REINWARDTIA
Vol. 22. No. 1. pp: 37–53
DOI: 10.55981/reinwardtia.2023.4565

FLORISTIC COMPOSITION AND STRUCTURE OF VEGETATION IN GUNUNG SALAK GEOTHERMAL POWER PLANT, WEST JAVA, INDONESIA

Received March 28, 2023; accepted May 25, 2023

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ABSTRACT
IRAWAN, A., PENIWIDIYANTI, AINURROFIAH, DESTRIANTO, H., KUSUMAH, M. & APRIANDANA, V. 2023. Floristic composition and structure of vegetation in Gunung Salak geothermal power plant, West Java, Indonesia. *Reinwardtia* 22(1): 37–53. — This research had been conducted in the forest area around the Gunung Salak Geothermal Power Plant of PT. PLN Indonesia Power. Plant diversity data in the geothermal power plant area had yet to be fully available. This study aimed to analyze the composition and structure of vegetation in the conservation forest area around the Gunung Salak Geothermal Power Plant unit. This study used a quadrat plot with a purposive sampling method. We sampled 873 individuals from 56 families of 110 species, consisting of native and introduced species. Some introduced flora species that have the potential to become invasive include *Calliandra houstoniana*, *Asystasia gangetica*, *Bellucia pentamera*, *Miconia crenata*, *Maesopsis eminii*, and *Solanum torvum*. The families with the highest number of species at each growth level were Fagaceae (tree), Fagaceae (pole), Arecaceae and Moraceae (sapling), also Acanthaceae, Arecaceae, Melastomataceae, and Poaceae in the understory. Several species of plant at the site are listed as Endangered (EN) based on the IUCN Red List, including *Alpinia scabra*, *Castanopsis argentea*, and *Dipterocarpus hasseltii*. These endangered plants are expected to become priority for conservation strategies and action plans. The Important Value Index (IVI) analysis shows different values at each growth stage. The highest IVI at the seedling and herb was *Selaginella plana* (29.74), the sapling was *Macaranga triloba* (20.59), the pole was *Ficus fistulosa* (43.27), and the tree was *Schima wallichii* (54.90). The value of the Shannon-Wiener (H') diversity index was 3.784, which indicates that the level of diversity is high.

Key words: Conservation, *Dipterocarpus hasseltii*, endangered, Halimun-Salak, Importance Value Index.

ABSTRAK
IRAWAN, A., PENIWIDIYANTI, AINURROFIAH, DESTRIANTO, H., KUSUMAH, M. & APRIANDANA, V. 2023. Komposisi dan struktur vegetasi di pembangkit listrik tenaga panas bumi Gunung Salak, Jawa Barat, Indonesia. *Reinwardtia* 22(1): 37–53. — Penelitian ini telah dilaksanakan di kawasan hutan di sekitar Pembangkit Listrik Tenaga Panas Bumi (PLTP) Gunung Salak, PT. PLN Indonesia Power. Data keanekaragaman tumbuhan di daerah pembangkit listrik tenaga panas bumi belum sepenuhnya tersedia. Penelitian ini bertujuan untuk menganalisis komposisi dan struktur vegetasi kawasan hutan konservasi di sekitar unit PLTP - Gunung Salak. Penelitian ini menggunakan kuadrat plot dengan metode *purposive sampling*. Sampel individu tumbuhan terkumpul sebanyak 873 yang termasuk ke dalam 56 suku dari 110 jenis. Jenis flora tersebut terdiri dari jenis asli dan jenis asing. Beberapa jenis tumbuhan asing yang berpotensi menjadi invasif adalah *Calliandra houstoniana, Asystasia gangetica, Bellucia pentamera, Miconia crenata, Maesopsis eminii,* dan *Solanum torvum.* Suku tumbuhan dengan jumlah jenis terbanyak pada tiap tingkat pertumbuhan yaitu; Fagaceae (pohon), Fagaceae (tiang), Arecaceae dan Moraceae (pancang), serta Acanthaceae, Arecaceae, Melastomataceae, dan Poaceae pada tumbuhan bawah. Beberapa jenis tumbuhan di lokasi tersebut berstatus *Endan-*

