



Ecological Value of Tree Vegetation at Ere-ere Biosite of Ijen Geopark, Indonesia

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Abstract. Ere-ere is Ijen Geopark Biosite located in an area above 1000m altitude. It is a primary tropical rain forest ecosystem in a quarter volcano which is already in the stage of climax succession because the canopy stratification is very complex. However, there is limited information on the tree vegetation that composes this Ijen Geopark Biosite, therefore a study aimed to estimate the species diversity and ecological value was carried out. Tree data collections were sampled in 10x10m² plots. All tree species in the plots were identified and its parameters such as trunk diameter, height, canopy height, canopy width, and canopy density were measured. The tree species composition and dominance were analysed based on the taxa. Furthermore, species diversity was calculated by Shannon-Wiener formula while ecological values were analysed by calculating ecoval formula. The tree vegetation of Ere-ere Biosite consist of low number species composition (14 families, 16 genera, and 17 species). This community had moderate species diversity and was dominated by *Dendrocnide sinuata* (Blume)-*Trema orientalis* (L.) Blume. The total ecoval of tree vegetation of Ere-ere biosite is 5,299,281.89 million IDR/ha of which 99.98% was contributed by the structure value (Rp. 5,298,725.56 million/ha). The function value of carbon stock only contributes 0.02% or 556.33 million IDR/ha. The large number of individual populations of the species *D. sinuata* (Blume), *Syzygium aqueum* (Burm. f.) Alston, and *T. orientalis* (L.) Blume play an important role in big volume dimensions of structure value. The *Ficus* genera that have big diameter with high trunk contributes to high structure values, namely 11,343.36 million IDR/tree in average.

Keywords: Ecological value · Biosite · Ere-ere · Ijen Geopark

1 Introduction

Geopark is an area with an outstanding geological heritage and a strategy to promote that heritage for the benefit of the local community. One of the magnificent geoparks in Indonesia is Ijen Geopark. Ijen Geopark administratively located in two districts

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Banyuwangi and Bondowoso Regencies of East Java. The Ijen Geopark have 21 potential Geological Sites (Geosite), six Biological Sites (Biosite), and 10 Cultural Sites (Culturesite). Among them, Erekek Biosite located on the eastern slope of Ijen Crater Nature Park at an altitude of 1000–1800 masl is typical tropical forest ecosystem [1].

Geomorphologically, the Erekek forest area is located right in an inter-volcanic valley. The distribution of this forest stretches from the southwest slope of Mount Ijen Crater to the south-eastern slope of Mount Rante. This inter-volcanic valley forms a watershed whose entire flow goes to the lowest point of the valley, namely Kali Erekek. The Erekek River flow separates the volcanic products of Mount Ijen Crater in the east and volcanic products of Mount Rante in the west. Volcanic products dominated by explosive eruptions in the form of pyroclastic and effusive in the form of lava from Mount Ijen Crater, Mount Rante, and Mount Merapi. The direction of the slope of the inter-volcanic valley that faces relatively to the south-southeast makes this area unaffected by the volcanism of the acidic lake of Ijen Crater, which is dominant to the west [2]. This causes the forest in this area to be relatively undisturbed by active volcanism activities so that it becomes fertile.

As an impact, the undisturbed Erekek biosite is covered with various types of tree community in complex layers. Based on the pre survey, the canopy layers of the tree vegetation are suitable habitats for various birds, insects, primates, small reptiles and amphibian. Among the tree layers, based on the pre survey there are tree ferns, *Cyathea contaminans* and *C. orientalis*, appearing in the Jurassic period. Based on the initial survey, the existence of *Cyathea* which is capable of growing up to 6–15 m in height indicates this biosite is still preserved with its constituent vegetation. However, information regarding the composition and diversity of the tree vegetation of the Erekek biosite stands is very limited. As part of Ijen Geopark, information and the value of vegetation diversity in this biosite are needed to update information Biosite-Ijen Geopark UGGp, and support ecotourism development.

List of tree species scientific or local names, species diversity, and its value are important information to support ecotourism. The identified tree species and local name can be used by local people for guiding the tourists and birdwatchers. The information is benefited for management of Erekek Biosite for further conservation actions. Therefore, this research study was done to estimate the ecological value of tree vegetation at Erekek Biosite of Ijen Geopark - Indonesia. It covers tree species composition, dominance tree species, tree species diversity, and ecological value of tree vegetation.

