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Composition, diversity and association of pioneer plants on post-landslide areas in Palopo, South Sulawesi, Indonesia

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Abstract. *Nuryanti DM, Liana, Witno, Soma AS, Asrianny, Ayu SM, Awalia IM. 2023. Composition, diversity and association of pioneer plants on post-landslide areas in Palopo, South Sulawesi, Indonesia. Biodiversitas 24: 1862-1870.* The existence of pioneer plants is very important because of their role in initiating vegetation succession as well as regulators of the physical properties of a disturbed environment. Landslide is one type of environmental disturbance that causes vegetation loss, either partially or entirely. In many cases, several pioneer plants start to appear following a landslide. This study aims to assess the vegetation composition, diversity and interspecific association of plant species in post-landslide areas in Palopo City, South Sulawesi, Indonesia. We employed sampling plot methods with a size of 5 x 5 m^2 in 12 landslide sites with varying landslide characteristics during the period of 2021 to 2022. Vegetation composition was analyzed using Important Value Index and an interspecies association was analyzed using Chi-square analysis. The results of the study found that the pioneer plants on post-landslides consisted of a total of 112 species which can be classified into eight habitus, namely bamboo, herbaceous, vines, ferns, palms, shrubs, trees and bushes. Herbaceous plants had the largest number of species, with 53 species. Species with the highest IVI for tree was *Trema orientalis* (L.) Blume (79.86%), shrub was *Homalanthus populifolius* Graham (61.49%), bush was unidentified species (53.41%), fern was *Nephrolepis cordifolia* (L.) C.Presl (6.99%), vines was *Merremia peltata* (L.) Merr. (57.92%), herbaceous was *Miconia papillosa* (Desr.) Naudin (22.65%), while palm was *Pandanus tectorius* Parkinson ex Du Roi and bamboo was *Bambusa balcoa* Roxb. each had IVI of 200% because only one species was found. The results of the diversity analysis showed that trees, shrubs, bushes, ferns, vines and herbs had a moderate level of species diversity, while palm and bamboo had a low diversity level. Similarly, trees, shrubs, bushes, ferns, and vines had high evenness levels, while bamboo and palm had low evenness index. There were three associations between dominant plants, namely *B. balcoa* with *T. orientalis*, *B. balcoa* with *H. populifolius*, and *B. balcoa* with *Macroptilium atropurpureum* (DC.) Urb. The findings of this study suggest that in just one year, pioneer plants rapidly colonized post-landslide areas which provided vegetation cover for the open landscape.

Keywords: Diversity, Important Value Index, landslides, pioneer plant, succession

INTRODUCTION

Landslide is the movement of slope-forming materials on the land surface in the form of rock, soil or mixed materials, moving down or out which is influenced by gravitational forces (Iverson et al. 1997; Hungr et al. 2013). Landslides involve the flowing, shifting, falling or spreading of geomorphic materials and vegetation, and many landslides show different combinations of types of movement, at the same time or during a landslide period (Gariano and Guzzetti 2016). The phenomenon of landslides usually arises due to natural causes such as earthquakes (Papathanassiou et al. 2013). In addition, landslides can also occur due to high rainfall and the unwise use of land on slopes (Hayati et al. 2013; Lai et al. 2013; Sabatakakis et al. 2013).

Landslide might cause damage to the natural environment or buildings, resulting in landscape change and even the loss of life. Landslide often poses a more complex threat to humans, both in time and space by inundating upstream and flooding downstream (Fan et al. 2020). Landslide also might cause clearing and damage to the aboveground vegetation, often leading to forest and tree cover loss. Landslide generally removes all existing vegetation along with the topsoil including the seeds and nutrients contained in the soil (Pang et al. 2018). When occurs, landslide causes the landscape to be an open area with no or limited vegetation remaining. After some period, this opening land will experience vegetation recovery which is initially started with the emergence of several types of plants called pioneer plants.

Pioneer plants are the plant species that grow and dominate in the initial process of succession in a disturbed area. Vegetation recovery in an open area following landslides occurs through a succession process. Vegetation succession begins with the presence of plants that can adapt to a very nutrient-deficient environment characterized by changes in plant composition, biomass and soil nutritional properties (Cline and Zak 2016; Wang et al. 2019). The process of vegetation succession will occur gradually and over a long time which is indicated by the changes in species structure and composition. During this process, the

sequence of plant communities with different species compositions will follow one another in a certain space (Eichel 2019). Generally, the types of vegetation that grow in the post-landslide area are pioneer plants, such as moss, because they are the first plant species to grow in disturbed ecosystems and pave the way for the growth of other plants. These pioneer species are the most common in primary succession because they have the ability to break down minerals to form soils and then build up organic matter. As soil forms, other species, such as grasses, start moving in.

