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Research Article

Herbaceous Diversity in the *Gumuk* Ecosystem in Ledokombo District-Jember Regency with Varied Land Use Type

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ABSTRACT
Gumuk is a unique landscape in Jember Regency resulting from the eruption of Mount Raung that can provide ecosystem services through its ecological functions. Increased mining activity in *Gumuk* and land-use changes can lead to a decline in biodiversity and affect ecosystem services. This study aims to determine the diversity of herbaceous in the *Gumuk* ecosystem. Conducted in January - March 2021 in Ledokombo District, Jember Regency. The spatial distribution of *Gumuk* was carried out using GIS. Herbaceous sampling was carried out using 2x2 plots on three types of *Gumuk* utilisation, namely mixed gardens, sand mining, and stone mining. The results showed that there were 136 *Gumuk* in Ledokombo District. One hundred twenty herbaceous species (49 families) were found in all types of *Gumuk*. Mixed gardens have the highest species diversity (109 species, 49 families) compared to other types. *Digitaria sanguinalis* (L.) Scop. has high dominance in all types. Species dominance showed a moderate category for all types of *Gumuk* (D = 0.07). Community complexity in all types was in the high class (D' = 0.90) and species diversity was in the high class (H' = 3.25). Evenness index € was different in the three types of *Gumuk*; in mixed gardens, the evenness of species was lower (0.23) than the other two types.

INTRODUCTION
Landscape changes can impact ecological communities (Turner et al. 2001), such as the loss of natural ecosystems that can cause vulnerability to some species, especially those who are sensitive to change (Gustafson 2002). The exposure to biodiversity can occur due to changes in the interrelationships between landscape elements and could lead to biodiversity extinction in a long run (Indrawan et al. 2007; Horvath 2019). The effects to ecosystem services are due to differences in agricultural production and hydrological systems, and changes in soil properties (Hasan et al. 2020).

Jember Regency, East Java, has a unique landscape including thou-

sands of small hills (hillocks) as a geological phenomenon, resulted from Mount Raung activities. This small hill is called *Gumuk* by the local community and spread across all sub-districts in Jember, particularly in the Ledokombo district. The height of *Gumuk* is less than 60 meters (Bemmelen 1949) and this is in line with the classification of landforms as wavy topography/sloping hill or small hill (Zuidam & Cancelado 1979). Geologically, *Gumuk* is an example of the ruins of a young volcanic cone on the western side of a volcano that is less stable (Bemmelen 1949). It has economic, social, cultural, and ecological values for a geological formation. Moreover, *Gumuk* also plays a role as habitat for various types of plants and feeding ground for birds as well as corridor in migration. The study of bird diversity in the Gumuk ecosystem shows a moderate level (Maisyaroh et al. 2021), indicating that the *Gumuk* ecosystem has potential as a bird habitat even though it has a low diversity of trees.

Currently, the exploitation of *Gumuk* in Jember for mining is increasing. The sand and stone of *Gumuk* are mined for the community's economy activities (Bemmelen 1949). Unfortunately, most mining activities are illegal. This is related to the private ownership status of *Gumuk* and some even become a joint ownership. *Gumuk* can become a source of local wealth for both economic and ecological interests. However, high exploitation is unavoidable, so in the long term, the loss of *Gumuk* and the change of land use will have ecological impact (Hasan et al. 2020), including the decrease in biodiversity. As we know, each species has a different response to disturbance (Newbold et al. 2020). Landscape changes due to mining activities can affect vegetation and hydrogeology (Ikhsan et al. 2019). In addition, the land conversion also contributes to the reduction of green open space which can affect the microclimate (Indrawan et al. 2007).

The diversity of herbaceous in a habitat can be used as an indicator of disturbance. Each herb species has a different tolerance level to changes in environmental conditions (da Silva et al. 2020; Jhariya & Singh 2021). Herbs can also play an essential role in an area because they can increase biomass (Khan et al. 2020). Furthermore, some species have the potential for phytoremediation (da Silva et al. 2020). Many herbaceous species also have high potential as sources of food and medicine for the community (Hakim 2015; La Rosa et al. 2021), as biopesticides (Saripah et al. 2020), as refugia (Maisyaroh 2014; Sutriono et al. 2019; Abidin et al. 2020), and as exotic plants (Khan et al. 2020). Herbs can also be used as alternative plants for reforestation other than trees (Khan et al. 2020). Herb abundance correlates with higher biomass, carbon storage, and CO2 mitigation (Khan et al. 2020). The number of *Gumuk* scattered randomly in Jember makes it possible to have a relatively complex diversity of herbs.

