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Vegetation and Species Diversity in a Mountain Region of Sipiso-piso, North Sumatra

Ariasta Bereona Tarigan[1], Delvian Delvian[2*], T Alief Aththorick[3]
[1]*Master Program in Natural Resources and Environmental Management, School of Graduate Studies, Universitas Sumatera Utara, Indonesia*
[2]*Department of Forestry, Faculty of Forestry, Universitas Sumatera Utara, Indonesia*
[3]*Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Indonesia*

Abstract

The mountain region of Sipiso-piso is located adjacent to the water catchment area in Lake Toba. The region is known to have a notable uniqueness in plant species diversity from the valley to the ridge of the mountain which is only inhabited by shrubs and less stands. However, near the top of the mountain, it was characterized by a dense forest community and diverse forest vegetation with unknown information. The purpose of this study was to determine the vegetation and species diversity in the Sipiso-piso mountain region. Vegetation observation in the field used a combination method between the line transect and quadratic plots. The study documented a total of 40 plant species, with 20 families and 23 species in the forest region; 9 families and 19 species in shrubland while 2 species were recorded in both plant communities. Based on the importance value index (IVI), the forest community was evenly dominated by certain species that in shrubland. Based on the diversity index, the diversity in the forest community was classified as moderately abundant for each structure, while the shrub community was classified as moderately abundant only in the seedling but lower in the sapling, pole and tree. The evenness in the studied region was categorized as low with a distinct of species similarity among forest and shrub community.

Keywords
community; forest; shrubland; vegetation; mount Sipiso-piso

I. Introduction

Any natural or artificial ecosystem always consists of two main components, namely biotic and abiotic components. Vegetation or plant community is one of the biotic components which occupy a wide range of habitats i.e forests, grasslands, shrublands, etc. The vegetation structure and composition in an area is influenced by other co-interacting ecosystem components, yet the tropical condition of vegetation is actually an output of various environmental factors and may undergo drastically changes due to anthropogenic activities (S.M Sundarapandian, 2000).

Montane forests in general have high vegetation diversity, due to a higher rainfall in highland areas than lowland areas which sufficiently supply the water sources for vegetation. However, in certain altitudes in the montane forest, many ecological factors may affect the surrounding vegetation, mainly the tree species richness or stand structures. Steenis (Setiawan, 2016) suggested that elevational gradients is an ecological pattern in which the higher the location, the lower the species richness especially from tree species. In contrary to

the mountain region of Sipiso-piso, the alpine region was still documented for a considerable diverse plant species which form a dense forest community, while other region of the mountain are inhabited by shrubs (shrubland).

Forest vegetation analysis is meant to assess the species composition and structure of a forest region (Fajri, 2012). Studies on vegetation generally use parameters such as density (number of individuals per unit area), frequency (proportion of the number of samples), dominance (proportion of the basal area occupied by a species compared to the total area) and importance value index (IVI) generated from the sum of relative density, relative frequency and relative dominance. Together, the parameters will show the detailed reference of an ecosystem from the view of an ecological survey, which may be used for further forest management and risk analysis. Based on our understanding, the baseline data for the plant species diversity and vegetation in the mountain region of Sipiso-piso is still limited and worth for investigation. The aim of this study was to inventory the plant species and differentiate between shrubs and forest community around Mountain Region of Sipiso-piso.

II. Research Method

This study was conducted from January to February 2021 in the montane forest region of Sipiso-piso, Merek District, North Sumatra, at 1400–1990 m asl. The study region was distinguishable by the presence of ecotones namely the montane forest and montane shrublands. The survey was initiated from the random points in the valley until the alpine region using a combination method of line transect and quadratic plots with gradient plots for each group i.e tree (20×20 m), pole (10×10 m), sapling or shrubs (5×5 m), and seedling (2×2 m). A total of 30 sampling plots was placed in the forest region and 45 plots in the shrubland community. Ecological parameters was measured such as importance value index (IVI) obtained from the sum of relative density (RD), relative frequency (RF), and relative dominance (RD) for tree and pole class and (-) RD for sapling and seedling class. Species diversity of each class was measured using the following equation (E. Odum, 1993):

