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The Understory Herbaceous Vegetation at Tropical Mountain Forest of Mount Bawakaraeng, South Sulawesi

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Abstract. The structure and diversity of understory herb vegetation were studied at Tropical Mountain Forest of Mount Bawakaraeng, South Sulawesi. The study was conducted at two areas. The first area was natural forest (NF) (Site 1). The second area (Site 2) was dominated by *Pteridium aquilinum* (L.) Kuhn ferns and *Lantana camara* shrubs (NP). The value of similarity index between the two sides was 22,15. The mean values of diversity parameters at Site 2 relatively higher compared to those in Site 1. The Dominance Diversity Curve for Site 2 shows curve that longer than that of Site 1. There are 12 species that are found at both sites. At Site 1, the highest mean value of Species Richness (S) and Shannon Wiener Diversity Index (H') are found in Rather Steep Slope (RSS) and the lowest are in Gentle Slope (GS). In the Site 2 area, the highest mean value of S, H', Simpson's Diversity Index (1-D) and Pielou's Evenness Index (E) are found in Flat Slope (FS) and the lowest is in RSS, whilst the highest value of Simpson's Dominance Index (D) is in RSS and followed in FS and finally in GS. At Site 1, species with highest important value index (IVI) are varying. The most dominant species at Site 2 is *Isachne globosa*. The Asteraceae family is the family that has species with highest IVI at Site 1. At Site 2, Poaceae family is the plan family that has the most species with the highest IVI at all slope level.

Keywords: Understory herbaceous vegetation, Dominance Diversity Curve, Tropical Mountain Forest, Mount Bawakaraeng, Important Value Index

1. Introduction

The tropical rain forest is a very valuable natural resource for humankind, ²² however, this ecosystem disappear rapidly at an alarming rate, and leave behind only separate and divided regions which also shows a high probability of disappearing [1]. Tropical mountainous regions are areas that are ecologically very important, because they play a role in the hydrological cycle process, by capturing water directly from clouds and storing it which is then released slowly in the dry season [2], controlling the regional air humidity, and also the reduction of erosion and sedimentation. In these forest landscapes are concentrated terrestrial biodiversity. Mountain forests also provide important timber and non-timber resources [3].

Life forms of plants that compose of vegetation are vary [4], and one of them is the understory herbaceous [5], which is an unseparated component of forest [6] and also an important component in a tropical rainforest [7]. Although the herbaceous layer possess high species richness [8] and it is widely

understood that the condition of forest structure and composition is largely determined by herbaceous strata, however, this strata is still rarely considered in studies of forest ecosystems [9].

The Island of Sulawesi is an important center of endemism that located in the Wallace area [10]. The tropical mountain of Sulawesi is an area that has a very high species diversity but very few researches have been done, and this area needs high priority to conservation [11]. Knowledge of the factors that contribute to the existence of vegetation composition at various altitudes in tropical rain forests will improve our understanding of patterns and processes that affect species distribution and diversity [12]. Information about the ecology of herbaceous vegetation on Mount Bawakaraeng is rare. The objective of this research is to know the structure and diversity of understory herbaceous vegetation at the tropical mountain forest of Mount Bawakaraeng, South Sulawesi.

2. Materials and methods

Herbaceous plants are all vascular plants with parts of the body above the surface of the ground which are not woody or ferns with maximum height when mature 50 cm from the ground.

2.1. Study Site

Mount Bawakaraeng is administratively included in the area of Gowa Regency. There is the upstream of Jeneberang river at west slope area of Mount Bawakaraeng which downstream its there is The Bili-Bili dam which is catchment area for Gowa Regency and Makassar City. Mount Bawakaraeng has an altitude that reaches to 2.830m asl and located about 75 km from Makassar City [13].