This study aims to explore the potential of herbs in the *Gumuk* ecosystem. This study begins with mapping the spatial distribution of *Gumuk* in the Ledokombo district to see the number and distribution of *Gumuk*. The spatial distribution of *Gumuk* then used as the basis for sampling herbs. The areas were grouped into three sampling areas based on the type of land use, namely mixed gardens, sand mining, and stone mining. The diversity of herbs was analysed for each kind of land use to see the dynamics of biodiversity in the changing landscape of *Gumuk*.

MATERIALS AND METHODS

Study Site

This research was conducted from January to March 2021 in the Ledokombo District, Jember Regency, East Java. This district has an area

of 57.03 km² and consists of 10 villages. Ledokombo is one of the districts in Jember which is close to Mount Raung, so the distribution of *Gumuk* in this area is quite large. Ledokombo has an altitude of 370 m above sea level (8°07'54.2" S 113°52'42.5" E) and the average rainfall is 254 mm per year. In Ledokombo District, various land- use types represented all *Gumuk* land uses in Jember Regency. Community empowerment activities in the social and economic have been productive in the last ten years. The Ledokombo community declared their territory as the *Ledokombo Learning Tourism Village* (Hang 2020) to pioneer *Gumuk* conservation efforts.

Distribution and Determination of Gumuk, Sampling Area, and Vegetation Survey

Manuscript is divided using the numbered sections. Authors should divide the manuscript into clearly defined and numbered sections. Second level section numbering is done automatically; following the upper level's number. Use this numbering also for internal cross-referencing: do not just refer to the text. Any subsection should be given a brief heading.

The distribution of the *Gumuk* was mapped using SAGA GIS (Conrad et al. 2015) and ArcGIS (Esri, USA). The determination of the *Gumuk* was conducted by classifying the landform using the TPI (Topographic Position Index) method, which measures the difference elevation at the midpoint and the average height of the surroundings at a certain radius. Moreover, the determination was continued according to the classification of Van Zuidam (Zuidam & Cancelado 1979), that the topography with a slope level of 8 -13% and a height difference of 25-75 m is a category of undulating land topography/sloping hills. Based on that determination, the type of the *Gumuk* ranged from 10-50 m in height, and the area is >1 ha.

The *Gumuk* distribution map was then used as a reference in vegetation sampling. The sampling area is divided into three land-use locations: mixed garden, sand mining, and stone mining. *Gumuk* with diverse garden is *Gumuk* that is currently used for plantations, dominated by certain types of plantation crops, and some are interspersed with seasonal crops. *Gumuk* with sand mining is *Gumuk* which is presently used for sand and gravel mining. Moreover, *Gumuk* with stone mining is *Gumuk* used for block stones and stone plates mining. The vegetation survey was carried out by making plots 2x2 m (Wijana 2014). Each plot counts the species found and records the abiotic parameters. The Sampling point of *Gumuk* was determined by purposive sampling according to the number of village representation and the type of land use. Fifty *Gumuk* became the sampling area, the number was more than 30% of the total samples. Thirty samples of *Gumuk* for a mixed garden, ten for sand mining, and ten for stone mining. The total number of plots is 100, wherein each *Gumuk* two plots are assigned. Species found in sample plots were identified using Flora of Java (Becker & Brink 1965) and The Mountain Flora of Java (Van Steenis 2006).

Data Analysis

The analysis of the *Gumuk* distribution map is carried out by counting the number of *Gumuk* in each village. The Important Value Index (IVI) is calculated from the sum of the Relative Density (KR) and Relative Frequency (FR) (Mueller-Dombois & Ellenberg 1974). Dominance Index Index (D), Simpson's Index (D'), Shannon Wiener Diversity Index (H'), and Index of Evenness (E) were analyzed using PAST (Paleontological Statistics), ver. 3.22 (Hammer 2001). Vegetation data from three sam-

pling areas were then compared.