gered (EN) berdasarkan IUCN *Redlist*, antara lain *Alpinia scabra*, *Castanopsis argentea*, dan *Dipterocarpus hasseltii*. Tumbuhan yang terancam punah ini diharapkan menjadi jenis tumbuhan prioritas untuk strategi dan rencana aksi konservasi. Analisis indeks nilai penting (INP) menunjukkan nilai yang berbeda pada setiap tahap pertumbuhan. Nilai INP tertinggi pada semai dan herba yaitu *Selaginella plana* (29,74), pancang yaitu *Macaranga triloba* (20,59), tiang yaitu *Ficus fistulosa* (43,27), dan pohon yaitu *Schima wallichii* (54,90). Nilai indeks keanekaragaman Shannon-Wiener (H') sebesar 3,784, yang menunjukkan bahwa tingkat keanekaragamannya tinggi.

Kata kunci: *Dipterocarpus hasseltii,* genting, Halimun-Salak, Indeks Nilai Penting, konservasi.

INTRODUCTION

Gunung Halimun Salak National Park (GHSNP) is the largest tropical mountain rainforest conservation area on Java Island, with more than 700 species of plants that can be found (Prasetio *et al*., 2022). It is divided into several zone classifications, including utilization zones within conservation areas with natural potential that can be utilized for tourism purposes and utilization of other environmental services (Ministry of Forestry Regulation No. 56 of 2006). Now, one of the geothermal potentials around Mount Salak has been utilized and managed by PT PLN Indonesia Power since 1994 under the Geothermal Environmental Services Management Permit (*Izin Pemanfaatan Jasa Lingkungan Panas Bumi* (IPJLPB)) that has been issued. Various conservation activities, such as planting and maintaining conservation areas and monitoring biodiversity have been carried out for corporate social responsibility for the sustainability of forest ecosystems around the geothermal power plant unit (Peniwidiyanti *et al*., 2021). The condition of the mountain rainforest ecosystem around the Gunung Salak Geothermal Power Plant unit must be managed to remain the best and most sustainable.

Basic studies regarding the condition of the cover area around geothermal in Indonesia are generally carried out as a preliminary study before exploring the source location of the power plant. The methods commonly used are based on remote sensings, such as Enhanced Vegetation Index (EVI) using Landsat 8 imagery in the Ungaran Mount geothermal area (Nugroho & Domiri, 2015) or identifying using the Normalized Difference Vegetation Index (NDVI) method in Lampung (Immanuel *et al.,* 2019). Whereas in the Gunung Salak Geothermal Power Plant unit, the biodiversity studies that have been published include the diversity of bird species and herpetofauna particularly (Husodo *et al*., 2020; Megantara *et al*., 2022). Studies on detailed plant diversity for the forest area around the geothermal area have yet to be available and published in Indonesia. Whereas research on the diversity of the composition and structure of plants around geothermal areas is very important as basic information for evaluating conservation area management and as an indicator of the health of mountain rainforest ecosystems. So, this research needs to collect information about the diversity of plant species around the geothermal area. This study aimed to analyze the composition and structure of the vegetation in the conservation forest area around the Gunung Salak Geothermal Power Plant unit.

MATERIALS AND METHODS

Study Area

The research was conducted from April to May 2022 in the Gunung Salak Geothermal Plant conservation forest at PT. PLN Indonesia Power. The coordinates position 6°44'25.6” S and 106°38'35.6” E (Fig. 1). PT. PLN Indonesia Power has generation units and services in Kamojang and Gunung Salak. The Gunung Salak power plant unit is inside the conservation area of the Gunung Halimun Salak National Park (GHSNP). Observations were made at 960–1,028 m asl with an air temperature of 23–32°C, humidity of 23–32%, and soil pH 6.2–7.5. The topography of the research site is slightly flat and uphill, covering an area that are slightly open to densely covered by vegetation.