2 Methodology

2.1 Location

This research was carried out in July–November 2020 the Erekek Biosite Banyuwangi, East Java-Indonesia at 8° 6'15.56"S and 114°14'26.99"E until 8° 6'24.87"S and 114°14'27.79"E (Fig. 1). This site has a mean annual precipitation of 1,303 mm/yr with average temperature of 26.8 °C and humidity of 79%. The topography is mostly undulated with a slope of around 0–40 percent and has a mixed tropical forest type ecosystem.

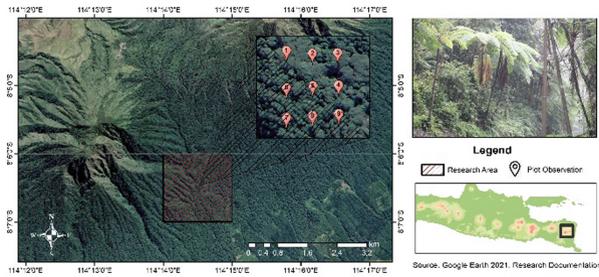


Fig. 1. Research study location of Ere-erek biosite at Ijen Geopark (constructed from google earth 2021 and research documentation).

2.2 Data Sampling

Plot sampling method consisting of a hundred $10 \times 10 \text{ m}^2$ plots was selected to get more plant species composition with the height $\geq 1 \text{ m}$. Each of the $10 \times 10 \text{ m}$ was placed randomly and used to sample tree species. Each tree species circumferences found in the plots were measured using a diameter tape before each value was converted into diameter at breast height (DBH).

The tree species with $\geq 5 \text{ cm}$ DBH were measured at 1.37 m, while those with $< 5 \text{ cm}$ DBH were measured at 10 cm above the ground level, following [3]. Heights at the lower level and at the upper level of crown were also measured. To get the value of crown volume, the crown width and length were measured using a clinometer. Furthermore, the crown height was derived from the difference between the upper and lower tree heights.

The biomass of the crown was estimated through a non-destructive method. In this study, visual estimation was used to measure the crown character of the individual tree—its width, length, height and percentage crown density. The measurements were done by standing beneath the canopy or crown, beside the trunk, and obtaining a careful visual appreciation of the canopy structure [4]. Both upper and lower crowns were estimated using a handy clinometer.

All tree species were harvested from and weighed to get the value of wood density for aboveground biomass (AGB) estimation. For plant species with $< 30 \text{ cm}$ DBH, a destructive method was used to measure wood density of species, specifically, by cutting the plant stems and collecting 10 samples of wood chips. Each wood chip was 10 cm long and measured at its middle diameter for volume computation.

For tree species with $\geq 30 \text{ cm}$ DBH, two wood samples were taken from the trunk by using auger or borer at 1.3 m height, then sealed in polythene bags [3]. Both collected wood cores and wood chips were fresh- weighed on site using CHQ pocket scale PS-100A (for materials $< 100 \text{ gr}$). While the wood chips were oven-dried at $105 \text{ }^\circ\text{C}$ until it reached constant weight. This activity was done to get the dry weight of those samples.

2.3 Data Analysis

To estimate the ecological value (ecoval) of tree vegetation at Ere-erek Biosite of Ijen Geopark-Indonesia, data analysis was done to determine:

2.3.1 Tree Species Composition, Dominance, and Diversity

Based on its morphological characteristics of the tree specimens, each tree species was identified using Plant identification book [5]. Species name was verified using plant species databased of International Plant Names Index (IPNI) at <https://www.ipni.org>. The tree species composition was classified based on family, genus, and species names.

The dominance species of the vegetation was determined based on the Important Value Index (IVI) percentage. This value was the sum of all relative frequency, dominance, and density values of tree vegetation.