RESULTS AND DISCUSSION

Gumuk Distribution in Ledokombo District

The GIS mapping showed 136 *Gumuk* in Ledokombo district and spread over ten villages (Figure 1).

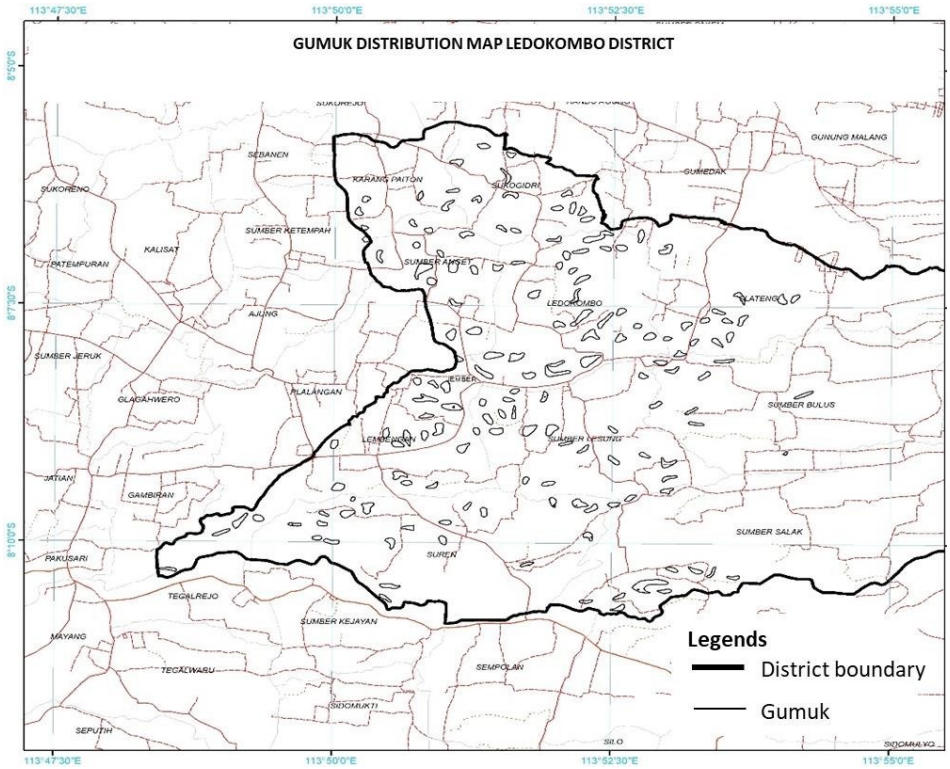

Figure 1. *Gumuk* distribution map in Ledokombo District.

The total area of those *Gumuk* was 222.80 ha. A total of 50 *Gumuk* were used as sampling areas. The villages with the highest *Gumuk* distributions and the highest area were Ledokombo village, Lembengan village, and Suren village (Figure 2).