The study was conducted through the hiking path from Lembanna Village, Gowa Regency. The first area of research is natural forest (Site 1). Trees that were found in this forest include *Michelia montana* Blume, *Homalanthus populneus* (Geiseler) Pax, and *Kibara coriaceae* with their canopies covering the ground. The altitude of the Site 1 area has a range between 1515-1625 m asl. The substrate consists of soil. This area is located less than 1 km from residential and agricultural areas. The second area (Site 2) is dominated by *Pteridium aquilinum* (L.) Kuhn ferns and *Lantana camara* shrubs. Trees are so rare with their canopies are very open compared to the Site 1 area. The trees in this area including *Pinus merkusii*, *Eucalyptus urophylla*, and *Acacia mearnsii*. The Site 2 area is located at an altitude of 1655 - 1757 m asl. Substrate is in the form of soil with rock layers.

2.2. Vegetation sampling

The samplings at both sites were done at three slope levels as follows, an area with slope level 0-8% was a flat slope (FS), an area with slope level 8-15% was a gentle slope (GS), and an area with slope level 15-25% was a rather steep slope (FS). At site 1 and site 2, either in FS, GS, and RSS, we randomly put a 100 m transect with 5 replications. The transects were laying perpendicularly to the topography at the height direction. We made 10 quadrats with the size of 5 x 5 m at each transect and the distance between each quadrat was 5 m. The number of all transects was 30 that composed of 300 quadrats. The total sampling area was 2500 m².

2.3. Data Analysis

Species distribution on FS, GS, and RSS is determined based on the presence of species in all quadrats that are present on all of the slopes in both sites. We compute at each transect:

Important Value Index (IVI) = Relative Dominance + Relative Frequency [14]

Shannon Wiener Diversity Index (H') = $-\sum p_i \ln p_i$; where: $p_i = \frac{n_i}{N}$; n_i : IVI of i th species, N : Total IVI of all species.

We calculated diversity parameters as follow [15]:

Pielou's Evenness Index: $E = \frac{H'}{\ln S}$; where: H' : Shannon Wiener Diversity Index; S : number of species (Species richness).

Simpson's Dominance Index (D) = $\sum \left(\frac{n_i}{N}\right)^2$; where: n_i : IVI of i th species, N : Total IVI of all species.

Simpson's Diversity Index ($1-D$) = $1 - D$; where D : Simpson's Dominance Index .

Sorensen's ²⁵ index of similarity [14], $IS = (2c/A+B) \times 100$, was used for comparing species similarity in the sample blocks and the study forests, where c = sum of important values of species common to both stands and samples, and $A + B$ = total importance values of species in first sample and in the second sample or stand, respectively. All the analysis was conducted with Microsoft Excel and R Statistical Software.

3. Result

The number of species found in both sites is 43, where the number of species at Site 1 is 24 and at Site 2 is 31. The conspicuous difference between the two areas can be seen in the similarity index value, where the value is = 22.15 (values ranging from 0 to 100), indicating that the two areas are by structurally and composition different.

¹³ **Table 1.** The mean values of herbaceous vegetation ¹³ diversity parameters at Site 1 and Site 2 obtained from 15 transects.

Diversity Parameters*	Site 1		Site 2	
	mean	standart deviation	mean	standart deviation
S	16,3	2,53	17,4	2,95
H'	2,35	0,243	2,45	0,155
D	0,124	0,0353	0,109	0,0179
1-D	0,876	0,0353	0,891	0,0179
E	0.857	0.0549	0.863	0.0262

Note: Diversity Parameters: S: Species Richness (Number of Species); H: Shannon Wiener Diversity Index; D: Simpson's Dominance Index; 1-D: Simpson's Diversity Index; E: Pielou's Evenness Index

The mean values of diversity parameters at Site 2 relatively higher compared to those in Site 1, where there is only 1 diversity parameter has lower mean value, which is D. The higher value of S and E might be caused the value of H' is higher at Site 2 (Table 1).

The Dominance Diversity Curve for Site 2 shows curve that longer than that of Site 1 which indicated that species diversity is higher, however, there are dominance species at this curve, which is shown with the long distance from the first species to the second species (Figure 1). This supposedly makes the value of diversity between Site 2 and Site 1 relatively not very much difference.