The research was conducted on the Eastern and Western sides of the geothermal unit (Fig. 1). The whole forest area can originally be defined as a primary forest. However, the forested area was affected by the geothermal power plant development. The Eastern and Western forests have slightly different contours and are separated mostly by infrastructure, such as office buildings, roads, bridges, power plants, cooling towers, and steam pipelines. A rocky stream crosses the eastern forest. The contours of the Eastern forest are ridges, valleys, and cliffs. The Western forest has a larger area than the Eastern side and is bordered by rivers. In this forest, the land condition at some points is low slopes, ridges, and valleys with cliffs at some points that are difficult to access. The company introduced a replanting program in several cleared areas to maintain the forested area, as shown in Fig. 1. The replanting program was conducted from 2017 to 2021; every planted individual was labeled (Peniwidiyanti *et al.,* 2021) and monitored. Thus, planted individuals and naturally regenerated individuals can be easily distinguished. The species used for replanting were *Schima wal-*

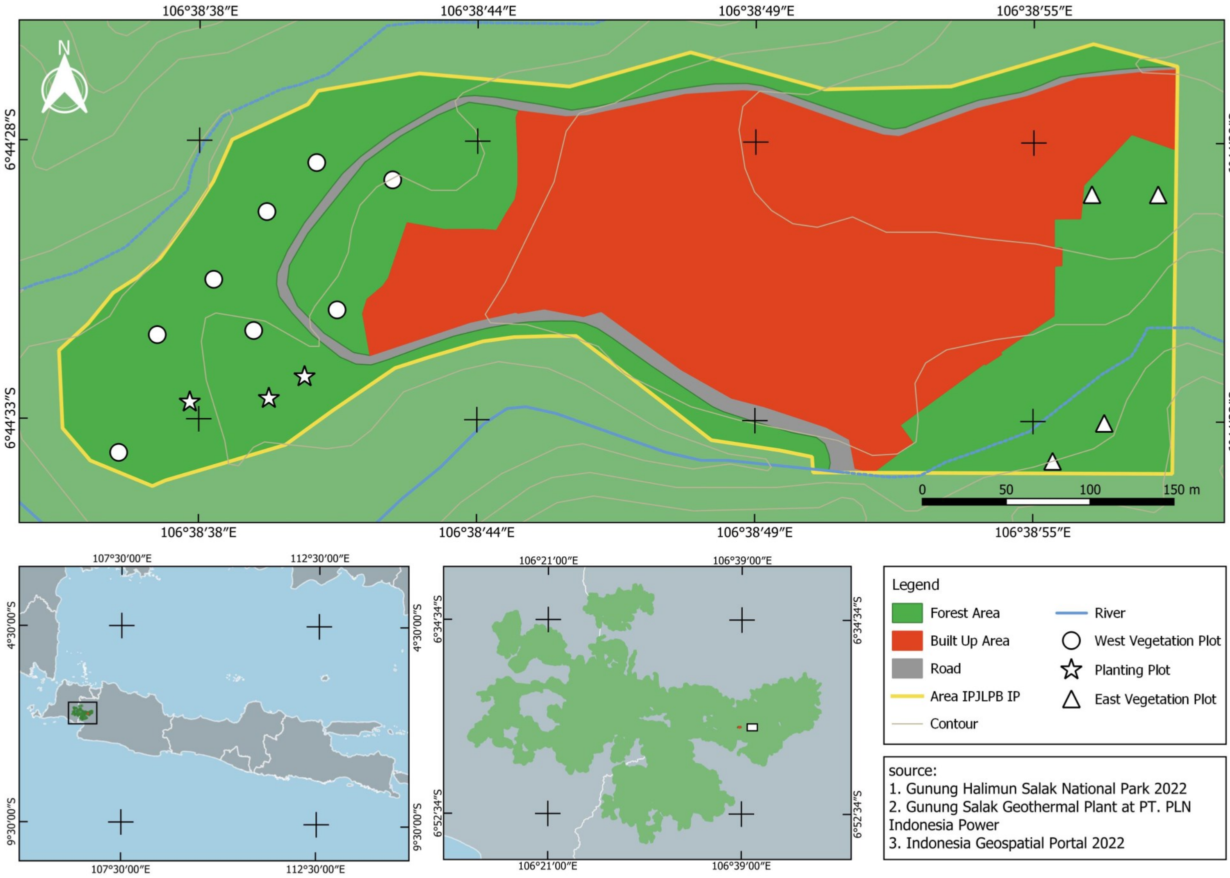


Fig. 1. Study area on Gunung Salak Geothermal Plant at PT. PLN Indonesia Power.

lichii, *Liquidambar excelsa*, *Litsea* spp., *Syzygium lineatum,* and *Castanopsis argentea.*

Data Collection

Vegetation data were collected using a quadratic plot method (Mueller-Dombois & Ellenberg, 1974). Fifteen (15) plots were made, 11 on the western and four on the eastern side. Three (3) of the western side plots were located in the replanting areas. The coordinate of all plot's location was then recorded. The observation plot size was 20 m × 20 m and located by using purposive sampling methods. Each plot was divided into four sub-plots to measure vegetation based on growth stages. Observation plot measuring 20 m × 20 m for tree, 10 m × 10 m for pole, 5 m × 5 m for sapling and shrub, and 2 m × 2 m for understory as seedling and herb. Each plant in the plot was recorded for the species name, the number of individuals, and stem diameter at breast height (DBH) using a diameter tape, then as a sapling or tree. For identification purposes, we collected leaves, twigs, fruit, and flower of the plant in the plots, photographed each directly in the field for each specimen and made some herbarium.

