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The structure and diversity of vegetation treelets of tropical mountain forest on mount Bawakaraeng

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Abstract. The study about the diversity and structure of treelet vegetation in three slope areas on the mountainous forest of mount Bawakaraeng, Regency of Gowa, Province of South Sulawesi had been done. There were 17 species of treelets throughout the study area, from 13 families and 16 genera. The Asteraceae family has the highest number of species with 3 species, followed by Fabaceae and Solanaceae which each has 2 species. *Pteridium aquilinum*, *Chromolaena odorata*, *Breynia oblongifolia*, and *Pogostemon cablin* are the species with the highest important value index. The number of treelet species ranges from 15-16. Treelet species were mostly found in the flat slope area. The Shannon-Wiener diversity index (H') ranges from 2,033-2,161 and was found to be highest on steep slopes and lowest on flat slopes. The H' has the same tendency as Simpson's Diversity Index and Evenness Index of Pielou (E) and reverse relationship with Simpson's Dominance Index.

1. Introduction

Mount Bawakaraeng has located about 75 km from Makassar City with an altitude of 2.830 m asl [1], is the highest mountain in the province of South Sulawesi, and is part of the Lompobattang protected forest area [2]. Administratively, it belongs to the Gowa Regency area. This mountain is important, because on its western slopes there is an upstream of the Jeneberang river, and downstream of this river there is the Bili-Bili reservoir which is a water catchment area for Gowa and Makassar [1]. This reservoir is a multipurpose reservoir to control floods, fulfill the need for irrigation water, supply raw water, and hydroelectric power generators [3]. Many people around mount Bawakaraeng consider the mountain as a sacred place [2].

Forest is a structurally complex ecosystem that contains understorey layers that play a role in ecological processes and are often a large constituent of forest species richness [4]. Understorey vegetation including treelet plants on mount Bawakaraeng is one of the components that make up the ecosystem on this mountain. Changes and disturbances to mount Bawakaraeng will also affect this vegetation. According to Tchouto et al., [5] the understorey vegetation including shrubs, saplings, and herbaceous have an important role in the diversity of vegetation in tropical rain forests. According to Chavda and Mehta [6], trees and shrubs have many benefits. As vegetation grows in an area, these plants can protect the soil, become food for both wild and domestic animals, source of foods, medicines, fibers, and buildings.

Many environmental problems that occur in mount Bawakaraeng such as forest damage due to the increasing number of illegal logging, the amount of garbage scattered and the lack of awareness from visitors and the surrounding community about the importance of protecting this mountain [7]. The Natural habitats will be difficult to adapt to environmental change, also the culture and lives of local residents will be affected if there is a decline in biodiversity [8]. The high rates of deforestation and species loss in various ecosystems in tropical rainforests making the understanding of biodiversity in this area becomes important [9].

Given the importance of mount Bawakaraeng and also treelet vegetation, it is necessary to maintain their sustainability. The first step that needs to do, is to understand the ecological condition of the vegetation, which includes treelet vegetation on mount Bawakaraeng. Data about treelet vegetation on this mountain is needed for further conservation of this area. This study aims to determine the diversity and structure of treelet vegetation structure in three slope areas on the mountainous forest of mount Bawakaraeng, Regency of Gowa, Province of South Sulawesi.

2. Materials and Methods

2.1. Study Area

This research was conducted on the mountain forest of mount Bawakaraeng in the Lembana village, Gowa Regency. The morphology of this mountain is characterized by high relief, extreme slope, high weathering rate, and erosion such as soil movement and landslides. Mount Bawakaraeng was formed as a result of volcanic activity during the Pleistocene period, which consists of andesite rocks such as breccias, pyroclastics, tuff, and interstratified lava. Because most of the pyroclastic rocks, especially those that have not been compacted, can easily rot, erode, and degenerate. In addition, the rock consists of layers of lava, coated by ash, and then build up to form slopes. The contact between the layers is considered a vulnerable part to be eroded [10].

