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The Composition of Undergrowth Vegetation in Forest Area with the Special Purpose of Gunung Bromo, Karangayar, Central Java, Indonesia

Abdul Ghaffar Amiruddin Zaki[1], Yus Andhini Bhekti Pertiwi[2,*], Malihatun Nufus[2], Amalia Tetrani Sakya[1]

[1] Agrotechnology Program, Faculty of Agriculture, Universitas Sebelas Maret. Jl. Ir. Sutami No. 36A, Kentingan, Jebres, Surakarta 57126, Central Java, Indonesia

[2] Forest Management Program, Faculty of Agriculture, Universitas Sebelas Maret. Jl. Ir. Sutami No. 36A, Kentingan, Jebres, Surakarta 57126, Central Java, Indonesia

[*] Corresponding Author. E-mail address: yus_andhini@staff.uns.ac.id

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ABSTRACT

Data on the biodiversity is essential to support the Forest Area with the Special Purpose (KHDTK) of Gunung Bromo as an educational forest and training center. This study aimed to obtain basic information on undergrowth vegetation composition under pine stands. Furthermore, the important value index (*IVI*), species diversity index (*H'*), species richness index (*R*), and evenness index (*E*) were determined. The data was systematically obtained by marking 35 plots of 2 m × 2 m. The distance between plots was 100 m. The results showed that the undergrowth vegetation consisted of 39 species from 26 families. The habitus of undergrowth vegetation was herb (15 species), shrub (14 species), liana (3 species), fern (6 species), and palm (1 species). *Eragrostis tenerum* was the dominant species with an *IVI* of 58.84%). *Centrosema pubescens* showed an *IVI* of 18.38%, while the other species showed less than 10%. Furthermore, *H'* was classified as moderate (2.35), *R* was classified as moderate (4.69), and *E* was classified as uneven (0.64). This condition indicated that the undergrowth species that grew in KHDTK of Gunung Bromo was limited and uneven. It was considered due to inhibiting factors such as allelopathy in pine leaf litter and low light intensity. Undergrowth species that grow in KHDTK of Gunung Bromo showed several potential utilizations, such as medicinal plants (30 species), ornamental plants (9 species), food sources (5 species), forage (4 species), culture and crafts (4 species), and conservation (3 species).

1. Introduction

Forest Area with Special Purpose or *Kawasan Hutan Dengan Tujuan Khusus* (KHDTK) of Gunung Bromo is a forest area that Universitas Sebelas Maret (UNS) currently managed based on the Decree of the Minister of Environment and Forestry SK.177/MENLHK/SETJEN/PLS./4/2018. The primary purposes of this forest area are for research and education. Before being handed over to UNS, KHDTK of Gunung Bromo was a limited production forest managed by a state-owned forestry enterprise (Perum Perhutani). The main forest product was pine (*Pinus merkusii*) resin at that time. Thus, pine was the dominant tree species in KHDTK of Gunung Bromo. The covering area of the pine stand was 100.3 ha or equivalent to ± 80% of the total area.

Studies on vegetation analysis and stand biomass in KHDTK of Gunung Bromo had been reported (Ikhsan et al. 2021; Nufus et al. 2020). Nufus et al. (2020) reported that pine's volume and stand potency were 156.7 m^3/ha and 202 trees/ha. In addition, Ikhsan et al. (2021) reported that the total biomass and carbon stock in pine-mahogany mixture stands were 45.90 ton/ha and 68.57 ton C/ha. It is necessary to conduct an inventory of undergrowth vegetation because undergrowth vegetation has ecological (environmental services) and economic functions. Several studies have been reported that undergrowth vegetation has the potency to be used as food, medicine, forage, and botanical insecticides (Abdiyani 2008; Hadi et al. 2016). Djufri (2003) suggested that the presence of undergrowth vegetation could be used as an environmental indicator. In addition, undergrowth vegetation has an essential role in the forest ecosystem and microclimate (Hilwan et al. 2013). The presence of undergrowth vegetation on the forest floor act as a barrier against rainwater and surface runoff (Abdiyani 2008; Hilwan et al. 2013). Furthermore, the undergrowth litter increases the forest soil nutrients (Sabaruddin et al. 2009; Hilwan et al. 2013). Moreover, data on biodiversity is essential to support KHDTK of Gunung Bromo as the location for forestry education and training center. Thus, the composition and diversity of undergrowth vegetation must be considered.