Species number, species occurrence, and basal area were recorded and used for vegetation analysis, following [6]. The diversity of tree species was calculated using the Shannon Index (H') (1):

$$H' = -\sum p_i \ln p_i \quad (1)$$

where, p_i is proportion of total sample represented by i species

2.3.2 Ecological Value (Ecoval) of Tree Vegetation

The ecoval (IE) was estimated by using formula established [7] (2):

$$\begin{aligned} IE &= \{bS \cdot D\} + \{bF \cdot 3.667W \cdot Ef\} \\ &= (bSt \cdot Vt) + \{(c+o) \cdot 3.667W \cdot Ef\} \end{aligned} \quad (2)$$

where IE is ecological value in USD, S is ecological structure value, F is ecological function value in USD, bS is ecological base value of structure in USD, D is dimension form of volume in m^3 , bSt is wood price of tree species, Vt is tree volume, bF is ecological base value of function in USD, 3.667 is conversion of C to carbon dioxide, W is carbon content of biomass in kg or Mg unit, c is carbon credit, o is ecological resources value, and Ef is the existence factor of each plant species that is representative of distribution of plant species in its ecosystem. This value is representative of three categories, which are: frequency (Fr), conservation status (Cs), and geographic extension or distribution (Gd) of species. As rated at [8], the bS for tree species was at the price of USD 25.72–42.93/ m^3 (for $DBH < 30$ cm) and USD 74.38–89.75/ m^3 (for $dbh \geq 30$ cm).

The bF represents two types of basic price taken from carbon trade or credit and basic cost from resource offset in USD currency of each plant species. The standard price of carbon credit (c value) was in the range of USD 7–20 tCO_2 [9]. The ecological resource offset (o value) was taken from the standard, commonly used to ratify the transaction cost of forest offset. The prices range from USD 4–15 tCO_2 [10]. The currency rate USD 1 = IDR 14.104,27 (Indonesia Bank in November 2021) was used as ecological base value in the calculation.

The regression equation developed by [11] that takes into account DBH, height, and wood density was used to estimate AGB of tree species (3).

$$\begin{aligned} (AGB)_{est} &= \rho \times \exp(-1.499 + 2.148 \ln(D) + .207(\ln(D))^2 \\ &\quad - .0281(\ln(D))^3) \sim 0.0509 \times \rho D^2 H \end{aligned} \quad (3)$$

where AGB test is tree biomass estimated; ρ is wood density in gr/cm^3 ; D is DBH in cm; H is tree height in meter.

The wood density of each tree species was calculated based on the proportion of dry weight to its fresh volume as follows (4):

$$\rho = dW/V \quad (4)$$

where dW is oven dried weight of sample, and V is fresh volume of sample.

The tree crown biomass was estimated based on its shape using the equations proposed by [4]. Based on the crown density proposed by [12], the volume was determined using its percentage proportion (0%–99%). As suggested by [4], 0.5 convention of tree wood density was used as an approximation of crown wood density. On the other hand, the belowground biomass (BGB) was determined using 0.2 ratio of aboveground forest biomass.

The carbon stocks per living plant species were calculated by dividing the total stock per number of individual species expressed in $\text{kg C}/\text{ha}$. The convention of 0.5 or 50 percent for carbon content estimation was used in this study [13, 14, 15]. The total biomass was the sum of tree stem biomass, crown biomass and BGB.

3 Results and Discussion

3.1 Tree Species Composition, Dominance, and Diversity

A total of 2205stem/ha the tree species belongs to 14 families, 16 genera, and 17 species (Table 1). Three families such as Euphorbiaceae, Moraceae, and Sapindaceae, while the other species consist of one species. The total tree species of Erekek Biosite is similar to tree species composition in South Eastern Bangladesh [16]. Tree species composition in Erekek Biosite is lower than that of Natural Tropical Rainforest-South Papua which is about 76 species [17] and that of Mount Sigogor Nature Reserve which is about 43 species [18].

Among the tree species composition, *Dendrocnide sinuate* species occupies the highest number (28% or 625 stem/ha). This species is typical tropical forest species well adapted to moist area. Dense and complex structure of the Erekek benefit to *D. sinuate* having broad and thin leaves. These leaves characteristics support the tree species to maximize the intake of sunlight for the photosynthesis process.

The Erekek biosite is a mixed forest that has a high stratification complexity with the dominance of large diameter trees with an average tree height of more than 10 m (Fig. 2). The presence of *C. contaminans* which is the first tree fern in the world to thrive in this area indicates that the area is very humid with high fertility. It is supported by the temperature measured is lower than 28 °C and the humidity above 60%.