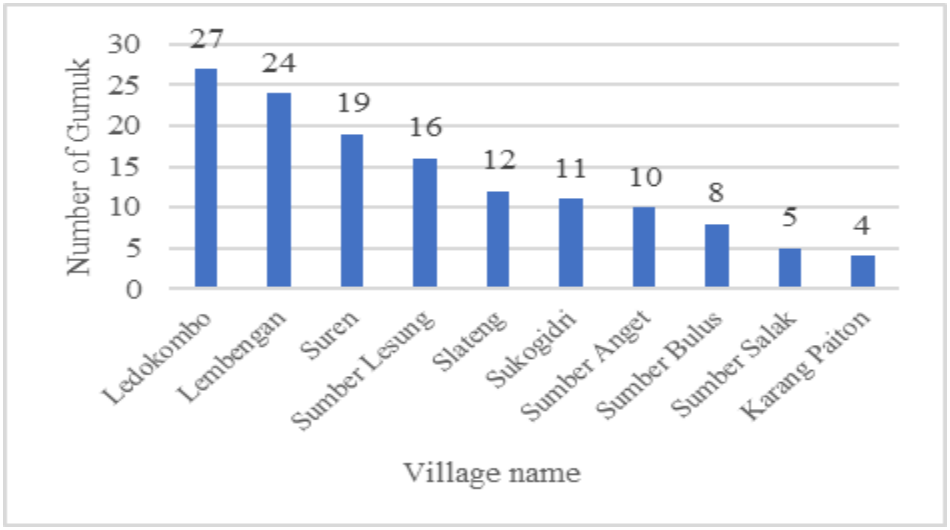

Figure 2. Number of *Gumuk* in each village in Ledokombo District.

The land use of *Gumuk* in Ledokombo village and Lembengan village was dominated by the mixed garden with various plantation commodities, such as Sengon (*Albizia chinensis*), Mahogany (*Swietenia ma-*

hagoni), Papaya (*Carica papaya*), Banana (*Musa* sp.), White Teak (*Gmelina arborea*), Balsa (*Ochroma lagopus*), Bamboo (*Bambusa* sp.), and Coffee (*Coffea* sp.). Several *Gumuk* in these two villages are also used for sand mining; some showed intense mining activities with a large mining area. Sand mining activities use heavy and large-scale equipment and employ many workers. The use of these heavy equipments accelerate the process of land degradation and loss of vegetation. *Gumuk* in Suren Village is dominated by stone mining, namely stone blocks and stone slabs. Suren village is famous for having the best slab mining products compared to other areas in Jember Regency. Stone mining activities are still carried out traditionally. The distribution of *Gumuk* by land use type is shown in Figure 3.

Herbaceous Diversity in Ledokombo District

A total of 120 herbs consisting of 49 families were found in all types of *Gumuk*. The ten most commonly found families are Asteraceae (14 species), Poaceae (10 species), Lamiaceae (9 species), Cyperaceae (6 species), Rubiaceae (5 species), Amaranthaceae (5 species), Pteridaceae (4 species), Zingiberaceae (4 species), Commelinaceae (3 species), and Oxalidaceae (3 species). Asteraceae is a family that has a high species diversity that can live in various habitats; this family has essential benefits as food providers, medicine, and ornamental plants, as well as the Lamiaceae family (Michel et al. 2020; Saini et al. 2020; Garcia-Oliveira 2021; Kurniawan et al. 2022). Even some Asteraceae have a high potential for new functional foods (Garcia-Oliveira 2021; Kurniawan et al. 2022). Asteraceae dominance was also reported on herbaceous dynamics in urban areas in India (Khan 2020), also became the family with the highest IVI value