Several studies have been conducted on undergrowth vegetation inventories in various plantation forests, such as in pine (Destaranti et al. 2017; Djufri 2003; Kunarso and Azwar 2013; Purnomo et al. 2018; Yusra et al. 2017), *Swietenia macrophylla*, *Peronema canescens*, *Schima walichii* (Kunarso and Azwar 2013), *Casuarina equisetifolia* (Atmanto et al. 2017), *Agathis alba* (Purnomo et al. 2018), *Enterolobium cyclocarpum*, and *Samanea saman* (Hilwan et al. 2013). The results of the previous research showed that species, numbers, habitus, and distribution of undergrowth were diverse. Thus, it indicated that the stand species, shade, site quality, altitude, and environmental condition create a unique and specific microclimate. Therefore, studying undergrowth vegetation is necessary.

The present study aimed to obtain basic information on the composition of undergrowth vegetation in KHDTK of Gunung Bromo. Therefore, the important value index, species diversity index, species richness index, and species evenness index of undergrowth were analyzed. In addition, the potential utilization of undergrowth was described. Therefore, data on the composition of undergrowth vegetation could support the management of KHDTK of Gunung Bromo.

2. Materials and Methods

2.1. Study Area

The study was conducted in KHDTK of Gunung Bromo, Karanganyar, Central Java (7° 34' 21.93" – 7° 35' 38.90" S and 110° 59' 40.39" – 111° 0' 49.36" E), with an altitude of 244-362 masl (**Fig. 1**). The total area of KHDTK of Gunung Bromo is 126.291 ha. The study was conducted on the mixed stands of pine (*Pinus merkusii*) and mahogany (*Swietenia macrophylla*) that were planted in the range of 1991-2007. The data was collected from May to July 2019.

The average air temperature, humidity, and light intensity at KHDTK of Gunung Bromo were 31.8°C, 71.24%, and 814 Cd, respectively. Meanwhile, the average annual rainfall was about 1,966 mm/year. The climate in KHDTK of Gunung Bromo is classified as type C with an average dry-wet month ratio of 37.5% with eight wet months, three dry months, and one humid month. In addition, the soil temperature, humidity, and pH were 26.8-30.9°C, 1.4-7.5%, and 6.4-6.9, respectively (Ikhsan et al. 2021).

2.2. Methods

The plots used in the present study were determined by systematic sampling with a random start. The sampling intensity was 0.05%. The method and sampling intensity were determined by considering the condition of KHDTK of Gunung Bromo. The forest area is a plantation forest consisting mainly of pine; therefore, the stand condition was uniform in all forest areas. The first plot was randomly determined under the pine stand, and the following plots were systematically set by 100 m in the distance. In total, 35 square plots were set up under the pine-mahogany mixture stands. The plot size was 2 m x 2 m (Destaranti et al. 2017; Indriyanto 2017; Kusmana 2017; Purnomo et al. 2018; Syahbudin et al. 2020). The number, species name, and habit were collected. The herbarium samples and photos were taken for undersigned plants and then identified at Dendrology Laboratory, Faculty of Forestry, Gadjah Mada University.