The tree fern (*C. contaminans*) population is found in quite high numbers (14% or 319 stem/ha). The height of the tree ferns which on average reaches a height of more than 5 m can be assumed that the Erekek area is a relatively old forest that is not affected by disturbances from Mount Ijen.

Table 1. Tree species composition of Erekek-erek biosite

No	Family	Genus	Species
1.	Cannabaceae	<i>Trema</i>	<i>T. orientale</i> (L.) Blume
2.	Casuarinaceae	<i>Casuarina</i>	<i>C. junghuhniana</i> Miq., Pl. Jungh. [Miquel]
3.	Cyatheaceae	<i>Cyathea</i>	<i>C. contaminans</i> (Wall. Ex Hook.) Copel
4.	Ebenaceae	<i>Diospyros</i>	<i>D. cauliflora</i> De Wild
5.	Euphorbiaceae	<i>Mallotus</i>	<i>M. paniculatus</i> (Lam.) Mull. Arg.
		<i>Ricinus</i>	<i>R. communis</i> L.
6.	Hernandiaceae	<i>Hernandia</i>	<i>H. peltata</i> Meisn.
7.	Magnoliaceae	<i>Michelia</i>	<i>M. champaca</i> L.
8.	Malvaceae	<i>Grewia</i>	<i>G. hirsuta</i> Vahl.
9.	Melastomaceae	<i>Melastoma</i>	<i>M. malabathricum</i> (L.) Smith
10.	Meliaceae	<i>Toona</i>	<i>T. sureni</i> (Blume) Merr.
11.	Moraceae	<i>Ficus</i>	<i>F. consociata</i> (Blume)
			<i>Ficus</i> . sp.
12.	Myrtaceae	<i>Syzygium</i>	<i>S. aqueum</i> (Burm. f.) Alston
13.	Sapindaceae	<i>Erioglossum</i>	<i>E. rubiginosum</i> (Roxb.) Blume
		<i>Mischocarpus</i>	<i>M. sundaicus</i> -BL
14.	Urticaceae	<i>Dendrocnide</i>	<i>D. sinuata</i> (Blume)

**Fig. 2.** Erekek-erek biosite tropical forest.

The existence of this species needs special supervision because this species is widely used by the community as planting media. There are 10 less common tree species indicated by Important Value [IV] less than 10%, including *H. peltate*, *E. rubiginosum*, *C. junghuniana*, and *D. cauliflora* as seen at Fig. 2.

The dominance of species in Erekek-erek Biosite was determined on the basis of the IV of each species (see Fig. 3). Species *D. sinuata*-*T. orientalis* (IV = 66.34%–60.32%)

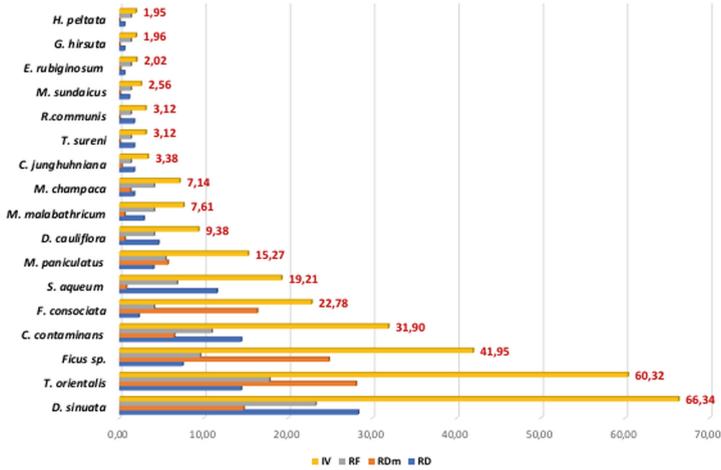


Fig. 3. The most common tree species at erekek biosite (in percentage); IV = Important Value, RF = Relative Frequency, RDm = Relative Dominance, RD = Relative Density.

appeared to be the most common species. Each was found to be dominant. *Dendrocnide sinuate* was commonly found dominant in areas with relatively moist area; while *T. orientalis* or Anggrung prefers the slightly wet habitat and high elevation. This is in agreement with the works of [19].

