae	0	0	0	14
Filicium decipiens (Wight & Arn.) Thwaites.	*Kerai Payung*	Sapindaceae	0	5	0	0
Hibiscus tiliaceus L.	*Waru*	Malvaceae	2	0	0	0
Melia azedarach L.	*Mindi*	Meliaceae	0	0	0	1
Pinus merkusii Jungh. & de Vriese.	*Pinus*	Pinaceae	1	1	1	155
Psidium guajava L.	*Jambu kristal*	Myrtaceae	1	2	0	0
Schima wallichii (DC.) Korth.	*Puspa*	Theaceae	12	3	47	2
Syzygium polyanthum (Wight.) Walp.	*Salam*	Myrtaceae	2	0	0	0
Tarenna incerta Koord. & Valeton.	*Berasan*	Rubiaceae	2	0	1	0
Toona sureni (Blume) Merr.	*Surian*	Meliaceae	0	1	0	2

Table 3. Estimation of diversity index

Station	Habitus	H’	Description
Sapuangin	Pole	0.700	Low
	Tree	1.407	Medium
Deles	Pole	0.802	Low
	Tree	0.827	Low

However, this shows the rapid and dominating growth of the invasive *A. decurrens*. This was supported by a statement from Suryawan et al. (2015) which states that the dominance of the growth of species *A. decurrens* in the MMNP region is considered invasive. Introduction of foreign species can affect the balance of the ecological system so that a species may only be introduced after analysis of risk and assessment of the environment (Suryawan et al. 2015). Therefore, there needs to be an action against the introduction of the invasive species. According to Kuncari (2011), the dominance of invasive species can be overcome both by mechanical, clear, and quarantine.

Diversity index of pole and tree vegetation

Fabaceae is a prominent and most dominating plant family at Sapuangin Station. Sapuangin Station itself has 12 species of pole and tree species found, with details of *A. decurrens, S. wallichii, T. incerta, A. excelsa, P. guajava, S. polyanthum, Toona sureni* (Blume) Merr.*, Filicium decipiens* (Wight & Arn.) Thwaites*, Cinnamomum verum* J.Presl.*, P. merkusii, C. argentea,* and *H. tiliaceus*. Meanwhile, Deles Station is dominated by the Pinaceae, with 10 species of pole and tree species, with details of *A. decurrens, S. wallichii, T. incerta, A. excelsa, T. sureni, Melia azedarach* L.*, Cupressus lusitanica* Mill.*, C. verum, P. merkusii*, and *C. argentea*.

From Table 3, it can be seen that tree species diversity at Sapuangin Station is medium, while Deles Station has low diversity. The species diversity index value describes the species diversity level in a plant community (Naemah et al. 2020). The level of plant species diversity is analyzed, and the Shannon-Wiener Diversity Index value is produced. The H' is related to species richness at a location, which is influenced by species distribution. According to Indriani et al. (2009), the low-level diversity index value is less than 1, medium level 1-3, and high diversity is more than 3. The diversity index value at Sapuangin Station has a lower value for poles than trees. One of the driving factors was the eruption and fire that occurred on Merapi in September 2023. The eruption material slid 1,600 meters upstream to the Krasak River, followed by material that slid 1,700 meters upstream to the Bebeng River; this triggered fires and land damage in the Merapi area. Therefore, one of the impacts is the loss of some vegetation. Many Sapuangin locations showed damage, such as fallen trees, fire residue, and even ashes.

Pole and tree biomass estimation

Forests contribute significantly to mitigating global climate change through photosynthesis, which removes CO_2 from the atmosphere and stores carbon in biomass. Plants ability to absorb atmospheric carbon can mitigate the impact of greenhouse gasses (Kusumaningrum and Izdihar 2022). The ability of trees to absorb carbon and biomass is not influenced by age; however, old trees in tropical forests contribute to carbon stocks through long carbon retention periods and maintain carbon accumulation levels. Compared with herbaceous plants and shrubs, tree biomass accounts for 98% of total biomass in forest habitats (Ensslin et al. 2015).