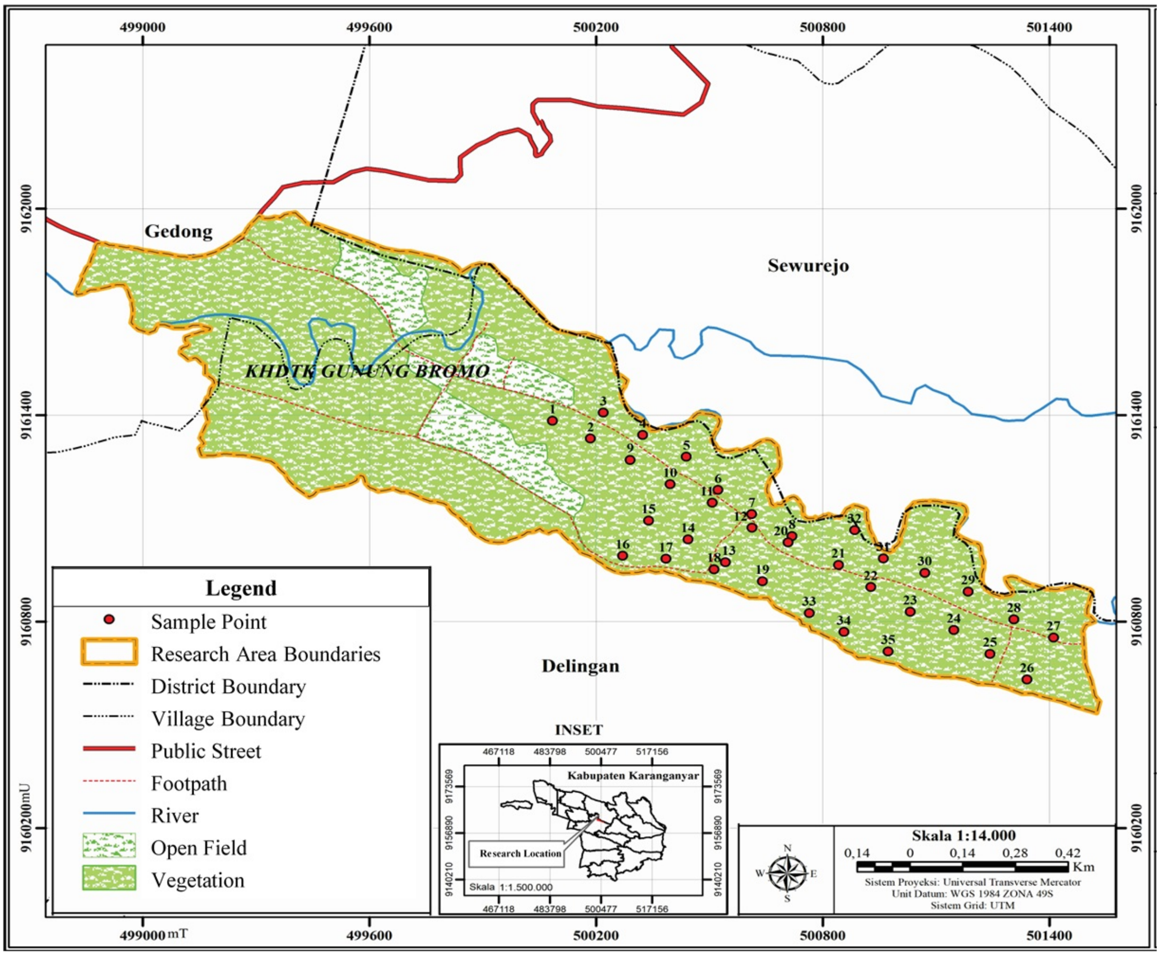

Fig. 1. Map showing the study area and plots observed in KHDTK of Gunung Bromo, Karanganyar, Central Java.

2.3. Data Analysis

The research data obtained from the plots were analyzed. Each species was analyzed using the importance value index. Furthermore, the diversity index, evenness index, and species richness index were also calculated.

2.3.1. Importance value index

The role of each undergrowth species on the ecosystem was analyzed by the important value index (*IVI*) (Purnomo et al. 2018). *IVI* was obtained by summarizing the density and frequency for each species by using the following equations (Destaranti et al. 2017; Purnomo et al. 2018; Syahbudin et al. 2020).

$$Density\ (D) = \frac{\sum individual}{Plot\ area} \tag{1}$$

$$Relative\ density\ (RD) = \frac{Species\ density}{The\ total\ density\ of\ all\ species} \times 100\% \tag{2}$$

$$Frequency\ (F) = \frac{\sum plots\ in\ which\ species\ occur}{\sum plot\ studied} \tag{3}$$

$$Relative\ frequency\ (RF) = \frac{Frequency\ of\ species}{The\ total\ frequency\ of\ all\ species} \times 100\% \tag{4}$$

$$IVI = RD + RF \tag{5}$$

2.3.2. Diversity index

Diversity Index (*H'*) was used to determine the diversity level of undergrowth species. The undergrowth diversity was analyzed by Shannon-Wiener Index (Indriyanto 2017) using the following equations:

$$H' = -\sum_i p_i \ln p_i \tag{6}$$

$$p_i = \frac{ni}{N} \tag{7}$$

where p_i is the comparison of the number of individual species with all species, n_i is the number of individual species-i, and N is the total individuals of all species. The criteria of H' are as follows: $H' \leq 1$ = low diversity, $1 < H' < 3$ = medium diversity, $H' \geq 3$ = high diversity.