$$Shannon's\ diversity\ index\ (H') = -\sum_{i=1}^{s} pi \ln pi \qquad (1)$$

Where, p is the proportion of (n/N) of individuals of a certain plant species (n) divided by the total number of individuals (N). ln is a natural logarithmic value, Σ is the sum of calculations while s is the number of species. The level of species diversity is classified as high (H'>3), moderate (1≤H'≤3), and low (H'<1) [5]. Similarity among compared plant community is determined using the following equation by Sørensen's (M. Ferianita, 2006):

$$Similarity\ index\ (s) = \frac{2c}{a+b} x100\% \qquad (2)$$

Where, c is the number of similar species, a or b is the number of species from each location. The level of similarity is classified as highly similar (s>75%), moderately similar (50%≤s≤75%), and distinct (s<50) (Prijanto, 2017). Species evenness is a measure of the relative abundance of the different species in an area. The index was determined using the following equation (E. Odum, 19930:

$$E = \frac{H'}{H_{max}} \qquad (3)$$

Where, H' is the Shannon's diversity index of a study site, H_{max} is the natural logarithmic value of S (species richness).

III. Discussion

3.1 Vegetation Composition in the Sipiso-piso Montane Forest

Vegetation analysis was implemented from a total of 30 plots in the forest community and 45 plots in shrubland communities. The structures recorded in this study were trees, poles, saplings, and seedlings. Based on the results, The study obtained total of 40 plant species, with 20 families and 23 species in the forest region; 9 families and 19 species in shrubland while 2 species (*Eupatorium inulifolium* and *Eragrostis patula*) were recorded in both plant communities (Table 1).

Table 1. Number of Individuals per Structure in the Forest and Shrubland Community

No	Class	Forest		Shrubland	
		S	*N*	*S*	*N*
1	Seedling	15	803	17	5026
2	Sapling	13	276	5	741
3	Pole	11	207	1	6
4	Tree	9	255	2	11
	Total	48	1541	25	5784

S = species richness, *N* = number of individuals.

In both communities, the number of plant species were higher in the seedling class, followed by saplings, poles, and trees. With an exception to the results in the shrubland, the number of species and individuals in pole structure was lesser than the trees. A large variation of the number of inidividuals was recorded from the shrubland communities reaching >5000 individuals compared to the forest community.

Based on the results of the vegetation analysis in the field, it was found that species diversity in the forest community was higher than that in the shrubland community. The floristic diversity was documented higher in the forest community than shrub community due to the ecosystem stability that provided optimal growth for each species. Tropical rain forest harbors a high biodiversity at the species level which support the complex community of each organism (Prijanto, 2017).

3.2 Importance Value Index (IVI) of Vegetation in the Sipiso-piso Montane Forest

In general, a plant species with high IVI may indicate the species adaptability and resistance towards biotic competition and enviromntal conditions with a progressive reproductive ouputs in an area (T.D. Irwan, 2009). The composition and dominance of plant species or the ecological position of a species in the community can be interpreted from the IVIs. The IVI for the forest community in the montane forest is presented in Table 2.

Table 2. Importance Value index (IVI) of each Class in the Forest Community

No	Species	Seedling	Sapling	Pole	Tree
1	*Homalanthus populneus*	-	1.9746	2.3682	-
2	*Cinnamomum parthenoxylon*	1.6092	-	-	-
3	*Ficus benjamina*	-	-	-	10.7335
4	*Celtis tetrandra*	1.3601	3.5869	23.4403	22.7369
5	*Amorphophallus variabilis*	1.3601	-	-	-
6	*Quercus gemelliflora*	6.1879	14.5833	64.7956	182.4276
7	*Begonia* sp.	2.7203	-	-	-
8	*Prunus Acuminata*	-	3.9492	9.702	11.0545

9	*Macropanax* sp.	-	-	3.1734	-
10	*Urtica* sp.	6.1879	6.2862	-	-
11	*Eupatorium inulifolium*	1.4847	-	-	-
12	*Spatholobus ferrugineus*	-	6.8115	-	-
13	*Garsinia dioca*	14.6077	31.4311	69.3773	8.5845
14	*Madhuca cuneata*	-	6.6485	18.4163	24.5782
15	*Tectaria crenata*	36.026	-	-	-
16	*Pinanga javanica*	95.1501	53.2427	-	-
17	*Ficus grossularioides*	-	30.7065	89.5706	14.9636
18	*Alstonia pneumatophora*	1.8583	1.9746	8.7338	9.7782
19	*Eragrostis patula*	3.6017	-	-	-
20	*Dacrydium elatum*	-	-	-	15.1026
21	*Payena Leerii*	2.1073	-	2.3695	-
22	*Clidemia hirta*	8.6591	15.2717	-	-
23	*Dicksonia blumei*	17.079	23.5326	8.0525	-
	Total	200	200	300	300