There are 12 species that are both found at Site 1 and Site 2. These species are *Centella asiatica* (L.), *Cyperus brevifolia*, *Drymaria cordata* (L.) (Family: Caryophyllaceae), *Hydrocotyle sibthorpioides* Lamk, *Mikania scandens* (L.), *Myosotis arvensis* (L.), *Oplismenus burmanii*, *Oxalis corniculata* L., *Persicaria nepalensis*, *Taraxacum officinale* (L.), *Tridax procumbens* L., and *Viola odorata* L.

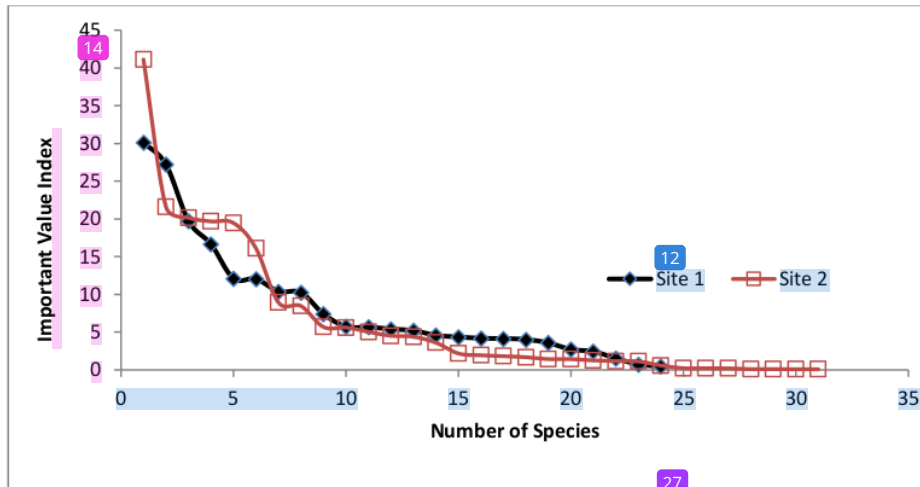


Figure 1. The Dominance-diversity curve of herbaceous vegetation at Site 1 and Site 2 on Mount Bawakaraeng

Table 2. The descriptive statistic of diversity parameters of herbaceous vegetation at Site 1 and Site 2 on Mount Bawakaraeng.

Diversity Parameters*	Site 1				Site 2			
	Flat Slope (FS)				Flat Slope (FS)			
	mean	std.dev*	max*	min*	mean	std.dev*	max*	min*
S	16.20	2.59	20.00	13.00	16.60	3.21	21.00	13.00
H'	2.35	0.21	2.63	2.15	2.41	0.13	2.63	2.32
D	0.13	0.03	0.16	0.09	0.11	0.01	0.12	0.09
1-D	0.87	0.03	0.91	0.84	0.89	0.01	0.91	0.88
E	0.85	0.03	0.88	0.80	0.87	0.03	0.90	0.84
	Gentle Slope (GS)				Gentle Slope (GS)			
S	15.00	3.08	17.00	10.00	19.40	3.05	23.00	15.00
H'	2.28	0.26	2.50	1.90	2.59	0.15	2.72	2.41
D	0.13	0.03	0.18	0.10	0.09	0.01	0.11	0.08
1-D	0.87	0.03	0.90	0.82	0.91	0.01	0.92	0.89
E	0.85	0.03	0.88	0.81	0.88	0.02	0.89	0.85
	Rather Steep Slope (RSS)				Rather Steep Slope (RSS)			
S	17.80	1.10	19.00	16.00	16.20	1.79	19.00	14.00
H'	2.53	0.23	2.77	2.15	2.35	0.10	2.48	2.22
D	0.11	0.04	0.18	0.07	0.12	0.02	0.15	0.10
1-D	0.89	0.04	0.93	0.82	0.88	0.02	0.90	0.85
E	0.88	0.06	0.94	0.77	0.85	0.03	0.87	0.80

Note: Diversity Parameters: S: Species Richness (Number of Species), H': Shannon Wiener Diversity Index; D: Simpson's Dominance Index; 1-D: Simpson's Diversity Index; E: Pielou's Evenness Index; std.dev: standard deviation; min: minimal value; max: maximum value.