Table 4 displays that the average biomass at Sapuangin Station for pole plots is 1,067.99 tons/ha, while for tree plots, it is 22,154.61 tons/ha. At Deles Station, the average biomass value for pole plots is 477.66 tons/ha, while for tree plots, it is 173,459.94 tons/ha. Plants with a tree habit have a higher biomass value than plants with a pole habit because of the tree's age; a small diameter indicates that the tree is still young, so its ability to absorb biomass is lower. The accuracy of biomass values is also influenced by selecting an allometric model suitable for the tree type and natural factors. For example, Mauya and Madundo (2021) discuss the climate and topography of the forest. The type of vegetation and density influence the biomass value, so land with a high density has more biomass than land with a low density (Simamora et al. 2013). This is evident at Deles Station, which has a higher biomass value than Sapuangin Station in both pole and tree habitus.

Pole and tree carbon storage estimation in Mount Merapi National Park, Kemalang Resort

Carbon stock calculations can be obtained by multiplying biomass by the estimated carbon conversion factor, 0.47. Table 5 shows that the average carbon storage at Sapuangin Station for pole plots is 501.96 kg/plot, and for tree plots, it is 10,381.01 kg/plot. Deles Station has an average carbon storage value in pole plots of 243.01 kg/plot and tree plots of 81,526.17 kg/plot. The highest amount of carbon storage is found at Deles Station in the tree plot, namely 81,526.17. This can happen because the type of vegetation influences carbon stocks in a land use system. The presence of trees with a diameter of >30 cm in a land use system significantly contributes to the total carbon stock. In primary forests, trees with a diameter of >30 cm contribute 70% of the total biomass, while trees with a 5-30 cm diameter only contribute around 30% (Nuranisa et al. 2020). Stored carbon stock is determined by biomass that can be observed in the field based on tree diameter measurements. An observation plot has larger trees than other plots and identifies that the biomass in the plot is large, so carbon storage is also large. *P. merkusii* at Deles Station on a tree plot has a biomass value of 6,627.84 tons/ha and stores 3,115.086 kg/plot of carbon. Forest vegetation is strongly influenced by the amount of biomass it has; large vegetation biomass value results in a large carbon value conversion, and the absorption of carbon dioxide has a relationship with standing biomass (Azzahra et al. 2020). This condition can occur because of the photosynthesis process in each plant. Plants absorb CO_2 from the air and convert it into organic compounds through photosynthesis. The photosynthesis results are then used by plants to carry out horizontal and vertical growth. Therefore, the increasing diameter of the trunk is caused by the storage of biomass from the conversion of CO_2 which is getting bigger along with the more CO_2 absorbed by the tree. The amount of carbon that is increasing at this time must be balanced with the amount of absorption by plants to avoid global warming.

Table 4. Biomass estimation in each station

Land area (ha)	Plot habitus	Biomass (ton/ha)	
		Sapuangin Station	Deles Station
0.01	Pole	1,067.99	477.66
0.04	Tree	22,154.61	173,459.94

Table 5. Carbon storage estimation in each station

Land area (ha)	Plot habitos	Carbon storage (Kg/plot)	
		Sapuangin Station	Deles Station
0.01	Pole	501.96	243.01
0.04	Tree	10,381.01	81,526.17

In conclusion, theres 14 species of trees and shrubs recorded at Sapuangin Station and Deles Kemalang Resort, Mount Merapi Klaten National Park. At Sapuangin Station, there are 8 species of poles and 9 species of trees, with the dominant vegetation being *A. decurrens*. In comparison, at Deles Station, there are 5 species of poles and 9 species of trees, with the dominant vegetation being *P. merkusii*. Other plants identified include *S. wallichii, T. incerta, A. excelsa, P. guajava, S. polyanthum, T. sureni, F. decipiens, C. verum, C. argentea, H. tiliaceus, M. azedarach,* and *C. lusitanica*. The vegetation at Deles Station has a low tree and pole diversity index. Meanwhile, the vegetation at Sapuangin Station has a low diversity index for poles and a medium diversity index for trees. Vegetation biomass capacity values at both stations with an average biomass of 1,067.99 tonnes/ha for poles and 22,154.61 tonnes/ha for trees at Sapuangin Station. Meanwhile, poles and trees at Deles Station were 477.66 tonnes/ha and 173,459.94 kg/plot, respectively. The average carbon storage at Sapuangin Station for pole plots is 501.96 kg/plot; for tree plots, it is 10,381.01 kg/plot. Deles Station has an average carbon storage value in pole plots of 243.01 kg/plot and tree plots of 81,526.17 kg/plot.