Species identification is needed to know the scientific names of plant species. The following references were used in the species identification process referring to the Mountain Flora of Java (van Steenis, 1971), A Picture Guide of Forest Trees in Gunung Gede Pangrango National Park, Indonesia (Toyama *et al*., 2018), Flora of Java (Backer & van den Brink Jr, 1963; Backer & van den Brink Jr, 1965; Backer & van den Brink Jr, 1968), and Plant of Southeast Asia (Slik, 2009). Validation of scientific species names and distribution refers to Plant of the World Online (POWO, 2022).

Distribution status is categorized as either native or introduced species. Native plant species occur naturally in a specific region without human intervention or other region's introduction. Introduced plant species, also known as non-native plant species, are intentionally or unintentionally brought into a region or ecosystem from another region. Determination of native or introduced plant species refers to Plant of the World Online (POWO, 2022), Global Invasive Species Database (GISD, 2023), and Central for Agricultural and Bioscience International (CABI, 2022). The plant species that have been identified are also known for their conservation status. The conservation status was analyzed based on data from the The International Union for Conservation of Nature (IUCN) Red List, Regulation of the Minister of

Environment and Forestry No.106/2018 Regulation, and the Convention on International Trade in Endangered Species (CITES).

Data Analysis

Importance value index (IVI)

The ecological parameters were analyzed by the Importance Value Index (IVI). The IVI helped to know about significance of species in the community structure. The Importance Value Index can be calculated using the following formula (Phillips, 1959; Mueller-Dombois & Ellenberg, 1974):

Density (D) = number of individual species A/ sample plot area

Relative density (RD) = (number of individual species A/number of all individual species) × 100%

Frequency (F) = number of the plot with species A/total number of all plot

Relative frequency (RF) = (frequency of species A/total frequency of all species) × 100%

Dominance (Do) = basal area of species A/ sample plot area

Relative dominance (RDo) = (dominance of species A/total dominance of all species) × 100%

Sapling and understory calculation is IVI=RD+FR, while calculated for pole and tree is IVI=RD+RF+RDo.