2.3.3. Evenness index

Evenness index (*E*) shows how the individuals in a community are evenly distributed among the different species. The evenness index was calculated using equation 8 (Indriyanto 2017).

$$E = \frac{H'}{\ln (S)} \tag{8}$$

where S is the total species. The criteria of E are as follow: $E \leq 0.4$ = low, $0.4 < E < 0.6$ = moderate, and $E \geq 0.6$ = high.

2.3.4. Species richness index

Species richness index (*R*) is simply a measure of biodiversity. It is the measure of the total number of different species in a community or given area. The undergrowth species richness index was determined by the Margalef index (Indriyanto 2017) as follows:

$$R = \frac{S - 1}{\ln N} \tag{9}$$

where S is the number of species and N is the number of individual species. The criteria of R are as follows: $R \leq 3.5$ = low, $3.5 < R < 5$ = moderate, and $R \geq 5$ = high.

3. Results and Discussion

3.1. Composition of Undergrowth Vegetation

Table 1 shows the composition of undergrowth vegetation under the pine stand in KHDTK of Gunung Bromo.

Table 1. Composition of undergrowth vegetation in KHDTK of Gunung Bromo

No	Species	Family	Habitus
1	*Artabotrys hexapetalus*	Annonaceae	Shrub
2	*Rauvolfia serpentina*	Apocynaceae	Shrub
3	*Philodendron hederaceum*	Araceae	Herb
4	*Caryota mitis*	Arecaceae	Palm
5	*Eupatorium odoratum*	Asteraceae	Shrub
6	*Cosmos caudatus*	Asteraceae	Herb
7	*Melanthera biflora*	Asteraceae	Herb
8	*Mikania micrantha*	Asteraceae	Herb
9	*Sarcandra glabra*	Cloranthaceae	Herb
10	*Costus spicatus*	Costaceae ·	Herb
11	*Vitis pentaphylla*	Cucurbitaceae	Herb
12	*Cyperus rotundus*	Cyperaceae	Herb
13	*Tetracera scandens*	Dilleniaceae	Liana
14	*Dioscorea alata*	Dioscoreaceae	Herb
15	*Mimosa pudica*	Fabaceae	Shrub
16	*Centrosema pubescens*	Fabaceae	Herb
17	*Flemingia macrophylla*	Fabaceae	Shrub
18	*Lygodium flexosum*	Lygodiaceae	Fern
19	*Lygodium palmatum*	Lygodiaceae	Fern
20	*Urena lobata*	Malvaceae	Shrub
21	*Clidemia hirta*	Melastomataceae	Shrub
22	*Melastoma affine*	Melastomataceae	Shrub
23	*Nephrolepis cordifolia*	Neprolepidaceae	Fern
24	*Bougainvillea sp.*	Nyctaginaceae	Shrub
25	*Bridelia stipularis*	Phyllantaceae	Liana
26	*Sauropus androgynus*	Phyllantaceae	Shrub
27	*Peperomia pellucida*	Piperaceae	Herb
28	*Eragrostis tenerum*	Poaceae	Herb
29	*Ischaemum timorense*	Poaceae	Herb
30	*Pteris latipinna*	Pteridaceae	Fern
31	*Adiantum pidatum*	Pteridaceae	Fern
32	*Pteris ensiformis*	Pteridaceae	Fern
33	*Ziziphus elegans*	Rhamnaceae	Shrub
34	*Chassalia curviflora*	Rubiaceae	Shrub
35	*Ixora javanica*	Rubiaceae	Shrub
36	*Meyna spinosa*	Rubiaceae	Shrub
37	*Tacca palmata*	Taccaceae	Herb
38	*Cayratia pedata*	Vitaceae	Liana
39	*Zingiber officinale*	Zingiberaceae	Herb

