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Characteristics of vegetation in the *gumuk* ecosystem in Jember District, East Java, Indonesia

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Abstract. *Maisyaroh W, Hakim L, Sudarto, Batoro J. 2023. Characteristics of vegetation in the gumuk ecosystem in Jember District, East Java, Indonesia. Biodiversitas 24: 1264-1271. Gumuk* is a unique Jember district landscape with high ecological value. Currently, *gumuk* mining is increasing. This study aims to look at the characteristics of the vegetation in the *gumuk* ecosystem based on a variety of landuses (mixed garden, sand mining, and stone mining). The field survey was carried out at Ledokombo Sub-district, Jember District, East Java, from January to March 2021. First, the distribution of *gumuk* was identified using GIS, referring to the Van Zuidam landform classification. Then, a vegetation survey was conducted to describe the vegetation structure of the *gumuk* ecosystem, found 136 *gumuk*. *Gumuk* can be classified as *gumuk* with mixed garden, *gumuk* for stone mining, and *gumuk* for sand mining. A total of 202 species (65 families) grow in the *gumuk* ecosystem. Seedlings had the highest number of species, dominated by Asteraceae and Poaceae, while Malvaceae dominated saplings, poles, and trees. The *Gumuk* with the highest number of species for all habitus was found at *gumuk* with mixed gardening category, followed by *gumuk* with stone mining activity and *gumuk* for sand mining. At *gumuk*, mixed garden (H' 4) and stone mining (H' 3.47) had a high diversity of vegetation for seedlings, with the species having the highest IVI being *Digitaria sanguinalis*. At *gumuk* sand mining, it also has a high diversity of vegetation (H' 3.06) for seedlings, with the species having the highest IVI being *Commelina erecta*.

Keywords: *Gumuk* ecosystem, Jember, vegetation characteristics

INTRODUCTION

Jember District on the eastern tip of East Java has a distribution of small hills called *gumuk*. It is a geological phenomenon that is thought to have been caused by the eruption of Mount Raung and formed a unique landscape in the form of a small hill (hillock) with a height of <60 meters. That hillock was formed by the erosion of a young volcanic cone on the west side of the mountain (Bemmelen 1949). *Gumuk* has excellent ecological value and high groundwater potential, especially those close together so they can serve as a water supply (Priyantari et al. 2017). Furthermore, *gumuk* as an ecosystem is a biodiversity source, habitat and corridor for various bird species (Maisyaroh 2021). *Gumuk* can also function as green open spaces that can affect the microclimate and are suspected as windbreaks (Khoiriyah et al. 2019). In addition to ecological value, *gumuk* also has educational value as a source of geology and agroecosystem knowledge.

Almost all *gumuk* have been impacted by human activity as of late, extensively used for mining and cultivation. Sand and rock from the *gumuk* can be mined to help the local economy. However, mining activity is currently rising, and regrettably, there is no cultural or legal restriction (Purwanto et al. 2021). Excessive exploitation can impact changes in landscape structure and their function, and in the long term, will have an ecological impact on ecosystem sustainability. Geology, topography, soils, natural and anthropogenic disturbances, and landuse can influence the landscape and the distribution of individual species. In an area with a close relationship between humans and nature, the degradation of ecosystems leads to decreased cultural landscapes. Conserving the particular ecosystem in which local has its dependency is crucial to ensure local community sustainability (Hakim 2017).

As a unique landscape with a certain elevation and slope, *gumuk* can become an ecosystem that can form certain vegetation types because altitude and slope have been shown to affect vegetation composition and distribution (Kunwar et al. 2020; Sutomo and Iryadi 2021). Furthermore, *gumuk* for plantations and mining shows a different appearance of landuse. That different types of landuse will lead to differences in the structure and composition of vegetation (Jiang et al. 2021; Nugroho et al. 2022; Rezekiah et al. 2022). *Gumuk* is also a biological marker for detecting changes in the landscape, vegetation's structure, composition, distribution, and relationship to environmental conditions. Vegetation change may be primarily caused by human activities, which may change how land is used (Zhang and Jin 2021; Zhao et al. 2021). The use of *gumuk* by the community for the cultivation of

woody plants is also often combined with agricultural crops forming agroforestry systems. In the agroforestry system, people's perceptions of local natural resource management positively correlate with species diversity (Lestari et al. 2019) because landscape conservation and biodiversity protection will be a symbiosis of mutualism for humans and the environment (Methorst et al. 2021).