2.2. Vegetation Samplings

We define treelets as all trees having a trunk diameter at breast height < 5 cm and grouped as sapling growth forms, all shrubs, and ferns which when mature its height do not exceed 5 m above the ground. Sampling was carried out on flat slopes of 0-8%, gentle slopes of 9-15%, and steep slopes above 15%. In each slope area, a 100 m long transect was placed with 5 replications. The placement of the first transect was carried out randomly in each area and cut the topography in the direction of elevation, then the next 4 transects were lined up beside the first transect. The distance between transects is 100 m or according to topography. At each transect, ten plots of 5 x 5 m were made, and the distance between the plots was 5 m. The number of transects contained in this study was fifteen, each of which contained ten plots. The sampling size on each slope area is 1500 m^2 and, for the entire slope area, is 3750 m^2. In each plot, the data of each treelet species was taken. During data collection, growth forms of plants were listed.

2.3. Data Analysis

We calculated the density and frequency of each species. The importance value index of each species is obtained by the following formula:

Important value index (IVI) = relative density + relative frequency [11].

Data for calculating IVI in each slope area was obtained from the combined data of 5 existing transects. We calculated various diversity indexes as follow: Shannon-Wiener diversity index (H’), Simpson’s Dominance Index (D), Simpson's Diversity Index (SDI), Evenness Index of Pielou (E) [12], and Species Richness (S) [13] was obtained from the number of species found. The data used to determine H' were obtained from the IVI of each species. All species from the study area were categorized into different growth forms. The analysis of growth forms of plant species from study areas. The data is processed and analyzed by using the program R version 4.0.1[14].

3. Results and Discussion

3.1. Results

There were 17 species of treelets throughout the study area, from 13 families and 16 genera. The Asteraceae family has the highest number of species with 3 species, followed by Fabaceae and Solanaceae which each has 2 species. The genus of Solanum consisted of 2 species and has the highest number of species. 14 species growing in all three areas. *Eucalyptus urophylla* was only found in steep and flat slope areas, while *Pinus merkusii* and *Elatostema lineolatum* Wight were only found in 1 slope area. In no one slope area were found all the species sampled, nor were there any species that were only present in steep slope (Table 1).

The growth form of the treelet species consisted of shrub, sapling, and fern with shrubs having the highest number of species, which was 13, followed by 3 saplings and 1 fern. The Fabaceae family has the growth form of shrubs and saplings, while all the Asteraceae and Solanaceae families were shrubs. The only family of species with a growth form of fern is Dennstaedtiaceae (Table 1).

Table 1. Treelet species on Mount Bawakaraeng.

No	Family	Species	Growth form	Slope area		
				Steep	Gentle	Flat
1	Anacardiaceae	Buchanania sessilifolia	sapling	1	1	1
2	Asteraceae	Ageratum conyzoides L.	shrub	1	1	1
3	Asteraceae	Chromolaena odorata (L.) King & H.E. Robins	shrub	1	1	1
4	Asteraceae	Gynura japonica	shrub	1	1	1
5	Dennstaedtiaceae	Pteridium aquilinum (L.) Kuhn	fern	1	1	1
6	Fabaceae	Acacia mearnsii	sapling	1	1	1
7	Fabaceae	Calopogonium mucunoides Desv.	shrub	1	1	1
8	Lamiaceae	Pogostemon cablin (Blanco) Benth.	shrub	1	1	1
9	Melastomataceae	Melastoma malabathricum L.	shrub	1	1	1
10	Myrtaceae	Eucalyptus urophylla	sapling	1	0	1
11	Phyllanthaceae	Breynia oblongifolia	shrub	1	1	1
12	Pinaceae	Pinus merkusii	sapling	0	1	0
13	Rosaceae	Rubus idaeus L.	shrub	1	1	1
14	Solanaceae	Solanum pseudocapsicum L.	shrub	1	1	1
15	Solanaceae	Solanum ptycantum Dunal	shrub	1	1	1
16	Urticaceae	Elatostema lineolatum Wight	shrub	0	0	1
17	Verbenaceae	Lantana camara L.	shrub	1	1	1

1: Present, 0: absent

Five species that have the highest IVI in all areas can be seen in Table 2. Six species fall into this category consisting of 3 growth forms, namely shrubs, saplings, and ferns. The shrub growth form consists of 4 species while sapling and fern each consist of 1 species. The ferns always occupy the first order of the five species with the highest IVI (FSHI). All of these dominant species belong to different families, and no family has more than one dominant species.