At Site 1, the highest mean value of S and H' are found in RSS and the lowest are in GS. The highest mean value of 1-D and E are in RSS, and have the same values in FS and GS, while on the contrary the lowest value of D is found in RSS and have the same value of D in FS and GS. This indicating that at Site 1 the highest diversity of herbaceous vegetation is found at RSS and at Site 2 is found at GS. In the

Site 2 area, the highest mean value of S, H', D and E are found in FS, followed in GS and the lowest is in RSS, whilst the highest value of 1-D is in RSS and followed in FS and finally in GS .

The mean values of herbaceous vegetation diversity parameters vary among at site 1 as well as at site 2. The mean values of S, H', 1-D, and E at Site 1 in FS and GS is lower than at Site 2, while in RSS are higher at site 2 than at site 1. The mean values of D for FS and GS in Site 1 are higher than that of Site 2, while on the opposite, these values are lower in Site 1 than in Site 2. The highest mean values of S, H', and 1-D are found in FS at Site 2 and the lowest values are found in FS at Site 2 (Table 2).

Most of the herbaceous species spreading are found in GS followed by FS and the last at RSS either at Site 1 or Site 2 with the number of species consecutively as many as 17, 15 and 12. *Drymaria cordata* (L.) Willd. ex Schultes (fam: Caryophyllaceae) is species that mostly found in all slopes, suggesting that species have the highest adaptability at research area.

At Site 1, species with highest IVI are varying, which constitute of *Centella asiatica*, *Hydrocotyle sibthorpioides*, *Oplismenus burmanii*, *Diplocyclos palmatus*, *Carex maculata*, *Mikania scandens*. *M. scandens* is the species that has the highest IVI which is in 6 transects followed by *O. burmanii* at 3 transects. The most dominant species at Site 2 base on IVI is *Isachne globosa* which has grass growth form. This species has the highest IVI at all of the transects at Site 2 and also as species with the highest IVI at all the transects in FS, GS, and RSS. However, *I. globosa* has never found as species with the highest IVI at Site 1.

The Asteraceae family is the family that has species with highest IVI at Site 1 wherein GS this family has 3 of the 5 species, and also in RSS. The Poaceae family also has species with highest IVI in FS and RSS. At Site 2, Poaceae family is the plan family that has the most species with the highest IVI at all slope level (Table 3).

Table 3. Herbaceous species with highest IVI at Site 1 and Site 2 on Mount Bawakaraeng

Trans*	Slope*	Site 1			Site 2		
		Species	Family	IVI*	Species	Family	IVI*
1	FS	<i>Centella asiatica</i>	Apiaceae	30.923	<i>Isachne globosa</i>	Poaceae	42.992
2	FS	<i>Hydrocotyle sibthorpioides</i>	Araliaceae	45.327	<i>Isachne globosa</i>	Poaceae	43.69
3	FS	<i>Oplismenus burmanii</i>	Poaceae	44.204	<i>Isachne globosa</i>	Poaceae	33.367
4	FS	<i>Oplismenus burmanii</i>	Poaceae	58.911	<i>Isachne globosa</i>	Poaceae	37.329
5	FS	<i>Diplocyclos palmatus</i>	Cucurbitaceae	46.169	<i>Isachne globosa</i>	Poaceae	42.672
6	GS	<i>Carex maculata</i>	Cyperaceae	36.637	<i>Isachne globosa</i>	Poaceae	35.33
7	GS	<i>Drymaria cordata</i>	Caryophyllaceae	56.617	<i>Isachne globosa</i>	Poaceae	44.335
8	GS	<i>Mikania scandens</i>	Asteraceae	39.808	<i>Isachne globosa</i>	Poaceae	43.099
9	GS	<i>Mikania scandens</i>	Asteraceae	40.391	<i>Isachne globosa</i>	Poaceae	35.851
10	GS	<i>Mikania scandens</i>	Asteraceae	47.309	<i>Isachne globosa</i>	Poaceae	35.144
11	RSS	<i>Centella asiatica</i>	Apiaceae	23.828	<i>Isachne globosa</i>	Poaceae	46.486
12	RSS	<i>Mikania scandens</i>	Asteraceae	28.81	<i>Isachne globosa</i>	Poaceae	47.662
13	RSS	<i>Oplismenus burmanii</i>	Poaceae	38.165	<i>Isachne globosa</i>	Poaceae	41.265
14	RSS	<i>Mikania scandens</i>	Asteraceae	38.255	<i>Isachne globosa</i>	Poaceae	59.83
15	RSS	<i>Mikania scandens</i>	Asteraceae	72.223	<i>Isachne globosa</i>	Poaceae	44.733