This study aims to explore the characteristics of vegetation in the *gumuk* ecosystem. Moreover, several types of landuse are considered to observe the diversity of plants. Types of landuse are grouped based on the community's current use of *gumuk*, which is categorized into three types: mixed gardens, sand mining, and rock mining. Information about the ecology of flora in a particular geographic location can be useful for building better management and sustainable use of landscapes (Nafeesa et al. 2021).

MATERIALS AND METHODS

Study area

The research was conducted in Ledokombo Sub-district, Jember District, East Java, Indonesia (Figure 1), from January to March 2021. Ledokombo Sub-district consists of 10 villages, has an area of 57.03 km^2, is located at an altitude of 370 m above sea level (8°07' 54.2" S 113° 52'42.5" E), the average rainfall is 254 mm per year (BPS Kabupaten Jember 2021). *Gumuk* is often found in this sub-district because it is close to Mount Raung. *Gumuk* is widely used for plantations, whereas some are used for mining areas. In this district, there is sand mining and a stone mining area, especially slab stone. For the last ten years, the Ledokombo community has carried out many social and economic empowerment processes, known as the Ledokombo Learning Tourism Village. Observing the potential of the community is the basis for exploring the potential of *gumuk* in Ledokombo Sub-district so that it can become a pilot area for *gumuk* conservation.

Procedures

Gumuk *spatial distribution*

The distribution of *gumuk* in Ledokombo was identified using SAGA GIS (Conrad et al. 2015) and ArcGIS (Esri, USA), determined based on the classification of landforms referring to the Van Zuidam classification (Zuidam and Cancelado 1979). *Gumuk* is included in the hilly/wavy topography category, having a height between 10-50 m and an area of >1ha. The distribution of *gumuk* is used as the basis for determining vegetation sampling, divided into three areas based on differences in landuse. The first landuse is a mixed garden, or *gumuk*, which is currently popular for plantations with lots of certain commodity crops. The second landuse is sand mining, which takes the shape of *gumuk*, where coral and sand mining operations are currently being carried out. Stone mining, specifically *gumuk*, which is now carrying out stone mining activities, is the third landuse. Many slab stones can be discovered here.