The highest IVI recorded for the seedling class was *Pinanga javanica* (95.1501%) while the lowest were *Celtis tetrarandra* (1.3601%) and *Amorphophallus variabilis* (1.3601%). The highest IVI for the sapling class was similar to the seedling class namely *Pinanga javanica* (53.2427%) while the lowest were *Homalanthus populneus* (1.9746%) and *Alstonia pneumatophora* (1.9746%). The highest IVI for the pole class was *Ficus grossularioides* (89.571%) while the lowest was *Homalanthus populneus* (2.3682%). The highest IVI for the tree class was *Quercus gemelliflora* (182.43%) while the lowest was *Garsinia dioca* (8.5845%).

Based on the IVI in the forest stucture, the highest IVI indicates the dominant vegetation in an area. The class with the highest IVI is obtained by different species. In the seedling class or understorey, *Pinanga javanica* dominated the forest community because this species is known as a shade-tolerant species. In contrast to other vegetation, light penetration is the limiting factor in a more stable forest community. Forest is an ecosystem unit in the form of an expanse of land with biological resources which is dominated by the selection and environmental fauna community that cannot be separated from one another (Hafik, 2021). According to Breiman in Utomo (2021), "Random Forest is a combination of tree predictors such that each tree depends on the values of a random vector sampled independently and with the same distribution for all trees in the forest". The current condition will lead to unstable ecosystem when disrupted by environmental pressure, leading to the existence of certain surviving species (Nugroho, 2015).

Quercus gemelliflora was documented as the highest IVI species in the tree class. The species present in all class although recorded for the lower IVI in the seedling, sapling, and pole classes. The result showed that this species competed and adapted well with other plant species in the community. Bismak and Heriyanto (2011) stated that dominant species are species that can utilize the environment more efficiently than other species in the ecological site. Meanwhile, The IVI for the forest community in the montane forest is presented in Table 3.

Table 3. Importance Value Index (IVI) of each Class in the Shrubland Community

No	Species	Seedling	Sapling	Pole	Tree
1	*Imperata cylindrica*	55.0587	-	-	-
2	*Spathoglottis plicata*	1.0809	-	-	-
3	*Artemisia vulgaris*	1.1207	-	-	-

4	*Anaphalis longifolia*	0.5006	-	-	-
5	*Pteris tripartita*	28.5858	-	-	-
6	*Uraria lagopodioides*	3.9622	-	-	-
7	*Calliandra calothyrsus*	1.3594	16.0593	300	117.0704
8	*Cassia* sp.	-	5.1282	-	-
9	*Bidens biternata*	2.6227	-	-	-
10	*Rubus moluccanus*	4.0617	-	-	-
11	*Eupatorium inulifolium*	16.93	87.3144	-	-
12	*Clibadium surinamense*	1.6611	1.5519	-	-
13	*Leersia hexandra*	27.0451	-	-	-
14	*Pinus merkusii*	-	-	-	182.9296
15	*Eragrostis patula*	2.5102	-	-	-
16	*Themeda Gigantea*	28.4266	-	-	-
17	*Melastoma malabathricum*	19.921	89.1363	-	-
18	*Sida rhombifolia*	0.5603	-	-	-
19	*Elephantopus scaber*	4.5924	-	-	-
	Total	200	200	300	300

The highest IVI recorded for the seedling class was *Imperata cylindrica* (50.9729%) while the lowest was *Anaphalis longifolia* (1.3601%). The highest IVI for the sapling class was similar to the seedling class namely *Melastoma malabathricum* (89.1363%) while the lowest was *Clibadium surinamense* (1.5519%). The highest IVI for the pole class was only recoded for one species namely *Calliandra calothyrsus* (300%). The highest IVI for the tree class was *Pinus merkusii* (182.9296%) while the lowest was *Calliandra calothyrsus* (117.0704%).

The highest IVI in the seedling class were *Imperata cylindrica* and *Pteris tripartita* from Poaceae and Asteraceae families, respectively. In the shrubland community, these families are dominant due to their dense and rapid growth characteristics which suppress other species to grow properly. The dominance of *Imperata cylindrica* and *Pteris tripartite* at the understorey level (shrubs) holds an important feature to the habitat and plant community. Understorey plants may maintain the soil aggregation and prevent soil erosion by rainfall and surface runoff (Hilwan, 2013). However, the rapid growth of *I. cylindrica* may hinder the growth and development of other plant species (Susilo, 2018).