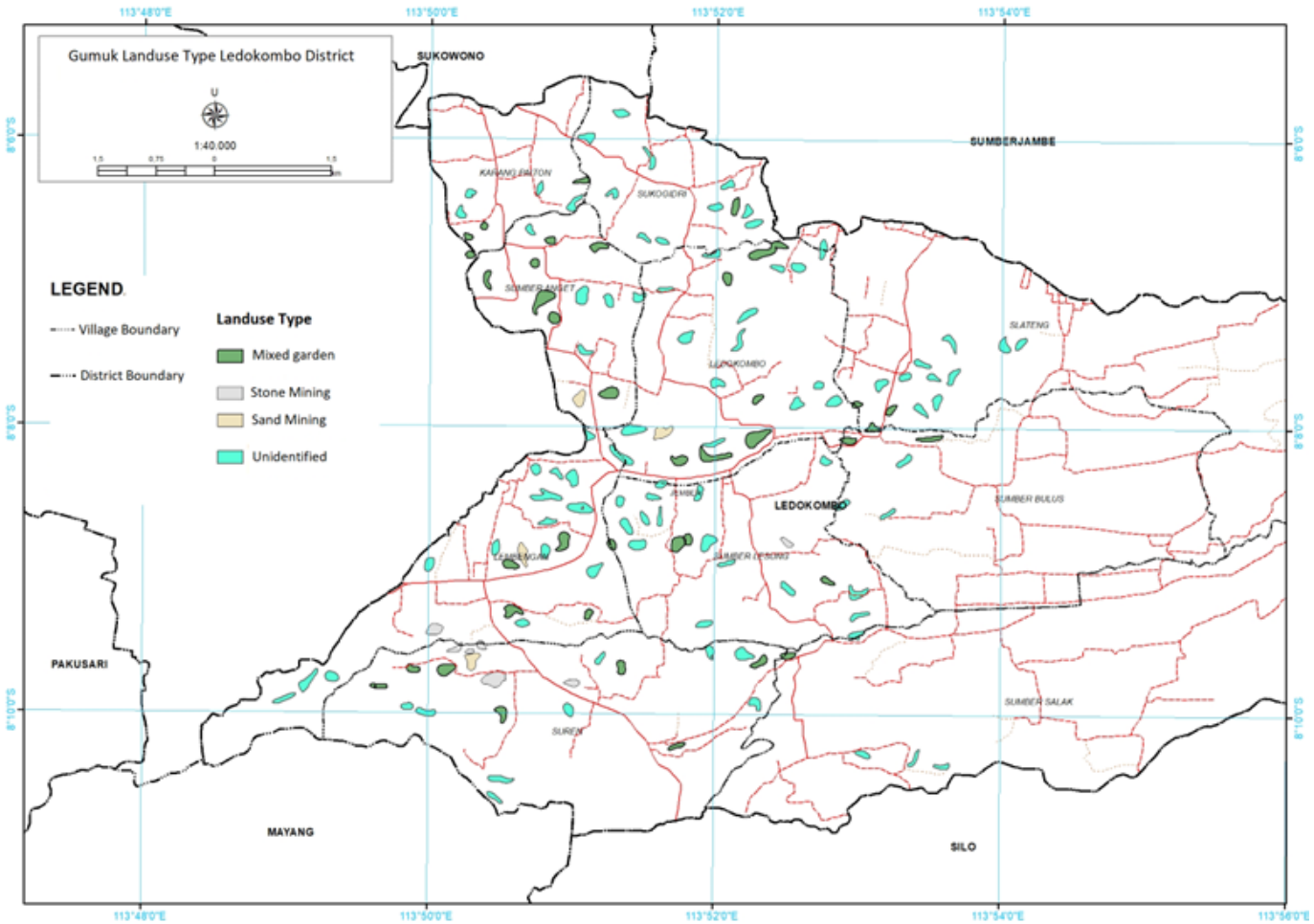

Figure 3. Distribution of *Gumuk* by land use type in each village in Ledokombo District.

in the Savannas in Padar and Komodo Islands (Sutomo 2020). This weed dispersal strategy is strongly influenced by geographical conditions (Dematteis et al. 2019), natural seed dispersal by wind also contributes to the breeding and spread of this weed at the landscape level (Mao et al. 2022).

Based on land use type, *Gumuk* with mixed gardens showed the highest species diversity (109 species, 49 families) compared to sand mining (46 species, 27 families) and stone mining (48 species, 25 families) (Figure 4). There is a significant difference in species diversity between mixed gardens and the other two types of land use. In the mining area, sand and rock excavation show almost the same diversity of species and families. However, the *Gumuk* material in the two mining areas are quite different; artificial influences are more dominant in the presence of plants. Landscape changes tend to be dominated by disturbances caused by human activities. It is clear that land cover changes are mainly caused by direct human use through agriculture, grazing, forestry, and development (Indrawan et al. 2007; Pearson 2022).