Pteridium aquilinum (L.) Kuhn, *Chromolaena odorata* (L.) King & H.E. Robins, *Breynia oblongifolia*, and *Pogostemon cablin* (Blanco) Benth are the species with the highest IVI in the order from 1 to 4 on each slope area. The first two species also have the highest frequency, density, and IVI in the order of 1 and 2 on each slope area. In each slope area, it appears that *P. aquilinum* always has an IVI greater than 50%, and *C. odorata* more than 40%, and these two species were found in all plots throughout the slope area. Another species, *Solanum pseudocapsicum* L., in flat slope, while in steep and flat slopes is *Acacia mearnsii*, which is also the only sapling growth form that includes in the FSHI. Both species have a low frequency of presence in the observation plot, which is below 40 plots.

Table 2. The five treelet species with the highest Important Value Index on Mount Bawakaraeng

Slope area	Species	frek	fre.rel	den	den.rel	IVI
steep	Pteridium aquilinum (L.) Kuhn	50	13.193	2499	43.161	56.353
steep	Chromolaena odorata (L.) King & H.E. Robins	48	12.665	1677	28.964	41.629
steep	Breynia oblongifolia	50	13.193	680	11.744	24.937
steep	Pogostemon cablin (Blanco) Benth.	48	12.665	389	6.718	19.383
steep	Acacia mearnsii	37	9.763	105	1.813	11.576
flat	Pteridium aquilinum (L.) Kuhn	50	15.625	2520	41.062	56.687
flat	Chromolaena odorata (L.) King & H.E. Robins	50	15.625	1789	29.151	44.776
flat	Pogostemon cablin (Blanco) Benth.	50	15.625	730	11.895	27.520
flat	Breynia oblongifolia	50	15.625	563	9.172	24.799
flat	Solanum pseudocapsicum L.	31	9.688	214	3.487	13.171
gentle	Pteridium aquilinum (L.) Kuhn	50	13.441	3010	44.632	58.073
gentle	Chromolaena odorata (L.) King & H.E. Robins	49	13.172	1985	29.433	42.606
gentle	Breynia oblongifolia	50	13.441	842	12.485	25.926
gentle	Pogostemon cablin (Blanco) Benth.	44	11.828	473	7.0136	18.842
gentle	Acacia mearnsii	32	8.602	82	1.2159	9.818

Frek: Frequency, Fre.rel: Relative frequency, den: Density, den.rel: Relative density, IVI: Important value index

Table 3. The treelet species diversity on Mount Bawakaraeng

slope	S	H’	D	SDI	E
gentle	16	2.147	0.164	0.836	0.774
steep	15	2.161	0.158	0.842	0.798
flat	15	2.033	0.173	0.827	0.751

Note: S: Number of species; H: Shannon-Wiener diversity index; D: Simpson's Dominance Index; SDI: Simpson's Diversity Index; E: Evenness Index of Pielou.

The number of treelet species ranges from 15-16. Treelet species were mostly found in the flat slope area, while in the other two slope areas the same number was found. The H' values range from 2,033-2,161. A higher number of species in an area does not result in a higher H' (Table 3). The H' was found to be the highest on steep slopes and the lowest on flat slopes. The SDI and E also show the same tendency as the H', where the higher the H', the higher SDI and E, otherwise, the D will decrease (Table 3).