In vegetation communities, including in post-landslide areas, interspecific associations among plant species will provide information on the function and role of each species in community structure and composition, as well as the mechanism of vegetation establishment and succession. Interspecific associations will reveal how a species adapts with habitat conditions and how the species interacts with other species through mutualism and competition in certain habitats (Su et al. 2015). The interspecific association is seen as an important population attribute regarding the relationship between different species in a habitat to understand plant communities and succession (Zhang 2014; Xu and Cai 2016). In the context of post-landslide areas, it is interesting to see how pioneer plants recolonize the disturbed areas and how their role in facilitating vegetation succession and their interaction with other plant species. This can be revealed through vegetation analysis to see the species richness, abundance, dominance and floristic composition of each species. Pioneer species in post-landslide areas might differ across areas that might be affected by biotic and abiotic factors.

There were several events of landslide in Battang Village, Palopo City, South Sulawesi Province which provide an excellent case study of vegetation succession in post-landslide areas. This study aimed to investigate the composition and diversity of pioneer plants and their interspecific association following landslides in Battang Village. This research is interesting and important to do because currently landslides often occur in Battang and West Battang Villages, Palopo City, and after landslides that occur at several locations, each landslide site started to be colonized by plants through succession. In a period of approximately one year, it has undergone a succession process and has been overgrown with various types of plants, which are dominated by herbaceous habitus. So that the succession after the landslide in Palopo requires information about the plant species data, yet there is no identification of the types and associations of pioneer plants that grow in the post-landslide area.

MATERIALS AND METHODS

Study period and area

This research was conducted in July-August 2022 in Battang and West Battang Villages, West Wara Sub-district, Palopo City, South Sulawesi, Indonesia (Figure 1). The Battang and West Battang are located at an altitude of 150-500 meters above sea level, at a hilly landscape with varying topographies. The slope conditions are quite varied, but dominated by steep slopes, although in some places there is flat and sloping land. Based on BMKG (Meteorological, Climatological, and Geophysical Agency) data, the temperature is 28.5ºC, the humidity is 76% and the average rainfall is 105 mm³. Soil characteristics include dominant soil texture from clay to clayey loam, generally having a fine texture or fraction, soil permeability is in the low to moderate category (0.5-5.88 cm/hour), the percentage of soil organic matter is very low and medium (<0.60%-1.66%), plasticity at the level of plastic, very plastic and somewhat plastic and granular soil structure (Witno et al. 2022).

Based on the data of Forest Management Unit (KPH) of Latimojong for November 2021, there were 19 points of landslides, where these landslides occurred in areas with protected status and Area for Other Uses (APL) status. All landslide points were on cliffs adjacent to the Trans Palopo-Toraja main road, so when a landslide occurs, it might close Palopo-Toraja transportation network.

Data collection procedure

Data were collected using the purposive sampling method. Among the 19 points of landslides which could be accessed by researchers, six observation plots were established each in protected areas and APL. Vegetation data were collected by establishing a quadrat with size 5 m x 5 m at each post-slide location that had been overgrown with pioneer vegetation.

Characteristics of research plots

The landscape condition after landslide of each sampling location is presented in Figure 2. Landslides in Battang and Battang Barat villages occurred on 10 November 2021, but landslides occurred again at plots 2, 9 and 10 at the same point around May 2022. The landslide area is located on a hilly landscape with many steep slopes. Also, areas at this altitude usually consist of weathered rocks which are prone to landslides.

The characteristics of each landslide location that was used as the observation plot is presented in Figure 3. The widest landslide in the APL area occurred in Plot 4 with a width of 39 meters (Figure 2D) and landslides in this plot occur continuously when it rains. Meanwhile, in protected areas, Plot 12 (Figure 2L) had the highest landslide width with 75 meters. The condition of the vegetation prior to the landslide was almost the same as Plot 4 which consisted of cloves, durian, vanilla and pepper, although it was located in a protected area, the community had changed the function of forest land into agriculture illegally. This shows the importance of trees vegetation, especially in sloping areas, because the roots of trees have an important role in stabilizing slopes (Viet et al. 2016) and are considered the main contributors to soil strength (Kim et al. 2013). The presence of trees and forests has the greatest beneficial effect of preventing or reducing shallow landslides (Forbes and Broadhead 2013).