The undergrowth consisted of 39 species from 26 families. Based on their habitus, the undergrowth is classified as herbs (15 species), shrubs (14 species), lianas (3 types), ferns (6 species), and palms (1 species). Similar research has been conducted in the other pine forest area (Destaranti et al. 2017; Djufri 2003; Kunarso and Azwar 2013; Purnomo et al. 2018; Yusra et al. 2017). In the pine forest owned by PT. Inhutani IV Aceh Besar, there was 66 species undergrowth

(Djufri 2003). Destaranti et al. (2017) reported that 32 and 19 species undergrowth under pine stands in RPH Kalirajut and RPH Baturaden Tengah. Yusra et al. (2017) reported that 25 species undergrowth were identified in Tahura Pocut Meurah Intan. The differences in undergrowth composition in various pine forest areas as mentioned above can be understood as a result of the combination of main vegetation types, canopy cover, microclimate, soil quality, and topographic conditions (slope and height).

The number, density, relative density, frequency, relative frequency, and *IVI* of each undergrowth species are shown in **Table 2**. *Eragrostis tenerum* was dominant species (IVI 58.84%). The high *IVI* indicated that the species could control and show high adaptability rather than other species (Lubis 2008; Nurkhotimah et al. 2017; Siappa et al. 2016). Abdiyani et al. (2008) also emphasized that the dominant species is essential, especially in terms of environmental conditions and the existence of other species. In addition, several dominant species with high adaptability are invasive (Solfiyeni et al. 2016). This trait makes plants dominate an area and suppress the growth of other plants around them through growth competition (Tjitrosoedirdjo et al. 2016).

Eragrostis tenerum belongs to Poaceae. Several researchers also reported that the dominant undergrowth species grown in pine stands belonged to Poaceae (Destaranti et al. 2017; Djufri 2003; Kunarso and Azwar 2013; Yusra et al. 2007). Djufri (2003) reported that *Oplismenus burmanii* showed *IVI* of 61.26% in pine plantations in Aceh Besar. In addition, Yusra et al. (2007) reported that *Panicum repens* (*IVI* 31.57%) was the most common species found under pine stands in Tahura Pocut Meurah Intan, Aceh Besar. Destaranti et al. (2017) reported that 9 species of undergrowth belonging to Poaceae grew under pine stands in Forest Management Unit (KPH) Kalirajut. Kunarso and Azwar (2013) reported that *Cyrtococcum accrescens* (IVI 56.18%) was the dominant species that grows under pine stand in KHDTK Benakat, South Sumatra. Poaceae lived in various habitats due to their high adaptability (Destaranti et al. 2017). The pine canopy was relatively light; therefore, the forest floor was quite suitable, especially in light intensity. In addition, the Poaceae that became dominant might be due to their capability to cope with pine allelopathy.

Centrosema pubescens showed an *IVI* of 18.38%. *C. pubescens* are long-lived legumes that grow twisted and spread, resistant to dry conditions, and can live in the shade and inundated land (Indriani et al. 2019). Indriani et al. (2019) also reported that forage production and quality were higher by planting *C. pubescens* in the same location. In addition, as a legume, *C. pubescens* can fix nitrogen from the air, and the litter act as a nutrient source. Therefore, the *C. pubescens* growth has a beneficial impact on the main forest stand.

The other species shows an *IVI* of less than 10%. The low *IVI* indicated that the species has poor adaptation to local environmental factors (Siappa et al. 2016). This condition was presumably because pine leaf litter mostly covered the forest floor. The pine leaf litter is difficult to decompose and contains high allelopathy. Allelopathy often has inhibitory or contributory effects on seed germination and plant growth (Rice 1984).

Table 2. Density, relative density, frequency, relative frequency, and importance value index of undergrowth vegetation in KHDTK of Gunung Bromo