Species diversity, richness, evenness, and dominance

The diversity of plant was determined using the Shannon-Wiener diversity index (Michael, 1984; Magurran, 1988) as the following formula:

$$H' = -\sum pi\,ln\,pi \quad \text{where} \quad pi = \frac{ni}{N}$$

Where, p_i is the proportion of individuals found in the i^{th} species, ni is the number of individuals of the i species, and N is the total number of individuals of all species. The diversity index shows the amount of species diversity in a habitat study. The value scale of this index is H' < 1.5, indicating that the diversity obtained is low, the value of H' 1.5–3.5 indicates that the diversity obtained is moderate, and the value of H' > 3.5 indicates that the diversity is high (Wilhm & Dorris, 1968).

Species richness was calculate using the Margallef Index (Magurran, 1988) as the following formula:

$$D_{mg} = (S-1)/\ln N$$

Where, *Dmg* is the richness index of community A, *S* is the total number of species, and *ln N* is a natural logatithmic value of the total number of individuals. Species richness index is classified as high ($D_{mg} > 5$), moderate ($3.5 \leq D_{mg} \leq 5$), and low ($D_{mg} < 3.5$).

Species evenness measures the relative abundance of the different species in an area. Species evenness was calculated using the following formula (Ludwig & Reynolds, 1988):

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

Where, *E* is the evenness index of community A, *H'* is the Shannon-Wiener diversity index, and *ln S* is a natural logarithmic value of the total number of species. The last quantitative analysis is the dominance index using the following formula (Odum, 1971):

$$C = \sum_{i=1}^{n} \left[\frac{n_i}{N}\right]^2$$

Where, *C* is the dominance index, n_i is the number of individuals of the *i* species, and *N* is the total number of individuals of all species.

RESULTS

Floristic composition

In this study, plant species in the Gunung Salak Power Plant unit recorded 873 individuals from 110 species in 56 families (Table 1), of which 58 species of them are trees, 15 shrubs, 17 herbs, five lianas, six palms, and nine fern species. The tree species that can be found were puspa *(Schima wallichii),* rasamala *(Liquidambar excelsa),* pasang *(Lithocarpus* spp.*),* saninten *(Castanopsis argentea),* and ki hujan *(Engelhardia spicata).* Palahlar/keruing *(Dipterocarpus hasseltii)* had very few populations in this forest.

The vegetation composition of Gunung Salak Geothermal Power Plant areas mostly consisted of native plant species. However, there were few introduced plant species (Table 1). Introduced species found in this research means plant species imported from other areas into a native plant community and can cause environmental damage due to their increasing population (Tjitrosoedirdjo *et al.*, 2016). These plants include *Calliandra houstoniana*, *Asystasia gangetica*, *Bellucia pentamera*, *Miconia crenata*, *Maesopsis eminii*, and *Solanum torvum*. Among those species, the most abundant populations at the study site were *C. houstoniana* and *M. eminii*.