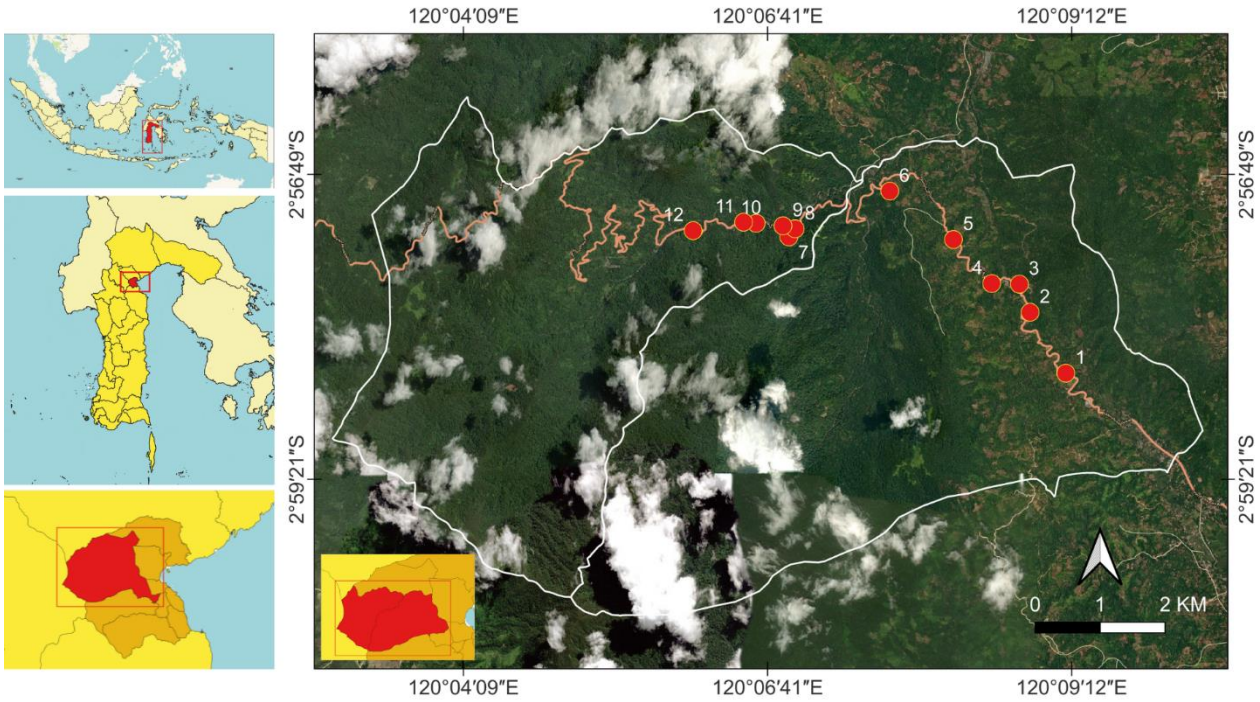

Figure 1. Map of the study area in Battang and West Battang Villages, West Wara Sub-district, Palopo City, South Sulawesi, Indonesia

Figure 2. Map of landscape condition of each observation plot: A: Plot 1; B: Plot 2; C: Plot 3; D: Plot 4; E: Plot 5; F: Plot 6; G: Plot 7; H: Plot 8; I: Plot 9; J: Plot 10; K: Plot 11; L: Plot 12

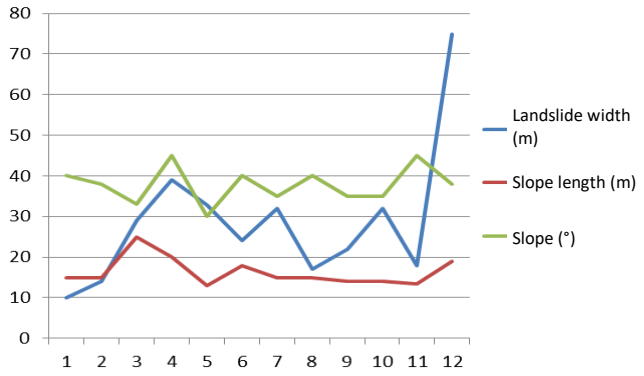

Figure 3. Landslide location characteristics in Palopo City, South Sulawesi Province, Indonesia