ACKNOWLEDGEMENTS

We would like to thank the Heads of Mount Merapi National Park Kemalang Resort, Klaten, Central Java, Indonesia, and their staff, who have been kind enough to help us provide information.

REFERENCES

Ahada N, Zuhri AF. 2020. Maintaining forest sustainability and environmental love attitudes for MI/SD learners in Indonesia. El Banar: Jurnal Pendidikan dan Pengajaran 3 (1): 35-46. https://doi.org/10.54125/elbanar.v3i1.43.

Anjani W, Umam AH, Anhar A. 2022. Diversity, evenness, and richness of forest vegetation in Lae Kombih Forest Park, Penanggalan District, Subulussalam City. Jurnal Ilmiah Mahasiswa Pertanian 7 (2): 770-778. https://doi.org/10.17969/jimfp.v7i2.20136.

Astuti R, Wasis B, Hilwan I. 2020. Carbon stock potential in rehabilitation land at Gunung Mas District, Central Kalimantan. Media Konservasi 25 (2): 140-148. https://doi.org/10.29244/medkon.25.2.140-148.

Azzahra FS, Suryanti S, Febrianto S. 2020. Estimation of carbon sequestration in mangrove forest of Bedono Village, Demak, Central Java. J Fish Mar Res 4 (2): 308-315. https://doi.org/10.21776/ub.jfmr.2020.004.02.15.

Brown S. 1997. Estimating Biomass and Biomass Change of Tropical Forests: A Primer. FAO, Rome. https://www.fao.org.

Drexler S, Gensior A, Don A. 2021. Carbon sequestration in hedgerow biomass and soil in the temperate climate zone. Reg Environ Change 21 (3): 74. https://doi.org/10.1007/s10113-021-01798-8.

Ensslin A, Rutten G, Pommer U, Zimmermann R, Hemp A, Fischer M. 2015. Effects of elevation and land use on the biomass of trees, shrubs and herbs at Mount Kilimanjaro. Ecosphere 6 (3): 1-15. https://doi.org/10.1890/ES14-00492.1.

Fadhilah AM, Saputra ADP, Ahtunnisa AR, Zain AN, Rahmania A, Torimbanu AR, Mustika AB, Revalitha AA, Nisfatulsanah A, Wiraatmaja MF, Setyawan AD. 2025. Estimation of aboveground biomass and carbon stock in riparian woody species of the upstream Bengawan Solo River, Central Java, Indonesia. Asian J Environ 1: 1-16.

Ha NT, Bao TQ, Tuan NT, Rodríguez-Hernández DI, Dung NT, Ngoan TT. 2025. Destructive sampling-based allometric equations for