No	Species	*D*	*RD* (%)	*F*	*RF* (%)	*IVI* (%)
1	*Artabotrys hexapetalus*	0.25	0.03	0.03	0.35	0.38
2	*Rauvolfia serpentina*	13.50	1.64	0.17	2.08	3.72
3	*Philodendron hederaceum*	2.50	0.30	0.14	1.73	2.03
4	*Caryota mitis*	3.75	0.46	0.11	1.38	1.84
5	*Eupatorium odoratum*	23.00	2.79	0.31	3.81	6.60
6	*Cosmos caudatus*	9.75	1.18	0.23	2.77	3.95
7	*Melanthera biflora*	12.00	1.46	0.03	0.35	1.80
8	*Mikania micrantha*	6.00	0.73	0.06	0.69	1.42
9	*Sarcandra glabra*	8.75	1.06	0.17	2.08	3.14
10	*Costus spicatus*	5.00	0.61	0.06	0.69	1.30
11	*Vitis pentaphylla*	13.25	1.61	0.40	4.84	6.45
12	*Cyperus rotundus*	27.00	3.28	0.17	2.08	5.36
13	*Tetracera scandens*	12.50	1.52	0.17	2.08	3.59
14	*Dioscorea alata*	29.25	3.55	0.49	5.88	9.44
15	*Mimosa pudica*	5.00	0.61	0.06	0.69	1.30
16	*Centrosema pubescens*	62.25	7.56	0.89	10.73	18.29
17	*Flemingia macrophylla*	6.00	0.73	0.06	0.69	1.42
18	*Lygodium flexosum*	19.50	0.91	0.23	2.77	3.68
19	*Lygodium palmatum*	5.75	0.67	0.11	2.77	3.44
20	*Urena lobata*	21.50	0.70	0.34	1.38	2.08
21	*Clidemia hirta*	3.25	2.61	0.09	4.15	6.76
22	*Melastoma affine*	2.50	0.39	0.06	1.04	1.43
23	*Nephrolepis cordifolia*	0.25	2.37	0.03	2.77	5.14
24	*Bougainvillea sp.*	4.50	0.30	0.29	0.69	1.00
25	*Bridelia stipularis*	1.00	0.03	0.06	0.35	0.38
26	*Sauropus androgynus*	391.50	0.55	0.91	3.46	4.01
27	*Peperomia pellucida*	32.25	0.12	0.40	0.69	0.81
28	*Eragrostis tenerum*	29.25	47.56	0.40	11.07	58.63
29	*Ischaemum timorense*	0.50	3.92	0.03	4.84	8.76
30	*Pteris latipinna*	7.50	3.55	0.23	4.84	8.40
31	*Adiantum pidatum*	21.50	0.06	0.23	0.35	0.41
32	*Pteris ensiformis*	5.50	2.61	0.23	2.77	5.38
33	*Ziziphus elegans*	1.25	0.15	0.09	1.04	1.19
34	*Chassalia curviflora*	7.75	0.94	0.20	2.42	3.36
35	*Ixora javanica*	7.75	0.94	0.14	1.73	2.67
36	*Meyna spinosa*	0.50	0.06	0.03	0.35	0.41
37	*Tacca palmata*	3.75	0.46	0.11	1.38	1.84
38	*Cayratia pedata*	9.00	1.09	0.20	2.42	3.52
39	*Zingiber officinale*	7.25	0.88	0.31	3.81	4.69
	Total	823.25	100.00	8.26	100.00	200.00

Notes: Σ = number of individual, *D* = density, *RD* = relative density, *F* = frequency; *RF* = relative frequency, *IVI* = important value index.

The species diversity index (*H'*) was classified as moderate (**Table 3**). Higher diversity index (*H'* > 3) indicated that the vegetation community was stable (Wirakusumah 2003). Thus, the undergrowth vegetation in KHDTK of Gunung Bromo was heading towards a more stable condition. The species richness index (*R*) was also classified as moderate. This condition was presumably due to some limiting growth factors, for example, environmental factors such as altitude, soil conditions, temperature, light intensity, and rainfall (Siappa et al. 2016). In the present study, allelopathy in pine leaf litter and light intensity were suspected as the main limiting factors.

In addition, the evenness index (*E*) was considered uneven, indicating that the distribution of individual species was uneven.

Table 3. Species diversity index, species richness index, and evenness index of undergrowth vegetation in KHDTK of Gunung Bromo

Index	Score	Category
Species Diversity Index (H')	2.35	Moderate
Species Richness Index (R)	4.69	Moderate
Evenness Index (E)	0.64	Uneven

3.2. Potential Utilization of Undergrowth Vegetation

Table 4 shows the potential utilization of undergrowth vegetation in KHDTK of Gunung Bromo based on various references. Several species might show several potential utilizations. The greatest potential utilization of undergrowth was as medicinal plants (30 species), such as *E. oderatum*, *C. caudatus*, *C. spicatus*, *C. rotundus*, *M. pudica*, and *P. pellucida*. These herbs have potential utilization for minor diseases (colds, stomachache, diarrhea, and cough) and chronic diseases (diabetes, lung, liver, and cancer).