The length of the slope varied from 13-25 meters. In APL the longest extent of landslide occurred in Plot 3 (Figure 2C) with a length of 25 meters in which at the upper end of the landslide there are durian gardens and community rambutan. While in a protected area the longest extent of landslide occurred on Plot 12 with a length of 19 meters in which the remaining surrounding vegetation were clove, durian, vanilla and pepper plants. Generally, the landslides started from the end of the slope to the main road except on Plot 6 as they occurred within the community's clove gardens but the impact formed a small ditch that reached the end of the main road.

The slope ranged from 33º-45º (steep to very steep slope) in which Plot 4 and Plot 11 had a very steep slope. Plot 4 had landslides every rainy season when heavy rain happened which was coupled with a land cover of only one stratification and soil type. Plot 11, which is located in a protected area, was also prone to landslide since there was land clearing for agriculture and is supported by soil and rock types. Steep (35º-45º) to very steep (45º-65º) slopes have a susceptibility to landslides (Amukti et al. 2017). Loess plateau landslides occur mainly on sunken slopes that have an inclination angle of 20º-35º (Zhuang et al. 2017).

Generally, the location of pioneer plants in the post-landslide areas is at the bottom or middle of the landslide (Figure 2B, D, F, G, H, I, G, K, L). This is possible because when a landslide happens, the soil is shifted and gathered in the middle and the end of the landslide area, and the seeds of the plant contained in the soil will eventually grow into a new plant. In line with the research, Mi et al. (2019) say that in soil residues, there is a collection of seeds that become the basis for natural vegetation recovery or become the basis for species regeneration and vegetation succession.

Data analysis

Vegetation composition

Vegetation composition was measured as Important Value Index (IVI) which is the combination Relative Density (RD) and Relative Frequency (RF). The calculation of IVI, RD and RF followed Fachrul (2007) as described below:

$$\text{Density (D): } K = \frac{\textit{Number individuals of a species}}{\textit{Plot Area}}$$

$$\text{Relative Density (DR): } DR = \frac{\textit{Density of a species}}{\textit{Density of all species}} \times 100\%$$

$$\text{Frequency: } F = \frac{\textit{Number of Plot Found a species}}{\textit{Number of all plots}}$$

$$\text{Relative Frequency: } FR = \frac{\textit{Frequency of a species}}{\textit{Frequency of all species}} \times 100\%$$

$$IVI = DR + FR$$

Diversity Index (H')

The diversity of species was calculated using the formula Shannon Wiener (1949) as follow:

$$H' = -\sum\left[\left(\frac{Ni}{N}\right)\ln.\left(\frac{Ni}{N}\right)\right]$$

Where:
H' : Diversity Index
Ni : Number of individuals of species i
N : Number of individuals of all species

The diversity is classified as low if H' <1.0, medium if 1<H'< 3, and high if H' > 3.

Evenness Index (E')

Evenness index was calculated with the following formula (Odum, 1996):

$$E' = \frac{H'}{\ln s}$$

Where:
H' : Shannon-Wiener index
ln : Natural logarithm
S : Number of observed species

The evenness is classified as low if E' < 0.3, medium if 0.3 < E' < 0.6, and high if E' > 0.6

Interspecific associations

Interspecific association was analyzed based on the dominant species and the association between two species using a 2 x 2 contingency table (Mueller-Dombois and Ellenberg 1974; Bratawinata 2001), as shown in Table 1.

Table 1. Contingency table to analyze the interspecific association between two species

Species B \ Species A	Present	Absent	Sum
Present	a	b	a + b
Absent	c	d	c + d
Sum	a + c	b + d	N = a+b+c+d

Where:
a: Number of sub-plots containing species A and species B
b: Number of sub-plots containing species B without species A
c: Number of sub-plots containing species A without species B
d: Number of sub-plots not containing species A and species B
N: Number of sub-plots

To find out whether there is an association or not between the two species, Chi-square count (X^2 count) was calculated as follows:

If the values a, b, c and d > 5, then the following formula was used:

$$X^2 = \frac{N(ad-bc)^2}{(a+b)(c+d)(a+c)(b+d)}$$

If the values a, b, c and d ≤ 5, then the following formula was used:

$$X^2 = \frac{N((ad-bc)-\frac{N}{2})^2}{(a+b)(c+d)(a+c)(b+d)}$$

The notation used in the formula above has the same meaning as the notation used in Table 1. Then the calculated Chi-square value (X^2 count) was compared with the Chi-square table (X^2 table) in degrees of freedom (df) equal to 1. If Chi-square count (X^2 count) is greater than Chi-square table (X^2 table) means there is a significant association (95% test level) or very real (99% test level). If the Chi-square calculated value (X^2 calculated) is smaller than the Chi-square table (X^2 table) it means that there is no association.