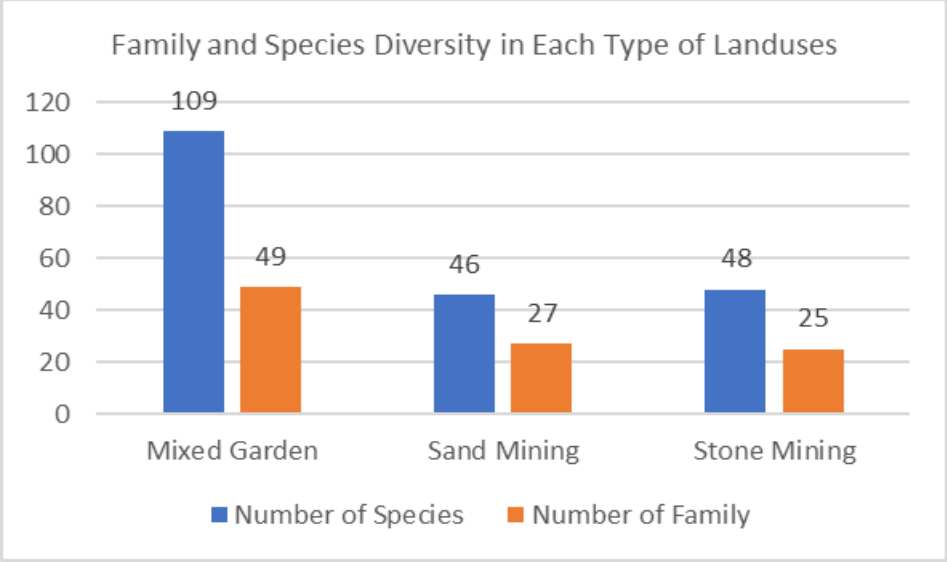

Figure 4. Family and species diversity in each type of land uses in Ledokombo District.

The highest Important Value Index (IVI) in the mixed garden was *Digitaria sanguinalis* (L.) Scop. (26.54%), *Commelina erecta* (14.72%), and *Oplismenus undulatifolius* (10.40%). While in sand mining, the species with the highest Important Value Index (IVI) was *C. erecta* (17.56%), *D. sanguinalis* (L.) Scop. (13.95%), and *Drymaria cordata* (13.34%). Furthermore, the highest Important Value Index (IVI) in stone mining was *D. sanguinalis* (L.) Scop. (20.74 %), *Alternanthera sessilis* (L.) R. Br. ex D (12.57%), and *Chromolaena odorata* (12.36%) (Table 1). The IVI can describe the role of a species in the ecosystem; the high IVI indicates that the species greatly affects the stability of the ecosystem (Fachrul 2007; Wijana 2014).

The *D. sanguinalis* (L.) Scop. was a species that have high dominance in all types of land use. This species belongs to the Poaceae family, which has a high tolerance for disturbance, is resistant to dry, hot, and highly competitive conditions, also known as an agricultural weed (Jones 2021; Kanupriya 2021). Dominance of *D. sanguinalis* (L.) Scop. was also reported in Wonogiri Indonesia (Solikhatun et al. 2019). This species contains phytotoxic substances that exhibit several types of bioactivities such as anti- inflammatory and antifungal (Kanupriya et al. 2021). Its

Table 1. The Five Highest Important Value Index (IVI) for each land-use type in Ledokombo District.

Landuse Type	Species	IVI (%)
Mixed Garden	*Digitaria sanguinalis* (L.) Scop.	26.54
	Commelina erecta	14.72
	Oplismenus undulatifolius	10.4
	Synedrella nodiflora	9.28
	Peperomia pellucida	8.00
Sand Mining	*Commelina erecta*	17.56
	Digitaria sanguinalis (L.) Scop.	13.95
	Drymaria cordata	13.34
	Eleusine indica	12.19
	Perilla frutescen	10.49
Stone Mining	*Digitaria sanguinalis* (L.) Scop.	20.74
	Alternanthera sessilis (L.) R. Br. ex D	12.57
	Chromolaena odorata	12.36
	Tithonia diversifolia	10.4
	Commelina erecta	9.3

high distribution and abundance could be utilized to explore its benefit and reduce its role as a weed. Meanwhile, *C. erecta* has the highest IVI in sand mining and ranks second in mixed gardens. This species also has a high adaptability and can be used as an environmental parameter to see the level of pollution (Tongo et al. 2021).

In addition to *D. sanguinalis* (L.) Scop and *C. erecta*, the species with the highest IVI values in the three landuses were quite varied, landuse differences being the main factor. However, other species that have a high IVI are dominated by Asteraceae, such as *Synedrella nodiflora*, *Chromolaena odorata*, *Tithonia diversifolia*, these three species were found in all types of landuse. Asteraceae is known as a family that has a high variety of species and spreads in almost every type of habitat.