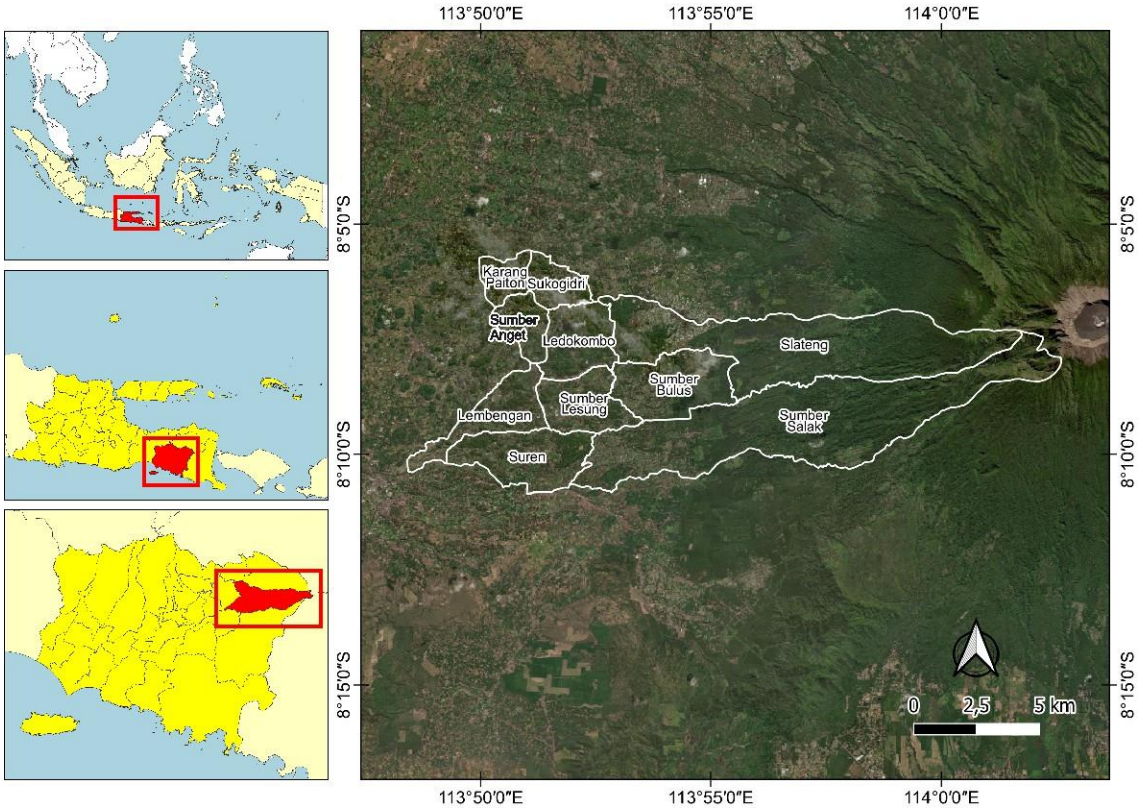

Figure 1. Study site in Ledokombo Sub-district, Jember District, East Java, Indonesia

Vegetation survey

Vegetation sampling was carried out on 50 *gumuk*, divided into 30 for the mixed garden, ten *gumuk* for sand mining, and ten for stone mining *gumuk*. Vegetation surveys are categorized based on their habitus, seedlings/ undergrowth, saplings, poles, and trees. Seedlings/ undergrowth are non-woody plants, including seedlings with a height of <1.5 m; saplings are plants with a height of 1.5 m with a stem diameter <10 cm; poles are young trees with a diameter of 10-20 cm; and trees are woody plants with a diameter of >20 cm. In each *gumuk*, two plots were made for each habitus using a nested plot. Plots measuring 2x2 m for seedlings/undergrowth, 5x5 m for saplings, 10x10 m for poles, and 20x20 m for trees. In each *gumuk*, abiotic factors were recorded consisting of temperature, humidity, soil pH, soil moisture, and light intensity.

Data analysis

Gumuk spatial distribution was analyzed descriptively based on their distribution in each village. Analysis of the vegetation structure and the diversity of plant species in the *gumuk* ecosystem was carried out by calculating the Importance Value Index (IVI) (using Microsoft Excel), Dominance Index (D), Simpson Index (D'), Shannon Wiener Diversity Index (H'). While Evenness Index (E) was analyzed using PAST (Paleontological Statistics), ver. 3.22.

RESULTS AND DISCUSSION

***Gumuk* spatial distribution**

The mapping results show 136 *gumuk* in Ledokombo Sub-district (Figure 2) with a total area of 222.80 ha. The villages with the highest number of *gumuk* distributions are Ledokombo, Lembengan, and Suren villages. Based on the landuse, *gumuk* is mostly used for plantations, while mining can be seen in several locations, both on a small and large scale. Sand mining is mostly carried out on a large scale using heavy equipment, while stone mining is still carried out conventionally and is dominated in Suren Village as a center for plate stone mining.

Vegetation of *gumuk*

The results showed 202 plant species from 65 families were found in all types of *gumuk*. Based on the habitus, the seedling has the highest diversity compared to the others, with 150 species consisting of 54 families. Sapling has 67 species in 30 families, while poles and trees are almost identical. Poles have 33 species in 14 families, and trees with 34 species in 16 families (Figure 3).