The association level obtained was calculated using the Ochiai Index formula (Ludwig and Reynolds 1988):

$$\text{Ochiai Index} = \frac{a}{\sqrt{(a+b)\sqrt{a+c}}}$$

The range of Ochiai index values is 0-1. The value of 0 indicates no form of association, while 1 indicates a high level of association. Association is classified as very high if the value 0.75-1.00; high if 0.49-0.74; low if 0.23-0.48 and very low if <0.22 (Kurniawan et al. 2008).

RESULTS AND DISCUSSION

Composition of vegetation

Landslides in Battang and West Battang Villages studied here occurred during the period of 2021 to 2022 (<1 Year). The landslides caused land clearing and the post-landslide areas slowly experienced natural succession marked by the growth of various vegetation. In this study, the vegetation was then classified into habitus and obtained as many as 8 habitus as pioneer plants. There are 112 species in the entire plots (Figure 4) with herbaceous plants having the most species (53 species), followed with trees (15 species), shrubs and ferns (12 species), vines (11 species), bamboo and palm with 1 species each. The habitus composition across the plots had almost similar characteristics where there were associations between the habitus of trees, shrubs, shrubs, herbs, ferns, vines and bamboo (Figure 5). Habitus palm was found only on Plot 10, while in Plot 3 tree habitus was absent since this plot is located on a community farm. Nonetheless, all plots were dominated by herbaceous plants.

The primary succession process in the post-landslide areas began with undergrowth in the form of herbs because these vegetation types are able to grow in areas that have lost topsoil, then followed by types of grasses and ferns at the age of <1-3 years. The ongoing succession process indicated by the growth of bush and herbaceous vegetation suggests that vegetation can recover naturally in disturbed areas (Huang et al. 2017). The presence of herbaceous plants in the succession process has a positive effect on soil formation through the use of carbon and nitrogen elements (Raihandhany et al. 2019). Then, pioneer plants such as ferns and later grasses will appear gradually to proceed with the succession into the climax community (Isnaniarti et al. 2017).

The presence of herbaceous plants, moss, spikes and grasses as the pioneer plants in the post-landslide areas is also influenced by the open condition of the land which allows full reception of sunlight (Pang et al. 2018; Hasanah et al. 2020). Such understorey vegetation supports rapid soil coverage and improves soil nutrients, while trees support soil protection from erosion (Parraga-Aguado et al. 2014).

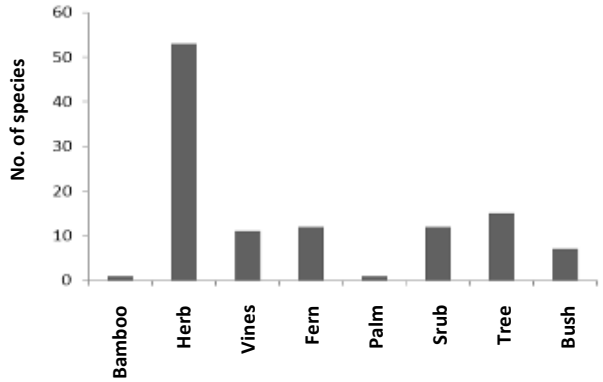

Figure 4. Number of species of each habitus across the entire observation plots on post-landslide areas

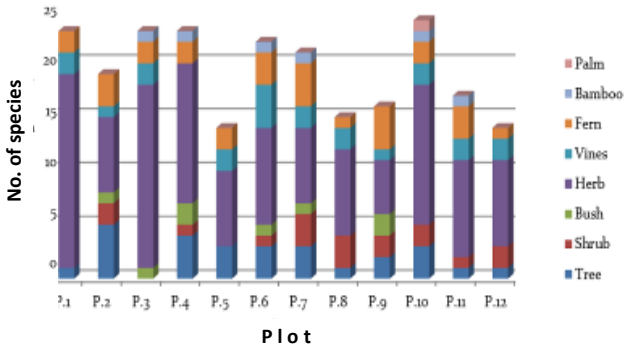

Figure 5. The number of species of each habitus at each observation plot in post-landslide areas