The results of the Shannon index (H') indicated moderate community diversity ($H' = 2.24$). This diversitas value is similar to the tree diversity vegetation at Karangsambung-Karangbolong National Geopark, Indonesia [20]. It could be explained by the fact that the biosite is dominated by several species such as *D. sinuate*, *T. orientalis*, and *Ficus sp.*

Ficus sp., *C. contaminans*, *F. consociata*, *S. aqueum*, and *M. paniculatus*. It also indicated that the stability of the community is moderate. Meaning, there are some species are dominant in the Erekek Biosite. These dominance species ensure their resiliency regarding to the disturbances. They have moderate performance in response to environmental change and recovery after disturbances. Thus, it gives impact on forest stability. As stated by [21, 22] the species and structural diversity give impact on forest stability.

3.2 Ecological Value (Ecoval) of Tree Vegetation

The total ecoval of tree vegetation of Erekek biosite is 5,299,281.89 million IDR/ha of which 99.98% was contributed by the structure value (Rp. 5,298,725.56 million/ha) (Table 2). The function value of carbon stock only contributes 0.02% or 556.33 million IDR/ha. The large number of individual populations of the species *D. sinuate*, *S. aqueum*, and *T. orientalis* play an important role in big volume dimensions of structure value. The *Ficus* genera (166 trees) that have big diameter with high trunk contributes high structure values, namely 11,343.36 million IDR/tree in average. On the other hand, the appraisal of *H. peltata* resulted in the lowest ecoval (7.44 million IDR/ha).

Table 2. The structure v identification of herbaceous, shrub and tree value (S), function value (F), and ecoval in million IDR/ha of tree vegetation

Species Name	S	F	Ecoval
1. <i>C. junghuhniana</i>	13,174.07	4.20	13,178.27
2. <i>C. contaminans</i>	231,620.2	9.22	231,630.04
3. <i>D. sinuata</i>	877,900,.0	34.93	877,935.84
4. <i>D. cauliflora</i>	18,894.83	2.80	18,897.63
5. <i>E. rubiginosum</i>	344.14	0.04	344,18
6. <i>F. consociata</i>	464,734.72	92.82	464,827.54
7. <i>Ficus sp.</i>	1,996,773.47	299.11	1,997,072.58
8. <i>G. hirsuta</i>	116.15	0.02	
9. <i>H. peltata</i>	7,.4	0.00	7.74
10. <i>M. paniculatus</i>	240,051.96	37.62	240,089.58
11. <i>M. malabathricum</i>	23,565.35	2.34	23,567.68
12. <i>M. champaca</i>	76,314.92	7.56	76,322.48
13. <i>M. sundaicus</i>	1,259.21	0.24	1,259.44
14. <i>R. communis</i>	206.48	0.02	206.50
15. <i>S. aqueum</i>	8,315.13	1,32	8,316.45
16. <i>T. sureni</i>	83.45	0.01	83.46
17. <i>T. orientalis</i>	1,345,362.22	64.08	1,345,426.30
Total	5,298,725.56	556.33	5,299,281.89

In conclusion, the tree vegetation of Erek-erek Biosite consist of low species composition (14 families, 16 genera, and 17 species). This community had moderate species diversity and was dominated by *D. sinuata* (Blume)-*T. orientalis* (L.) Blume. The total ecoval of tree vegetation at this area is 5,299,281.89 million IDR/ha. Most of total ecoval of tree vegetation at Erek-erek biosite was contributed by the structure value. The highest ecoval is contributed by *Ficus* population (1,997,072.58 million IDR/ha) because of their big volume of individual trees. On the other hand, the function value of carbon stock only contributes 0.02% or 556.33 million IDR/ha to the community. It is hoped that with this ecoval known, people would be more cautious in making decisions from as simple as cutting a single tree to as serious an act as land use conversion. Based on the complex stratifications of the Biosite vegetation, many species of birds will be attracted to particular fruiting and flowering trees such as *M. champaca*, *S. aqueum*, or *T. orientalis*. Some insects such as ants associated with *C. contaminans* will also attract insectivore birds to visit. So, it needs further research on recommended spots for bird watching as tourist destinations.

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Authors' Contributions. HS carried out the research design, identification of tree species, ecoval analysis, and writing of the manuscript. AMS contributed to the data collection species. AB contributed to mapping location area of research study. FPK contributed stock carbon sampling and estimation. FSNS contributed in stock carbon analysis. All authors read and approved the final manuscript.

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