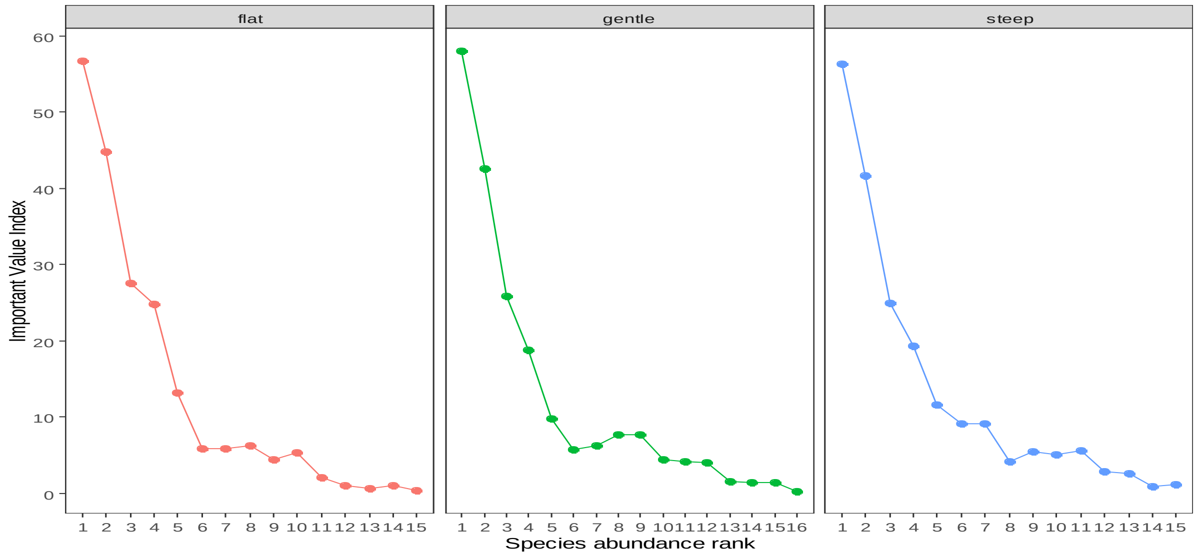

Figure 1. Rank abudance curve of treelet species on Mount Bawakaraeng.

The rank abundance curve of treelet species in the three slope areas shows that although the number of species in steep areas is less than in gentle areas, the distribution of individual species in both areas is relatively even. This can be observed from the change in ranking from one species to another, which is not too steep. In flat areas, apart from having fewer species than gentle areas, changes in the curve from species ranked 1 to 6 appear steeper and longer (Fig. 1).

Table 4. Five treelet species with the lowest Important Value Index on Mount bawakaraeng

Slope areas	species	frek	fre.rel	den	den.rel	IVI
Steep	Calopogonium mucunoides Desv.	3	0.792	7	0.121	0.912
Steep	Eucalyptus urophylla	4	1.055	5	0.086	1.142
Steep	Lantana camara L.	9	2.375	15	0.259	2.634
Steep	Buchanania sessilifolia	9	2.375	27	0.466	2.841
Steep	Ageratum conyzoides L.	12	3.166	58	1.002	4.168
Flat	Pinus merkusii	1	0.313	2	0.033	0.345
Flat	Buchanania sessilifolia	2	0.625	3	0.049	0.674
Flat	Melastoma malabathricum L.	3	0.938	3	0.049	0.986
Flat	Calopogonium mucunoides Desv.	3	0.938	4	0.065	1.003
Flat	Rubus idaeus L.	6	1.875	14	0.228	2.103
Gentle	Elatostema lineolatum Wight	1	0.269	1	0.015	0.284
Gentle	Eucalyptus urophylla	5	1.344	5	0.074	1.418
Gentle	Buchanania sessilifolia	5	1.344	7	0.104	1.448
Gentle	Calopogonium mucunoides Desv.	5	1.344	15	0.222	1.567
Gentle	Rubus idaeus L.	14	3.763	21	0.311	4.075

Frek: frequency, Fre.rel: Reletive Frequency, den: Density, den.rel: Relative density, IVI: Important value index

Nine species are included in the 5 species with the lowest IVI (FSLI). *Calopogonium mucunoides* Desv and *Buchanania sessilifolia* are species of this group that are found on all slope areas, and *Eucalyptus urophylla* and *Rubus idaeus* L., are found on 2 slope areas, while the other species are only found on 1 slope area. The species Elatostema lineolatum Wight have a density and frequency value of 1 and is only found on gentle slopes. Species *P. merkusii* is only found on flat slopes with a frequency of 1. On the flat and gentle slopes, *R. idaeus* is the species that has the highest IVI among species with FSLI. (Table 4).