Density, frequency and Importance Value Index

The results of vegetation analysis are presented in Table 2 which shows three species with the highest Important Value Index (IVI) at each habitus. Species with the highest IVI for trees, shrubs, bushs, ferns, vines, bamboo, palms and herbs were Trema (*Trema orientalis* (L.) Blume) with 79.86%, kareumbi (*Homalanthus populifolius* Graham) with 61.49%, not identified with 53.41%, shoe nails (*Nephrolepis cordifolia* (L.) C. Presl) with 6.99%, Manganese (*Merremia peltata* (L.) Merr.) with 57.92%, *Bambusa balcoa* Roxb. with 200%, *Pandanus* sp. with 200% and *Miconia papillosa* (Desr.) Naudin with 22.65%, respectively. The IVI value indicates species that dominated in each habitus and provides an overview of the role of a species in the community. A higher IVI value reflects the significant contribution of the species to the community and its habitat preferences (Rani et al. 2018; Marpaung et al. 2022).

The species that dominated the post-landslide area were invasive species such as Trema (*T. orientalis*) and Miconia (*M. papillosa*) which has the ability to grow rapidly and compete. Invasive plant species can be defined as native or alien plant species that can disrupt the balance of ecosystems because of their ability to dominate aggressively and cause a significant reduction in environmental quality and biodiversity in a short or long time (Ormsby and Brenton-Rule 2017).

Trema (*T. orientalis*) is a pioneer tree species that is adaptive and also catalytic for land rehabilitation and grows quickly which does not require intensive care. Trema is common as the pioneer plants on the post-mined lands and open land around the community in Malili, South Sulawesi, where the land was open with full light intensity (Mangopang 2016).

Kareumbi (*H. populifolius*) usually grows in secondary forests with an altitude of up to 3000 meters above sea level, on roadsides and steep slopes, and grows well in various types of soil, from shallow to deep, nutrient-poor and fertile soils (Prawiradiputra 2015). This is in accordance with the habitat conditions at the study site, which is at an altitude of 500-1000 meters above sea level, is on the roadside and is located on a steep slope.

Mantangan (*M. peltata*) in the Bukit Barisan Selatan National Park (TNBBS) area is known as an invasive local species. It can pose a danger to the environment such as being a competitor to other native species that fill the same ecological niche, interfering with food webs, and reducing biodiversity. Mantangan kills other native species by strangulation, threatening the plant populations around where they grow and lowering the level of habitat quality, interfering with natural aesthetic value, and inhibiting the mobility of large fauna. This species has been invading the natural habitat of several types of wildlife in TNBBS (Master et al. 2013). Similar characteristics are also found in Miconia (*M. papillosa*) which is classified as one of the worst invasive species. This species belongs to Melastomataceae family and has a woody herbaceous habitus that is able to grow under stands, and becomes very dense in open areas; it hinders the growth of other species (Sitepu 2020).

Diversity index

The diversity index determines the diversity level of the vegetation community in an area. The results in Figure 6 show that the diversity index for the habitus of herbs, trees, shrubs, shrubs, vines and ferns is classified in the medium category because the 1<H'<3. This result suggests that the diversity of such plant groups in the studied area is in good condition, meaning the ecosystem was quite productive and balanced. The higher the value of the H′ index, the higher the species diversity, ecosystem productivity and stability. Gomes et al. (2020) showed that the diversity of herbs on disturbed lands such as landslides had a higher number than other habitus types. Other factors that affect vegetation diversity are habitats that are close to humans (Santos-Filho et al. 2013), as well as disturbed areas close to access roads resulting in edge effects that increase diversity which will differ floristically from those in the forest (Otto et al. 2014).