Table 1. Plant diversity in Gunung Salak Geothermal Power Plant unit

No	Species	Local name	Habitus	Distribution status
	Acanthaceae			
1	*Asystasia gangetica* (L.) T.Anderson	Jukut Israel	Herb	Introduced
2	*Barleria cristata* L.	Landep	Shrub	Native
3	*Strobilanthes filiformis* Blume	Bubukuan	Shrub	Native
	Actinidiaceae			
4	*Saurauia pendula* Blume	Ki Leho	Tree	Native
	Altingiaceae			
5	*Liquidambar excelsa* (Noronha) Oken	Rasamala	Tree	Native
	Anacardiaceae			
6	*Mangifera* cf. *laurina* Blume	Limus Piit	Tree	Native
	Annonaceae			
7	*Huberantha rumphii* (Blume ex Hensch.) Chaowasku	Wihu	Tree	Native
8	*Goniothalamus macrophyllus* (Blume) Zoll.	Empalis	Tree	Native
9	*Monoon lateriflorum* (Blume) Miq.	Jalatrung	Tree	Native
	Araceae			
10	*Apoballis rupestris* (Zoll. & Moritzi) S.Y.Wong & P.C.Boyce	Taleus	Herb	Native
11	*Arisaema filiforme* (Reinw.) Blume	Ki Acung	Herb	Native
	Araliaceae			
12	*Macropanax concinnus* Miq.[(2)]	Pangpung	Tree	Native
	Arecaceae			
13	*Calamus javensis* Blume	Rotan	Palm	Native
14	*Calamus reinwardtii* Mart.	Rotan	Palm	Native
15	*Caryota mitis* Lour.	Sarai	Palm	Native
16	*Pinanga coronata* (Blume ex Mart.) Blume	Bingbin	Palm	Native
17	*Pinanga javana* Blume	Hanyawar	Palm	Native
18	*Plectocomia elongata* Mart. Ex Blume	Rotan Badak	Palm	Native
	Asparagaceae			
19	*Dracaena* sp.	Ki Beusi	Shrub	Native
	Aspleniaceae			
20	*Asplenium nidus* L.	Paku Sarang Bu-rung	Fern	Native
	Asteraceae			
21	*Strobocalyx arborea* (Buch.-Ham.) Sch.Bip.	Merambung	Tree	Native
	Begoniaceae			
22	*Begonia isoptera* Dryand. ex Sm.	Begonia	Herb	Native
23	*Begonia muricata* Blume	Begonia	Herb	Native
	Cyatheaceae			
24	*Sphaeropteris glauca* (Blume) R.M.Tryon[(*)]	Paku Tiang	Fern	Native
	Cyperaceae			
25	*Scleria ciliaris* Nees	Jukut Ilat	Herb	Native

	Dilleniaceae			
26	*Dillenia obovata* (Blume) Hoogland	Ki Sempur	Tree	Native
	Dipterocarpaceae			
27	*Dipterocarpus hasseltii* Blume[1]	Palahlar/Keruing	Tree	Native
	Elaeocarpaceae			
28	*Elaeocarpus petiolatus* (Jack) Wall.	Ganitri Gunung	Tree	Native
29	*Sloanea sigun* (Blume) K.Schum.	Beleketebe	Tree	Native
	Euphorbiaceae			
30	*Homalanthus populneus* (Geiseler) Pax	Kareumbi	Tree	Native
31	*Macaranga denticulata* (Blume) Müll.Arg.	Mara	Tree	Native
32	*Macaranga tanarius* (L.) Müll.Arg.	Mara	Tree	Native
33	*Macaranga triloba* (Thunb.) Müll.Arg.	Mara	Tree	Native
34	*Mallotus paniculatus* (Lam.) Müll.Arg.	Calik Angin	Tree	Native
	Fabaceae			
35	*Abrus precatorius* L.	Saga Rambat	Liana	Introduced
36	*Calliandra houstoniana* (Mill.) Standl.	Kaliandra Beureum	Tree	Introduced
	Fagaceae			
37	*Castanopsis argentea* (Blume) A.DC.[1][a]	Saninten	Tree	Native
38	*Castanopsis javanica* (Blume) A.DC.	Ki Hiur	Tree	Native
39	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Pasang	Tree	Native
40	*Lithocarpus indutus* (Blume) Rehder[2]	Pasang	Tree	Native
41	*Lithocarpus sundaicus* (Blume) Rehder	Pasang	Tree	Native
42	*Quercus lineata* Blume	Pasang	Tree	Native
	Gesneriaceae			
43	*Cyrtandra grandis* Blume	Reungdeu	Herb	Native
44	*Cyrtandra picta* Blume	Ramokuya	Herb	Native
	Hydrangeaceae			
45	*Hydrangea febrifuga* (Lour.) Y.De Smet & Granados	Kaciput	Shrub	Native
	Hypoxidaceae			
46	*Curculigo capitulata* (Lour.) Kuntze	Congkok/marasi	Herb	Native
	Juglandaceae			
47	*Engelhardia spicata* Lechen ex Blume	Ki Hujan	Tree	Native
	Lauraceae			
48	*Beilschmiedia madang* (Blume) Blume	Huru Madang	Tree	Native
49	*Cinnamomum parthenoxylon* (Jack) Meisn.	Selasihan	Tree	Native
50	*Litsea diversifolia* Blume	Madang	Tree	Native
51	*Machilus rimosa* Blume	Ki Puket	Tree	Native
52	*Neolitsea javanica* (Blume) Backer	Huru Batu	Tree	Native
	Magnoliaceae			
53	*Magnolia sumatrana* (Miq.) Figlar & Noot.	Manglid	Tree	Native
	Malvaceae			
54	*Commersonia bartramia* (L.) Merr.	Andilau	Tree	Native
55	*Sterculia oblongata* R.Br.	Hantap	Tree	Native