Table 4. Potential utilization of undergrowth vegetation in KHDTK of Gunung Bromo

No	Species	Potential utilization
1	*Artabotrys hexapetalus*	Medicinal plants produce aromatherapy oil[1]
2	*Rauvolfia serpentina*	Medicines to prevent fever, sedatives, hypertension[2]
3	*Philodendron hederaceum*	Ornamental plant[3]
4	*Caryota mitis*	Decorative plant, leaves contain antioxidants[4]
5	*Eupatorium odoratum*	Gout, rheumatism, antimicrobial, anti-hepatitis, colds, headaches, and fever[5]
6	*Cosmos caudatus*	Food[6], ornamental plants[7], antioxidants and decreased glucose levels in blood[8]
7	*Melanthera biflora*	Medicinal plants[9]
8	*Mikania micrantha*	Medicinal plants[10,39], bioherbiside[11]
9	*Sarcandra glabra*	Medicinal plants[12]
10	*Costus spicatus*	Medicinal plants[12,13,39]
11	*Vitis pentaphylla*	Medicinal plants for diabetes mellitus, detoxification, cough medicine, anti-inflammatory, chronic bronchitis[14]
12	*Cyperus rotundus*	Stomach pain medication, worm medicine, facilitate urination, hormonal cycles, ulcers, wounds, ulcers, nausea[15]
13	*Tetracera scandens*	Medicinal plants[16]
14	*Dioscorea alata*	Food[17]
15	*Mimosa pudica*	Asthma medication, worm medicine, kidney stone medicine, dysentery, hemorrhoids, jaundice, leprosy[18,39]
16	*Centrosema pubescens*	Forage[19]
17	*Flemingia macrophylla*	Rheumatism drugs, joint disorders, and nephritis (root). Cosmetics, deworming, cough and cold (pods), rheumatism and inflammation (stems)[18]
18	*Lygodium flexosum*	Ornamental plants[20]
19	*Lygodium palmatum*	Foods, handicrafts, organic fertilizers, medicinal plants[21]
20	*Urena lobata*	Medicines for param[22], drugs for malaria, gonorrhea, rheumatism, wounds, and fever[23]

No	Species	Potential utilization
21	*Clidemia hirta*	Forage and ulcers medicine[24,39]
22	*Melastoma affine*	Diarrhea medication, maintaining stamina, colitis, mouth sores, seizures[25]
23	*Nephrolepis cordifolia*	Food, medicinal plants, ornamental plants[26]
24	*Bougainvillea sp.*	Medicinal plants, ornamental plants, traditional events[27]
25	*Bridelia stipularis*	Medicinal plants, relieve cough, asthma, allergies, jaundice, malaria, scabies, allergies, anemia, natural dyes[28]
26	*Sauropus androgynus*	Food especially adequacy of breastfeeding, forage[27,39]
27	*Peperomia pellucida*	Medicinal and ornamental plants[27,39]
28	*Eragrostis tenerum*	Forage[29]
29	*Ischaemum timorense*	Forage, preventing environmental erosion[30]
30	*Pteris latipinna*	Ornamental plants[31]
31	*Adiantum pidatum*	Ornamental plants[31]
32	*Pteris ensiformis*	Food, handicrafts, organic fertilizers, medicinal plants[33]
33	*Ziziphus elegans*	Medicinal plants[34]
34	*Chassalia curviflora*	Medicinal plants[35]
35	*Ixora javanica*	Medicinal (abdominal pain medication and facilitate labor), ornamental plant[16,27]
36	*Meyna spinosa*	Medicinal plants, medicines for skin infections, headaches, diabetes, dysentery, indigestion, stomach worms, liver disorders[36]
37	*Tacca palmata*	Febrifuge for children, especially for infants[37]
38	*Cayratia pedata*	Antioxidants, anticancer, ulcer drugs, herbs for women who were giving birth[38]
39	*Zingiber officinale*	Reducing hypertension, nausea, stomach cramps, bloating, headaches[22]