In the seedlings habitus, the Asteraceae and Poaceae families dominated, while the Malvaceae family dominated the sapling, pole, and tree habitus (Table 1). Asteraceae and Poaceae are known for their plant groups, whose members are found in many habitats. They are recorded as the dominant family in the Bhimber hills of the Kashmir Himalayas (Nafeesa et al. 2021), also found dominantly in semi-arid mountain ecosystems (Staden et al. 2020). While Malvaceae is a group of dicot plants where many members of this family are important cultivated plants as producers of textile fiber and oil. Many of these species' families also have the potential as medicinal plants (Das and Islam 2019; Rodrigues and de Oliveira 2020). These species also have the potential to be an antioxidant, anti-inflammatory (Nwankwo et al. 2023), and antimicrobial (Rodrigues et al. 2022). Several species of this family are also known as pioneer species (Whitmore 1991). *Hibiscus tiliaceus* and *Ochroma lagopus* are the most common species from this family found in *gumuk*. *Ochroma lagopus* is currently in great demand by the people of Ledokombo to be planted after *Albizia chinensis*, because the selling price has started to rise. Meanwhile, *Hibiscus tiliaceus* has been growing in *gumuk* for a long time, intentionally planted or grown on its own.

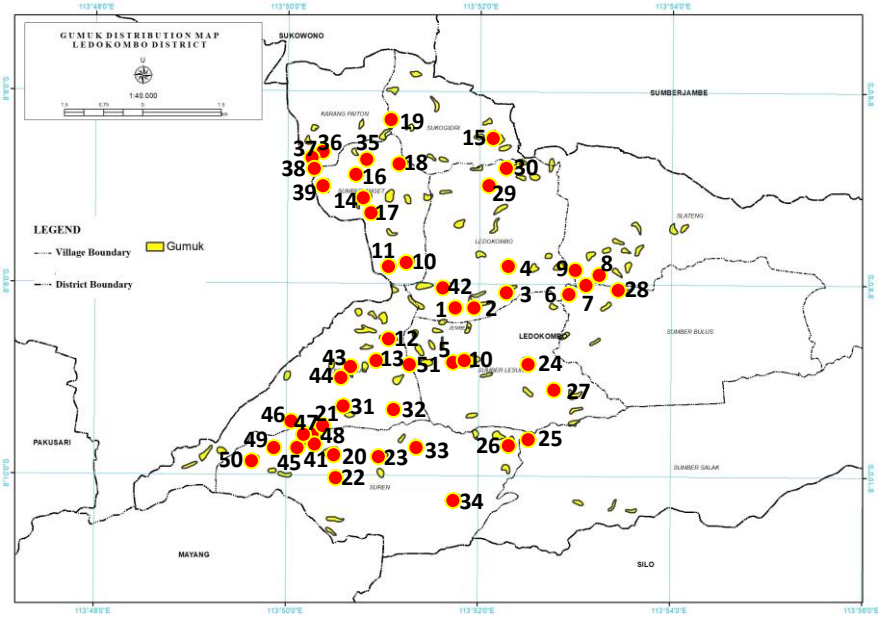

Figure 2. *Gumuk* distribution and vegetation sampling points Ledokombo Sub-district, Jember District, East Java, Indonesia

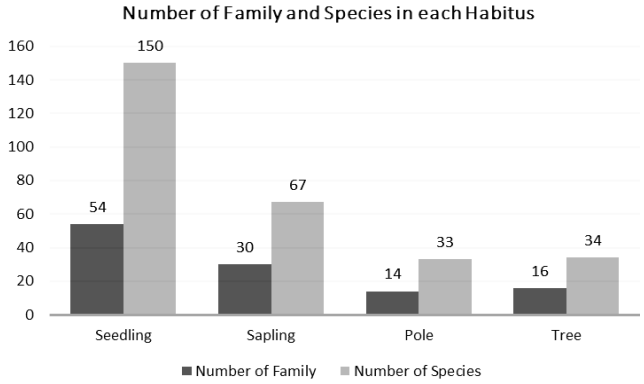

Figure 3. Number of families and species of each habitus in the *gumuk* ecosystem in Ledokombo Sub-district, Jember, Indonesia

Table 1. Family with the highest number of species in each habitus

Habitus	Family	Species diversity
Seedlings	Asteraceae	15 Species
	Poaceae	10 Species
Sapling	Malvaceae	7 Species
Pole	Malvaceae	5 Species
Tree	Malvaceae	5 Species