The Dominance index (D) in mixed gardens, sand mining, and stone mining shows almost similar values (0.07, 0.07, and 0.07) (Table 2). The dominance index ranges from 0 – 1; the smaller the value indicates the absence of a dominating species, while the closer to 1 indicates the dominance of certain species in an ecosystem (Odum 1971). The three land-use types show species dominance in the low category, which means that no particular species dominate in the three land-use types.

The Simpson Index (D') in three types of *Gumuk* land use showed the same value (0.92) (Table 2). This indicates that the complexity of the community in the *Gumuk* ecosystem is relatively high (Odum 1971). Likewise, the Shannon Wiener index (H') showed the same value for the three types of *Gumuk* (>3) (Table 1), which indicates that the species diversity of herb in the *Gumuk* ecosystem is in the high category (Odum 1971). The difference in land use types does not affect the diversity of herbaceous species; even though the ecosystem is disturbed, it still has a relatively wide variety of species. This is also supported by another report that the stability of herb composition was shown to be related to species richness before disturbance (Kermavnar et al. 2021). Before the disturbance, *Gumuk* was initially used for plantations and the plant diversity was quite complex. Even though there are mining activities, it is possible that the plant species could still survive.

Abiotic parameters (Table 3) in each land use type also show slight differences; the difference is quite visible in light intensity. In mixed gardens, the light intensity is lower due to the tree stands. Soil humidity in mixed gardens is higher than the two landuses, this soil moisture will determine the availability of water in the soil for plant growth. Several

Table 2. Diversity index for each type of land use in Ledokombo District.

Diversity Index	Mixed Garden	Sand Mining	Stone Mining
Dominance (D)	0.07	0.07	0.07
Simpson_(1-D)	0.92	0.92	0.93
Shannon (H)	3.25	3.03	3.18
Evennes (eH/S)	0.23	0.45	0.50

Table 3. Abiotic parameters in each type of land use in Ledokombo District.

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

families were noted to have significance on soil moisture and pH (Irakiza et al. 2022). The large number of stands in the mixed garden causes low light intensity, this makes the high soil moisture in this area higher than the others. These abiotic parameters were taken from each observation plot in the morning, afternoon, and evening.

Evenness index (E) showed different values in the three types of land use. The mixed garden was 0.23, sand mining was 0.45, and stone mining was 0.50. The evenness of species was in a low category in the diverse park, while in sand mining and stone mining, the evenness of species is in the moderate category. Evenness index value (E) ranged between 0 – 1. The value closer to 1 indicates that all species have an even abundance (Odum 1971; Magurran 1988).

CONCLUSIONS

There are 136 *Gumuk* in Ledokombo District; Ledokombo, Lembengan, and Suren villages have 51% of the total *Gumuk* in Ledokombo District. In mixed gardens, 109 species were found, indicating that herb diversity was twice as great as that of sand mining (46 species) and rock mining (48 species). The *D. sanguinalis* (L.) Scop. has highest IVI value in two types of *Gumuk*, including mixed gardens (26.54%) and stone mining (20.74%). While in sand mining, the highest IVI is *C. erecta* (17.56%). The Dominance index in the three types of *Gumuk* showed low category. The complexity of the herb community in the *Gumuk* ecosystem can be categorized as high (D' = 0.9), as well as the level of species diversity (H' > 3). Meanwhile, the evenness level of herbaceous species in the mixed gardens (E = 0.2) was lower than in sand mining (E = 0.4) and stone mining (E = 0.5). It is essential to continuously observe changes in vegetation composition to identify demographic patterns and impacts of changes to the *Gumuk* landscape.

AUTHOR CONTRIBUTION

WM, LH, JB, and SDT drafted the concept and developed the methodology; WM and LH collected the data; WM, LH, and JB were responsible for vegetation analysis and species verification; SDT was responsible for analysing and reviewing maps; WM wrote and edit the manuscripts; LH, JB, and SDT finalised the manuscripts.

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CONFLICT OF INTEREST

This research was conducted as an effort to conserve *Gumuk*, but to develop a strategy for *Gumuk* conservation one has to deal with the personal interests of the local community as the owner of *Gumuk*.

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