Notes: [1]Puri (2020); [2]Haryudin (2013); [3]Nainwal (2019); [4]Abdelhakim et al. (2017); [5]Fernandez et al. (2018); [6]Aziz (2012); [7]Megawati et al. (2017); [8]Sahid and Murbawani (2016); [9]Rosyada et al. (2018); [10]Samsuar et al. 2018); [11]Pebriani et al. (2013); [12]Uji (2002); [13]Susanti et al. (2018); [14]Li et al. (2016); [15]Nurjanah et al. (2018); [16]Nursanti et al. (2018); [17]Yusuf et al. (2016); [18]Widodo et al. (2018); [19]Pasaribu and Praptiwi (2014); [20]Yadav et al. (2012); [21]Hasan et al. (2016); [22]Hadi et al. (2016); [23]Kusuma dan Suryani (2017); [24]Rahayu et al. (2007); [25]Samad et al. (2018); [26]Gauchan et al. (2008); [27]Haryanti et al. (2015); [28]Yusufzai et al. (2019); [29]Sarwanto et al. (2015); [30]Widhyastini et al (2012); [31]Purnawati et al. (2014); [32]Sastrapradja et al. (1979); [33]Effendi and Lailathy (2016); [34]Mustika et al. (2014); [35]Rianti et al. (2019); [36]Sen and Chakraborthy (2017); [37]Lamxay et al. (2011); [38]Rumayati et al. (2014); [39]Mayangsari et al. (2019).

There were 9 species that had the potential to be developed as ornamental plants (**Table 4**). Those species belonged to Asteraceae, Nyctaginaceae, and Pteridaceae families. Asteraceae and Nygtaginaceae are well known for their beautiful flowers. However, even though Pteridaceae (fern) do not have flowers, they have diverse leaves and high aesthetic value (Sriastuti et al. 2018; Sukarsa et al. 2011), such as *P. latipinna*, *A. pidatum*, and *L. flexosum* (**Table 4**).

Furthermore, there were 5 species that had the potential to be utilized as food, namely *D. alata*, *N. cordifolia*, *S. androgynous*, *P. ensiformis,* and *L. palmatum* (**Table 4**). *S. androgynous* is a vegetable and food coloring agent (Juliastuti 2019), while *D. alata* is an essential species for functional food and food diversification (Yusuf et al. 2016). Meanwhile, *N. cordifolia*, *P. ensiformis*, and *L. palmatum* are the source of vegetables (Astuti et al. 2018).

C. pubescens, *E. tenerum*, *I. timorense*, and *C. hirta* were potentially used as forage (**Table 4**). *C. pubescens* was used as a mixed crop or as the secondary plant in the pasture. Several researchers reported that *C. pubescens* improve forage quality, especially protein content (Indriani et al. 2019; Pasaribu and Praptiwi 2014).

In addition, some herbs were potentially used for cultural ceremonies/handicrafts (4 species) and environmental conservation (3 species) (**Table 4**). For example, *Bougainvillea* sp. is widely used as an ornamental plant. However, it is also used in traditional ceremonies (Haryanti et al. 2015). This study shows that KHDTK of Gunung Bromo stores natural resources, not only wood but also undergrowth, as a source of medicinal and ornamental plant, food (fruit, seeds, and leaves), forage, and others.

4. Conclusions

There were 39 species of undergrowth from 26 families found under pine stands in KHDTK of Gunung Bromo. The highest *IVI* was shown by *E. tenerum* (58.84%), indicating that this species dominated the undergrowth composition. In addition, *C. pubescens* showed an IVI of 18.38%, while the other species showed less than 10%. Species diversity index (*H'*), species richness index (*R*), and evenness index (*E*) were 2.35, 4.69, and 0.64, respectively. This condition indicated that the undergrowth species grown in KHDTK of Gunung Bromo was limited and uneven. It was considered due to inhibiting factors such as allelopathy in pine leaf litter and low light intensity. The study also showed that undergrowth species grown in KHDTK of Gunung Bromo had potential utilization mainly for medicinal and ornamental plants, food sources, and forage.

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