Plant species in the Poaceae family is known to produce allelopathic compounds where these compounds will hinder the growth of other competing species. Samingan (2013) stated that the toxicity of allelopathic compounds was influnced by the producing species and climates. The exposure to allelopathic compounds by sensitive plant species will reduce the nitrogen fixation capability and nutrient assimilation leading to the delayed or stunted growth then reduced biomass for growth and development.

3.3 Diversity Index, Evenness Index, and Species Similarity among Vegetation in the Sipiso-piso Montane Forest

The ecological parameters for the vegetation analysis in the Sipiso-piso montane forest are presented in Table 4. The highest Shannon's diversity index in the forest community was recored from the seedling class (1.9456) while the lowest from the tree class (1.2249). In the shrubland community, the highest Shannon's diversity index was recorded in the seedling class (1.724) while the lowest was from the pole class (0).

Table 4. Ecological Index each Class among Plant Community

	Forest		Shrubland		*s*
	H	E	*H*	E	
Seedling	1.3017	0.1946	1.724	0.2022	12,5%
Sapling	1.9456	0.3461	0.8535	0.1291	0%
Pole	1.7834	0.3344	0	0	0%
Tree	1.2249	0.221	0.689	0.2873	0%

H = Diversity index, E = evenness index, *s* = species similarity

Based on the diversity index, the diversity of the forest community in the Sipiso-piso montane forest was classified as moderate ($1 \leq H' \leq 3$) for each class. In contrast to the shrubland community, the only highest diversity was recorded in the seedling class while other classes fell within the low diversity level. The results then again support our finding that the forest community is more stable than the shrubland community (Prijanto, 2017).

Based on the evenness index, the highest value was recorded from the sapling class (0.3461) while the lowest from the seedling class (0.1946) in the forest community. Meanwhile, in the shrubland community, the highest value was recorded from the tree class (0.2873), while the lowest from the pole class (0). Then, the evenness of species in both forest and shrubland communities are classified as low which indicated the presence of some dominating species.

The diversity index in the shrub community was lower than other forest community, as due to the location and topography of Mount Sipiso-piso which provide the optimum sunlight exposure to the tree and pole community. The need for sunlight in the photosynthetic process is influenced by altitude and land slope. The level of diversity and evenness of plants in a place varies depending on the availability of nutrients and the application of different nutrients (Resti, 2017).

In the forest community, the evenness index was documented the lowest for seedling class which may due to the inadequate sunlight that supported their growth. In a forest with a stable ecosystem, trees with dense canopy will hinder the growth of some understory plant species however some shade-tolerant species will thrive in the habitat and grow optimally. Herbaceous plants are easy to grow and flourish in environments where they are not shaded and receive adequate sunshine (Muslich, 2017).

Based on the species composition among plant community, it can be seen that the species are completely different as indicated from the similarity index (*s*) <50% [6]. The degree of difference was obvious in the sapling, pole, and tree classes. The results then again supported the ecotone theory that following the elevation of an ecosystem, especially in the montane forest, the greater difference may be observed in terms of plant species richness and the number of individuals. Competition increases the survivability of a species to thrive in the environment, hence the robust species will survive and suppress the growth of inferior species, causing the lesser species to become less adaptable and result in low reproduction rates and density (Kunarso, 2013). Because the similarity index value in the two communities is low, this indicates that different species are dominant at every level in each community, preventing other species from growing and developing properly.

Each community is dominated by very different species based on the ecological index in the forest community and shrub community, so they have their own characteristics where the forest (climax) community is dominated by tree species and the shrub community is dominated by shrub species, this is due to the fact that each species utilize proper resources from the environment. If a species is able to place the majority of the available resources in comparison to other species, it will dominate the community (Saharjo, 2011).

IV. Conclusion

The study reported that the plant community in the forest site of Sipiso-piso Montane Forest was more diverse than the shrubland site based on the Shannon's diversity index. The IVI from the forest community showed that the dominance was evenly distributed than the shrubland community. The species diversity was considered as moderate to low in both communities. Based on the evenness index, there was the presences of some dominating species in both communities. The species composition was highly distinctive between the forest and shrubland community.

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