Based on landuse type, the mixed garden had the highest number of species for all habitus, with 150 species of seedlings, 37 species of saplings, 32 species of poles, and 28 species of trees. Meanwhile, stone mining has more species than sand mining for all habitus (Table 2). These differences indicate that human activity correlates with an area's species diversity. Anthropogenic disturbances such as illegal logging, agriculture, and mining positively reduce tree species diversity and stand density, impacting reduced carbon stocks (Bentsi-Enchill et al. 2022). Analysis of satellite imagery also shows a decrease in vegetation in Ghana due to mining (Biney et al. 2022). In the mixed garden, although human intervention is very high in managing *gumuk*, the diversity of plants that grow wild is also quite high, apart from plantation crops that are deliberately planted. On the other hand, the number of species in stone mining is higher than in the sand mining area. That could be because sand mining activities are mostly carried out using heavy equipment, and transportation equipment movement also highly affects vegetation. Meanwhile, stone mining activities are still carried out manually, and there is not much traffic movement. Moreover, human activities can impact vegetation on net primary productivity (NPP), the amount of carbon retained in an ecosystem (Ge et al. 2021). The combination of climate and human activities has also been shown to affect regional vegetation changes (Yu et al. 2021; Lin et al. 2022).

Vegetation diversity index

The results of the analysis show that *Digitaria sanguinalis* has the highest Importance Value Index (IVI) for all landuse types at the seedling level, in mixed gardens at 24.77% and stone mining at 19.09%, while in sand mining, this species IVI is in second place (13.12%) (Table 3). The annual weed *D. sanguinalis* is well-known for proliferating across numerous agricultural lands and plantations (Zong et al. 2022). The community uses *gumuk* for plantations. Most plants are planted randomly, with irregular spacing causing lots of open space and exposure to direct sunlight. In habitat conditions with rare shade, *D. sanguinalis* can grow well because solar radiation can affect the dormancy of the seeds (Oreja and Fuente 2022).

Commelina erecta had the highest IVI in sand mining (16.30%) and the second highest IVI in mixed gardens (13.37%) for seedling habitus. This species belongs to the Commelinaceae family. This species can grow on hillsides, around large boulders, in the middle of bushes, and be exposed to sunlight (Mitta and Nandikar 2021). In sand mines, apart from gravel, large chunks of stone are also often found, which are usually left untouched by the local community. In sand mines, the ground surface may be exposed to direct sunlight due to sparse vegetation, which may be a growth factor for this species. In addition to the supportive habitat, the distribution of the Commelinaceae family is also influenced by various environmental factors; it has been proven that the distribution of this family is very significant for soil pH, available phosphorus, total nitrogen, fertility, and agricultural systems (Irakiza et al. 2022). In stone mining, *C. odorata* has a fairly high IVI; this is an invasive alien species that have been recorded to be found in many places. This plant is pollinated by various insects, resulting in a high growth rate and becoming an invasive weed (Layek et al. 2022).

Table 2. The number of families and species in each habitus and landuse in the *gumuk* ecosystem in Ledokombo Sub-district, Jember, Indonesia

***Gumuk* type**	**Seedling**		**Sapling**		**Pole**		**Tree**	
	Family	**Species**	**Family**	**Species**	**Family**	**Species**	**Family**	**Species**
Mixed garden	57	150	18	37	14	32	14	28
Sand mining	32	54	5	6	5	5	3	3
Stone mining	31	64	10	14	9	13	8	11

Since no undamaged *gumuk* was discovered throughout the survey, they all had human involvement from plantations. Visually it is clear that *A. chinensis* dominates *gumuk*. This species has long been a mainstay of the Ledokombo community as a *gumuk* commodity. As in a long-term economy, the selling price is high, following the trend. It can grow on sandy soil, and easy maintenance is why people grow *A. chinensis*. Not only do the people of Ledokombo make this species economically important, but in many places, it is also the selected lucrative commodity (Parikesit et al. 2021; Stewart 2021). The analysis results show that *A. chinensis* is a species that can greatly impact the *gumuk* ecosystem; this can be observed from the high IVI value of all landuse types. IVI explains the role of a species in the ecosystem; species with high IVI can significantly affect ecosystem stability (Wijana 2014). *Albizia chinensis* had the highest IVI in mixed gardens for saplings, poles, and trees. In sand mining, and has the second-highest IVI for saplings and the highest IVI for poles. *Albizia chinensis* has the second and third-highest IVI for saplings, poles, and tree habitus in stone mining.