Note: Trans: Transect; Slope: FS: Flat slope; GS: Gentle slope; RSS: Rather steep slope; IVI: Important Value Index

4. Discussion

The very different species compositions between both sites are thought to cause the IS to be very low. Herbaceous vegetation in Site 2 which is relatively richer and diverse than in the Site 1 allegedly because of the very open canopy in the Site 2. At an area with tree's canopy physiognomy is relatively more open, there will be more herbaceous, grass, and climbers [16]. It is difficult for the herbaceous plant to grow under the close canopy because there is little sunlight reach the forest floor [8].

At a tropical rainforest, the environmental factors can give an impact to the dominant species [17], where the distribution and abundance of plant species are influenced by variability of habitat [18], and one of the important factors that have impacts on understory vegetation are the compositions of overstory [19].

Species *I. globosa* which is very dominant at Site 2 possibly because of its ability to grow at open area and at high altitude. This species has high adaptation at various environmental conditions, where it can be found at many places such as swamp at lowland area [20] to the high altitude area [21]. The growth form of *M. scandens* which climb at others plant around it and cover it [22] possibility make the other herbaceous plants which grow under its cover cannot grow well make this species become dominance.

Many species from Poaceae's family have the highest IVI at Site 1 probably because this area is more open than that of Site 2. [23] showed that grasses were decreasing from open area to the area covered by vegetation canopy. The same things were found at Lore Lindu which is a national park in the central of Sulawesi, where at the location that managed with the agroforestry system, it was found that Poaceae was the family of dominant herbaceous plants [24]. Plants from Poaceae Family generally like an open area, and they are the main constituent of grass plants around the world [23].

The humid and moist climate of Mount Bawakaraeng probably made *D. cordata* could growth at every place of this research location. One of the dominant plants at herbaceous strata found in the home garden of south Meghalaya, India at high altitude is *D. cordata* [25]. This is the plant that like the moist areas and growth in Asia [26].

The value of the H' generally high at the tropical rainforest [27] but competition with trees at Site 1 and with ferns and shrubs at Site 2 probably make the H' value of the herbaceous vegetation was relatively low in our area. Based on [5] classification, this research area is included in the tropical upper mountain rainforest with a range of altitude 1500-3000 m asl. The environment's physic factor of mountain affects the plant's ability to grow and affect the relative importance of plants. Many environmental changes that accompanying along with the increase of altitude in the tropical mountainous area, among them are differences in rainfall, air temperature, and openness which have an impact on plant distribution and on the seasonal patterns of individual plants [28]. However, it is difficult to determine one factor that can explain the changes in the structure of vegetation in the tropical mountain [29].

The understory vegetation on Mount Bawakaraeng needs to be preserved because it is part of the tropical mountain forest ecosystem in this area. This forest ecosystem area has a production and protection function which is important for the area around and below the mountain. The forest area of Mount Bawakaraeng functions as a buffer zone to regulate the water management, prevent flooding, and control erosion [30].

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