biomass and carbon estimation in Acacia hybrid plantations in Southeastern Vietnam. Nusantara Biosci 16: 203-217. https://doi.org/10.13057/nusbiosci/n170203.
Indriani DP, Marisa H, Zakaria Z. 2009. Keanekaragaman spesies tumbuhan pada kawasan mangrove nipah (*Nypa fruticans* Wurmb.) di Kec. Pulau Rimau Kab. Banyuasin Sumatera Selatan. Jurnal Penelitian Sains 12: 1-4. [Indonesian]
Irundu D, Beddu MA, Najmawati N. 2020. Potential biomass and carbon stored in green open space of Polewali City, West Sulawesi. Jurnal Hutan dan Masyarakat 12 (1): 49-57. https://doi.org/10.24259/jhm.v12i1.9675.
Kuncari ES. 2011. Food plant diversity in Ketambe Lowland Forest, Gunung Leuser National Park. Berkala Penelitian Hayati 5A: 21-24.
Kusumaningrum L, Izdihar RS. 2022. Potential carbon storage in the forest area of Mount Merbabu National Park (MMbNP) Resort Selo Central Java. IOP Conf Ser Earth Environ Sci 1098 (1): 012055. https://doi.org/10.1088/1755-1315/1098/1/012055.
Larasati AD, Abrari FH, Fathoni MFM, Jabbar SA, Arifiani KN, Indrawan M, Sugiyarto, Setyawan AD. 2024. Short Communication: Estimation of aboveground biomass and carbon stock in agroforestry areas of Mergolangu and Karangsambung Villages, Wonosobo, Central Java, Indonesia. Asian J Agric 8: 161-168. https://doi.org/10.13057/asianjagric/g080210.
Lestari F, Tua IN, Muzanni A, Nugroho DF, Wibowo AA, Wartono T, Widanarko B, Saepullah A, Modjo R, Farida M, Erwandi D, Aryani DD, Kadir A, Widiatmoko AI, Hendra, Herwanto ZJ, Tejamaya M, Hamid RA, Fatmah, Gunawan EL, Setyowati DL, Hafids MF, Yuliani R. 2023. Carbon sink and greenhouse gas emission of dryland vegetation cover in tourism villages in Flores Island, East Nusa Tenggara, Indonesia. Biodiversitas 24: 1998-2005. https://doi.org/10.13057/biodiv/d240408.
Lupembe IB, Munishi PKT. 2019. Carbon stocks in the mangrove ecosystem of Rufiji River Delta, Tanzania. Bonorowo Wetlands 9: 32-41. https://doi.org/10.13057/bonorowo/w090104.
Magurran AE. 1988. Ecological Diversity and Its Measurement. Princeton University Press, New Jersey. https://doi.org/10.1007/978-94-015-7358-0.
Mauya EW, Madundo S. 2021. Aboveground biomass and carbon stock of usambara tropical rainforests in Tanzania. Tanzania J For Nat Conserv 90 (2): 63-82.
Ministry of Forestry. 2004. Decree of the Ministry of Forestry No. SK-134/MENHUT-II/2004 on Change of Function of Areas of Protected Forest, Nature Preserve, and Natural Recreational Park in Mount Merapi Forest Area, Sized 6.410 Hectares Located in the Magelang, Boyolali, and Klaten Districts, Central Java Province and Sleman Regency, Province of Special District of Yogyakarta to Mount Merapi National Park. Ministry of Environment and Forestry of the Republic of Indonesia, Jakarta. [Indonesian]
Naemah D, Rachmawati N, Pujawati ED. 2020. Keragaman jenis tumbuhan bawah hutan rawa gambut di Kabupaten Banjar. Jurnal Hutan Tropis 8 (3): 298-305. https://dx.doi.org/10.20527/jht.v8i3.9630. [Indonesian]
Nedhisa PI, Tjahjaningrum IT. 2020. Estimation of biomass, carbon stock and mangrove carbon sequestration in *Rhizophora mucronata* in Wonorejo Surabaya with allometric equation. Jurnal Sains dan Seni ITS 8 (2): 2337-3520. https://doi.org/10.12962/j23373520.v8i2.45838.
Ningtyas SRA, Mu'ali AYF, Putri DNAR, Silaningtyas NW, Tsabita FA, Aprianto MK, Sari SP, Fauziyyah MD, Nugraheni RS, Juniati SD, Isa MN, Nofitasari H, Sutarno, Sugiyarto, Yap CK, Budiharta S, Setyawan AD. 2023. Estimation of aboveground carbon stock based on mangrove zones in Ijo River Estuary, Ayah Village, Kebumen, Indonesia. Indo Pac J Ocean Life 7: 148-155. https://doi.org/10.13057/oceanlife/o070204.