Table 2. Highest Important Value Index (IVI) for each habitus and landuse type

Gumuk type	Habitus	Species	IVI (%)
Mixed garden	Seedling	*Digitaria sanguinalis*	24.77
		Commelina erecta	13.37
		Oplismenus undulatifolius	9.71
	Sapling	*Albizia chinensis*	68.34
		Gigantocochloa atter	50.72
		Gigantochloa pseudoarundinacea	41.31
	Pole	*Albizia chinensis*	81.95
		Dendrocalamus asper	75.55
		Swietinia mahagoni	27.28
	Tree	*Albizia chinensis*	89.55
		Swietinia mahagoni	34.23
		Gmelina arborea	25.21
Sand mining	Seedling	*Commelina erecta*	16.30
		Digitaria sanguinalis	13.12
		Drymaria cordata	12.70
	Sapling	*Schizostachyum brachycladum*	126.50
		Abizia chinensis	80.61
		Carica papaya	60.79
	Pole	*Abizia chinensis*	140.16
		Carica papaya	80.71
		Musa paradisiaca	28.54
	Tree	*Artocarpus elasticus*	117.66
		Cocos nucifera	96.83
		Musa paradisiaca	85.50
Stone mining	Seedling	*Digitaria sanguinalis*	19.09
		Alternanthera sessilis	11.45
		Chromolaena odorata	10.88
	Sapling	*Gigantochloa apus*	81.90
		Gigantochloa pseudoarundinacea	47.05
		Abizia chinensis	45.76
	Pole	*Dendrocalamus asper*	40.36
		Abizia chinensis	42.34
		Swietenia mahagoni	30.51
	Tree	*Swietenia mahagoni*	48.12
		Abizia chinensis	45.97
		Musa paradisiaca	38.69

Bamboo is also a plant often found in *gumuk*. Several bamboo species are deliberately planted, some grow by themselves, and the community uses bamboo for various purposes. Apart from being sold, bamboo is also often used for furniture and basic building materials. Five bamboo species are found in *gumuk*: *Gigantocochloa atter*, *Gigantochloa pseudoarundinacea*, *Gigantochloa apus*, *Dendrocalamus asper*, and *Schizostachyum brachycladum*. In all types of landuse, it was found that bamboo had a fairly high IVI; in mixed gardens, there were *G. atter*, *G. pseudoarundinacea*, and *D. asper*. *Dendrocalamus asper* or *Pring Petung* is a bamboo with a large girth; this bamboo is quite a mainstay of the community; besides being able to grow well on hilly lands, it also has the advantage of being more durable than other species of bamboo. It is proven that this bamboo can grow and develop properly at various elevations (Jihad 2021). This bamboo can be a source of hemicellulose dietary fiber (Felisberto et al. 2021), and it can also be processed into flour to get the benefits of fiber (Felisberto et al. 2017). In sand mining, *S. brachycladum* occupies the highest IVI for saplings. While in stone mining, there are *G. apus* and *G. pseudoarundinacea*, which have the highest IVI for saplings, while *D. asper* has the highest IVI value for pole habitus. Even though mining activities are carried out, many bamboo plants are deliberately left unattended, and the bamboo will be cut down when needed.

It is clear from saplings, poles, and trees in all types of landuse that most species with high IVI values are permanent plants the community has planted. *Albizia chinensis* is a plant grown extensively across the community in mixed gardens, sand, and stone mines. The community typically plants *A. chinensis* randomly on the ground that hasn't yet been used for mining. In mixed gardens and stone mines, *Swietenia mahagoni* stands out as well. In mixed gardens, this species has the third and second IVI orders for poles and trees, respectively, while in stone mining, it has the highest IVI for trees.