Table 2. Species with the highest Important Value Index for each habitus on post-landslide areas

Habitus	Common name	Scientific name	No. of ind.	D	DR (%)	F	FR (%)	IVI (%)
Tree	Trema	*Trema orientalis*	50	0.1667	43.86	0.7500	36.00	79.86
	Nyawai	*Ficus variegata*	13	0.0433	11.40	0.0833	4.00	15.40
	Mentepong	*Strobocalyx arborea*	8	0.0267	7.02	0.1667	8.00	15.02
Shrub	Kareumbi	*Homalanthus populifolius*	17	0.05667	32.08	0.4167	29.41	61.49
	Unident 12	N/A	18	0.06000	33.96	0.0833	5.88	39.84
	Waru gunung	*Hibiscus tiliaceus*	2	0.00667	3.77	0.1667	11.76	15.54
Bush	Unident 29	N/A	9	0.0300	40.91	0.0833	12.50	53.41
	Ketepeng cina	*Senna alata*	3	0.0100	13.64	0.1667	25.00	38.64
	Meniran hijau	*Phyllanthus niruri*	2	0.0067	9.09	0.0833	12.50	21.59
Fern	Paku sepat	*Nephrolepis cordifolia*	329	1.0967	50.69	0.3333	13.79	6.99
	Paku kawat	*Lycopodiopsida*	92	0.3067	14.18	0.4167	17.24	2.44
	Pakis kalakai	*Stenochlaena palustris*	107	0.3567	16.49	0.2500	10.34	1.71
Vines	Mantangan	*Meremia peltata*	63	0.2100	35.20	0.4167	22.73	57.92
	Kacang kupu-kupu	*Centrosema pubescens*	65	0.2167	36.31	0.1667	9.09	45.40
	Kacang semak ungu	*Macroptilium atropurpureum*	17	0.0567	9.50	0.4167	22.73	32.22
Bamboo	Bambu	*Bambusa balcooa*	47	0.1567	100.00	0.5000	100.00	200.00
Palm	Pandan duri	*Pandanus tectorius*	1	0.0033	100.00	0.5000	100.00	200.00
Herbs	Miconia	*Miconia papillosa*	269	0.8967	12.48	1.0000	10.17	22.65
	Rumput gajah	*Pennisetum purpureum*	214	0.7133	9.93	0.7500	7.63	17.56
	Rumput 1	*Panicum dichotomiflorum*	249	0.8300	11.55	0.2500	2.54	14.10

In contrast, the diversity index of bamboo and palm was in a low category because H'<1. This indicated that the post-landslide area had not yet favorable conditions for the habitat of bamboo and palm, where only one species of bamboo and palm were found in one plot. This is likely because the process of ecological succession is highly dependent on climate, water availability, edaphic conditions, interactions between biotic and abiotic factors and species distribution patterns as well as habitat dynamics that are less supportive for the growth of species from these two habitus.

Evenness Index

The evenness index for each habitus is presented in Figure 7. Evenness Index indicates the distribution/dispersion of a species. The Evenness Index of trees, shrubs, bushs, ferns, vines and herbs was above 0.6 and classified as a high category. This means that the individuals of trees, shrubs, shrubs, ferns, vines and herbs were evenly distributed across the landslide areas.

Conversely, bamboo and palm had a low category, meaning that the distribution of bamboos and palms was uneven. The low evenness index that in a vegetation community there are dominant, sub-dominant and dominated species (Pang et al. 2018). Although only one species of bamboo was recorded, it was found in 6 of 12 observation plots. The presence of bamboo as a pioneer plant in the landslide area is because bamboos are able to live in various habitat conditions, from dry to fertile soils.

Dominant interspesific association

Analysis of interspecific association of the dominant pioneer plants found that at least 5 out of 12 research plots had vegetation association as presented in Table 3.

There were 21 combinations of pioneer plant associations in the post-slide areas studied. Based on the results of the Chi-square test (X^2), among the 21 combinations, three associations had significant value since the results of X^2 count > X^2 table, namely *B. balcoa* with *T. orientalis*; *B. balcoa* with *H. populifolius*; and *B. balcoa* with *Macroptilium atropurpureum* (DC.) Urb. This is an interesting finding since all these three associations involved *B. balcoa* and showed a negative type of association. The Ochiai indices are classified as high, meaning that there is no tolerance for living together in the same area or there is no mutually beneficial relationship. Nonetheless, the relationship between species can be the other way around in different areas because the relationship between species is not always exclusive to one form, both positive and negative (Tasik et al. 2021).

On the other hand, the rest 18 combination showed a lack of association between species, meaning that each species in the community tends to be independent (Liu et al. 2017). In other words, it is almost unlikely for these species to interact with each other and there is competition between plant species to obtain resources for growth, such as light, groundwater, oxygen, nutrients and carbon dioxide (Karim et al. 2021). Species that are able to adapt will survive, and vice versa (Eichel 2019). Increasing the diversity of species in a plant community provides opportunities for competition between individuals which ultimately forms compositional diversity and dominance (Solikin 2015). An increase in species diversity can occur when vegetation conditions and ecosystem conditions are healthy and nutrients are available (Nurdiana and Buot 2021).