Nunes LJR, Meireles CIR, Pinto Gomes CJ, Almeida Ribeiro NMC. 2020. Forest contribution to climate change mitigation: Management oriented to carbon capture and storage. Climate 8 (2): 21. https://doi.org/10.3390/cli8020021.
Nuranisa S, Sudiana E, Yani E. 2020. Relationship between age and biomass, carbon dioxide stocks, and duku (*Lansium Parasiticum*) tree stands in Kalikajar Village, Kaligondang Sub-district, Purbalingga District. BioEksakta: Jurnal Ilmiah Biologi Unsoed 2 (1): 146-151. https://doi.org/10.20884/1.bioe.2020.2.1.1866.
Pusat Penelitian dan Pengembangan Hasil Hutan (P3HH). 2008. A Practical Guide to the Nature of Wood Types of Indonesia. Indonesian Sawmill Woodworking Association (ISWA), Bogor. [Indonesian]
Rahmayanti L. 2022. Literature review: Analysis of management potential of Mount Merapi National Park (MMNP) based on zones for terrestrial ecosystem preservation. Jurnal Sains Edukatika Indonesia 4 (1): 29-35. [Indonesian]
Rakib MH, Hossain SMS, Sadnan MWM, Chowdhury MIH. 2024. Unveiling the interplay between tree stand attributes, species diversity, and biomass carbon in Chunati Wildlife Sanctuary, Southeastern Bangladesh. Intl J Trop Drylands 8: 95-105. https://doi.org/10.13057/tropdrylands/t080204.
Rawal K, Subedi PB. 2022. Vegetation structure and carbon stock potential in the community-managed forest of the Mid-Western Hilly Region, Nepal. Asian J For 6: 15-21. https://doi.org/10.13057/asianjfor/r060103.
Sha Z, Bai Y, Li R, Lan H, Zhang X, Li J, Liu X, Chang S, Xie Y. 2022. The global carbon sink potential of terrestrial vegetation can be increased substantially by optimal land management. Commun Earth Environ 3 (1): 8. https://doi.org/10.1038/s43247-021-00333-1.
Simamora J, Widhiastuti R, Pasaribu N. 2013. Tree and pole diversity and potential carbon storage in a 30-year secondary forest and coffee plantation in Telagah, Langkat. Saintia Biologi 1 (2): 55-59. [Indonesian]
Siregar CA. 2007. Biomass estimation in pine plantation forests (*Pinus merkusii* Jungh et de Vriese) and Cianten soil carbon conservation, West Java. Jurnal Penelitian Hutan dan Konservasi Alam 4 (3): 251-256. https://doi.org/10.20886/jphka.2007.4.3.251-266.
Suhendang E. 2002. Introduction to Forestry Science. Fakultas Kehutanan IPB, Bogor. [Indonesian]
Suriani N, Risnita, Jailani MS. 2023. The concept of population and sampling and selection of participants in educational scientific research. IHSAN: Jurnal Pendidikan Islam 1 (2): 24-36. https://doi.org/10.61104/ihsan.v1i2.55. [Indonesian]
Suryawan D, Sutyarto E, Umaya R, Kurnia A, Hadiyan Y. 2015. Distribution of invasive alien species *Acacia decurrens* in Mount Merapi National Park. Pros Sem Nas Masy Biodiv Indon 1: 738-742. https://doi.org/10.13057/psnmbi/m010409. [Indonesian]
Toochi EC. 2018. Carbon sequestration: How much can forestry sequester CO_2? Forest Res Eng Intl J 2 (3): 148-150. https://doi.org/10.15406/freij.2018.02.00040.
Wibowo CNP, Azizah CKG, Risdian DA, Fathurrohman DTA, Tsurayya DA, Rizka DR, Renaldi DR, Saleh DA, Ridwan M, Setyawan AD. 2025. Review: Indigenous peatland bacteria and their role in heavy metal detoxification under extreme biogeochemical constraints. Cell Biol Dev 9: 113-128. https://doi.org/10.13057/cellbioldev/v090205.
Yuniawati D, Andini S. 2022. Potential carbon storage and CO_2 emissions from logging in Papua's Natural Forests. Jurnal Penelitian Hasil Hutan 40 (2): 61-73. [Indonesian]