3.2. Discussion

Asteraceae and Fabaceae are among the families with the highest number of species in The Gesha-Sayilem Afromontane Rainforest. This Asteraceae's ability is related to its pollination, seed dispersal, and adaptation to various environmental conditions [15]. Species with the Dennstaedtiacea family were found to have a higher number in the tropical mountain forests than in the tropical lowlands [16]. Ferns are very abundant and an important part of understory vegetation at various altitude [17].

The dominant of shrub growth forms shows that this growth form is more resistant to elevations and slopes than other growth forms. It is suspected that *P. aquilinum* can grow better than the others because of its ability to grow in extreme environments. Furthermore, it may be because this species reproduces with spores that can easily reach the new areas. The ability of *C. odorata* to grow well maybe attribute to its ability to form clumps that are firmly rooted in the soil. According to Cirimwami et al., [16], the altitude factor regulates several abiotic factors that affect the species distribution of the observed vegetation.

Both *P. aquilinum* and *C. odorata* were the dominant species in the study area. The dominant species are plants that can utilize the environment they occupy efficiently compared to other species in the same place [18]. This indicates that this species has high adaptability to the physical and chemical conditions of its environment so that this species has a better reproductive capacity than other species in the forest [19] Species that have a higher IVI will be more stable, in terms of species resistance and growth [20].

Sapling treelet growth forms that are difficult to develop are probably due to the dominant influence of *P. aquilinum*. This species will act as an ecological filter that affects the regeneration of other plants. Woody species are often slow to colonize fern-dominated forest landscapes, which indicates the influence of fern growth form on the growth of seeds and seedlings of other species [21]. The density of this growth form is lower at higher locations on Mount Qinglin, China, however the slope level does not affect [22]. The diverse species dispersal pattern can be explained through the ecophysiological and functional characteristics of the plant families [16].

The diversity of treelet vegetation appears to be influenced by slope factors. The high diversity and evenness in steep areas may be because this area is relatively safer from human disturbance compared to the other two areas. On the other side, the steep slope presents obstacles to plant growth, so they are found the least in this slope area. Addi et al., [15] said the same thing and added a location away from residential areas.

The value of H' for treelet vegetation at this location is higher than that of the tree regeneration on Mount Gede Pangrango, which is 0.852 [23]. The relatively high value of H' at our location may be due to the relatively high value of E. At Mount Gede Pangrango, an E value for tree regeneration vegetation was found as 0.388 [23]. The more even distribution of individuals in treelet species probably affects plant diversity on Mount Bawakaraeng.

The environmental and diversity values in a landscape vary due to biophysical and land use factors [24]. Population dynamics and tree dominance are affected by mortality, growth, and recruitment [25]. Many factors that affect the distribution of plants will produce spatial patterns in the composition of the community. The spatial structure of vegetation influenced by species distribution, biotic interactions, and gap dynamics tends to be more pronounced at relatively small spatial scales, whereas topographic and edaphic differences can produce structures at different scales depending on the geomorphological and geological layers [26].

The thing to note is, although the treelet vegetation diversity is higher in steep and gentle areas, there is a possibility that the stability of the ecosystem is easily disturbed due to the more sloping topography. In addition, the presence of a very dominant invasive species. *C. odorata* is an invasive species in Indonesia [27]. The influence of this invasive species is enormous on the ecosystem.

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Invasive species can damage native species and their ecosystems, thereby triggering the degradation and loss of habitat [25].

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