It can be concluded from this study that for the post-slide areas in Battang and West Battang Sub-Districts, within a period of approximately 1 year, there has been a succession process and 112 species from 8 habitus have been found. Based on the pioneer species found, it was dominated by invasive species such as Miconia (*M. papillosa*). The results of the diversity index showed that the habitus of trees, shrubs, shrubs, ferns, vines and herbs had a moderate level of species diversity, except for the habitus of palms and bamboo with a low diversity index. From the results of the Chi-square analysis, it was found that three combinations of species had associations with negative association types in the high category based on the Ochiai index classification.

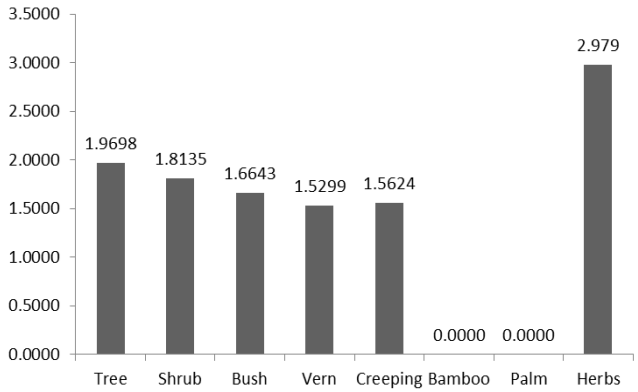

Figure 6. Diversity Index of each habitus at post-landslide areas

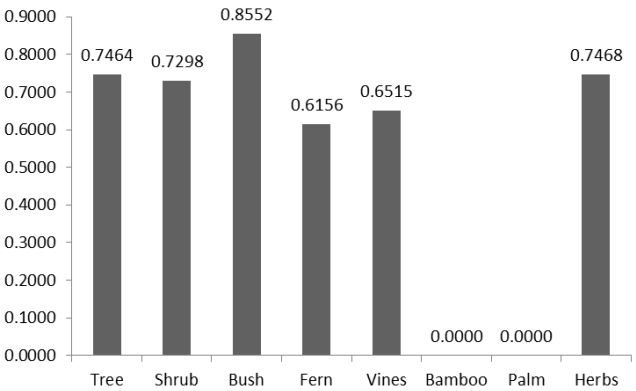

Figure 7. Evenness Index of each habitus at post-landslide areas

Table 3. Interspecific association between dominant plant species in post-landslide areas

Species	Paired spesies	Result of Chi-square test	Association	Type of association	Ochiai Index	Classification
Trema orientalis	*Homalanthus populifolius*	0.04	na	+	0.53	High
	Meremia peltata	1,07	na	-	0.53	High
	Pennisetum purpureum	0.50	na	+	0.61	High
	Bambusa balcooa	9.38	a*	-	0.55	High
	Lycopodiopsida	0.00	na	+	0.61	High
	Macroptilium atropurpureum	0.04	na	+	0.53	High
Pennisetum purpureum	*Homalanthus populifolius*	1.09	na	-	0.50	High
	Meremia peltata	2.86	na	-	0.50	High
	Macroptilium atropurpureum	2.86	na	-	0.50	High
	Bambusa balcooa	1.78	na	-	0.52	High
	Lycopodiopsida	1.03	na	+	0.50	High
Lycopodiopsida	*Homalanthus populifolius*	0.24	na	+	0.67	High
	Meremia peltata	0.48	na	-	0.67	High
	Macroptilium atropurpureum	2.95	na	-	0.75	Very high
	Bambusa balcooa	0.00	na	+	0.70	High
Homalanthus populifolius	*Meremia peltata*	0.48	na	-	0.67	High
	Macroptilium atropurpureum	0.24	na	+	0.67	High
	Bambusa balcooa	5.49	a*	-	0.70	High
Meremia peltata	*Macroptilium atropurpureum*	0.48	na	-	0.67	High
	Bambusa balcooa	0.00	na	+	0.70	High
Macroptilium atropurpureum	*Bambusa balcooa*	5.49	a*	-	0.70	High

Note: a: associated; na: no associated; (+): positive association; (-): negative association; (*): significant

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