Overall it can be concluded that species dominance in the *gumuk* ecosystem is in the low-medium category. Seedlings on all types of landuse showed that the Dominance Index was very low; no species dominated on the three landuses. The Dominance Index can indicate whether or not a dominant species in a particular habitat is indicated by a value range of 0-1 (Odum 1971). Dominance indices for saplings, poles, and trees in mixed gardens and stone mining have almost the same values and can be categorized as quite low dominance. While in sapling and pole, it shows moderate dominance in sand mining.

Based on the Simpson Index (D'), the complexity of the vegetation community in the *gumuk* ecosystem shows the high-medium category. In mixed gardens and rock quarries for all levels in the high category. In sand mining, seedlings and trees show high complexity, while saplings and poles show moderate complexity. The Simpson index values range from 0-1; the lower the value indicates the lower the complexity (Odum 1971). Based on the Shannon index (H'), all landuses for seedlings show that the level of species diversity is in the high category (>3).

Table 2. Diversity index for each habitus and landuse type

Landuse type	Diversity index	Seedling	Sapling	Pole	Tree
Mixed garden	Dominance_D	0.04	0.16	0.28	0.16
	Simpson_1-D	0.96	0.83	0.72	0.83
	Shannon_H	4.00	2.19	1.78	2.51
	Evenness_e^H/S	0.36	0.26	0.18	0.44
Sand mining	Dominance_D	0.09	0.45	0.52	0.39
	Simpson_1-D	0.91	0.55	0.48	0.60
	Shannon_H	3.06	1.04	0.97	1.02
	Evenness_e^H/S	0.40	0.47	0.52	0.92
Stone mining	Dominance_D	0.05	0.26	0.22	0.10
	Simpson_1-D	0.95	0.73	0.78	0.89
	Shannon_H	3.47	1.84	2.02	2.35
	Evenness_e^H/S	0.50	0.50	0.58	0.96

Table 3. Abiotic parameters in all landuse

Abiotic parameters	Mixed garden	Sand mining	Stone mining
Temperature (°C)	29.09 ± 2.76	26.68 ± 3.04	29.29 ± 2.20
Humidity (%)	78.58 ± 6.50	80.40 ± 4.16	74.71 ± 5.99
Soil pH	6.30 ± 0.35	6.43 ± 0.49	6.76 ± 0.16
Soil moisture (%)	69.77 ± 14.06	53.00 ± 23.35	45.57 ± 21.66
Light intensity (lux)	5737.60 ± 5502.44	12390.00 ± 6606.24	11147.14 ± 5727.46

Meanwhile, for saplings, poles, and trees in all landuses, the species diversity tends to be moderate ($1 \leq H \leq 3$). Differences in landuse seem to not affect the diversity of vegetation there, in mining areas that have high human activity also show diverse vegetation. Large biomass and plant stands can support large energy flows (Odum 1971).

Based on the Evenness index (E), the evenness of species in mixed gardens shows a low-medium category in all habitus. In sand mining, it shows a medium category for seedlings, saplings, and poles. Whereas in tree habitus, it shows high evenness. In stone mining, the evenness of species shows the same category as sand mining; for seedlings, saplings, and poles, it shows a medium category, while trees tend to be high. The Evenness Index (Index of Evenness) determines the evenness of each species in each community. Evenness index values (E) range from 0-1, where close to 1 indicates that all species have an even distribution (Odum 1971; Magurran 1988).

The vegetation structure in the *gumuk* ecosystem shows high diversity; even though the community uses it for plantations and is dominated by certain plant commodities, it still shows quite high diversity of vegetation. Especially in the seedlings that dominate all landuses, many species of seedlings/undergrowth have the potential as medicinal plants and food ingredients. The diversity index also shows medium-high, indicating that the *gumuk* ecosystem has an important role as a habitat for various plant species and can be correlated with animals living there. Therefore, changes in vegetation composition are important information to support the sustainable management of *gumuk* as a unique landscape.

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