	Marantaceae			
56	*Phrynium* sp.	Habana	Herb	Native
	Melastomataceae			
57	*Bellucia pentamera* Naudin	Tangkalak	Tree	Introduced
58	*Dissochaeta gracilis* Blume	Harendong Areuy	Liana	Native
59	*Melastoma malabathricum* L.	Harendong Jawa	Shrub	Native
60	*Memecylon oleifolium* Blume	Ki Beusi	Tree	Native
61	*Miconia crenata* (Vahl) Michelang.	Harendong Bulu	Shrub	Introduced
62	*Pternandra azurea* (Blume) Burkill		Tree	Native
	Meliaceae			
63	*Epicharis densiflora* Blume	Ki Panongo	Tree	Native
	Moraceae			
64	*Artocarpus elasticus* Reinw. ex Blume	Teureup	Tree	Native
65	*Ficus fistulosa* Reinw. ex Blume	Kondang	Tree	Native
66	*Ficus glaberrima* Blume	Ara	Tree	Native
67	*Ficus padana* Burm.f.	Hamerang Badag	Tree	Native
68	*Ficus tricolor* Miq.	Hemerang	Tree	Native
69	*Ficus variegata* Blume	Kondang	Tree	Native
	Myristicaceae			
70	*Knema cinerea* (Poir.) Warb.	Darah-darah	Tree	Native
	Myrtaceae			
71	*Syzygium antisepticum* (Blume) Merr. & L.M.Perry	Ki Tambaga	Tree	Native
72	*Syzygium cerasiforme* (Blume) Merr. & L.M.Perry	Ki Sireum	Tree	Native
	Nephrolepidaceae			
73	*Nephrolepis biserrata* (Sw.) Schott	Paku Pedang	Fern	Native
	Oleaceae			
74	*Chionanthus ramiflorus* Roxb.	Ki Bokol	Tree	Native
	Orchidaceae			
75	*Appendicula* sp.	Anggrek	Herb	Native
76	*Calanthe speciosa* (Blume) Lindl.	Anggrek	Herb	Native
	Pandanaceae			
77	*Freycinetia* sp.	Pandan Areuy	Liana	Native
	Pentaphylacaceae			
78	*Eurya acuminata* DC.	Ki Menir	Tree	Native
	Phyllanthaceae			
79	*Antidesma montanum* Blume	Ki Huut	Tree	Native
80	*Glochidion zeylanicum* (Gaertn.) A.Juss.	Semutan	Tree	Native
	Poaceae			
81	*Dinochloa scandens* (Blume ex Nees) Kuntze	Awi Cangkoreh	Shrub	Native
82	*Oplismenus burmanni* (Retz.) P.Beauv.	Jukut Bulu	Herb	Native
83	*Setaria latifolia* (Scribn.) R.A.W.Herrm.	Jukut Kerpe	Herb	Introduced
	Polypodiaceae			
84	*Microsorum* sp.	Paku	Fern	Native

85	*Polypodium* sp.	Paku Daun	Fern	Introduced
	Pteridaceae			
86	*Hemionitis* sp.	Paku	Fern	Native
87	*Pteris* sp.	Paku	Fern	Native
	Rhamnaceae			
88	*Maesopsis eminii* Engl.	Kayu Afrika	Tree	Introduced
	Rosaceae			
89	*Rubus moluccanus* L.	Arben	Shrub	Native
	Rubiaceae			
90	*Chassalia curviflora* (Wall.) Thwaites	Ki Kopi	Shrub	Native
91	*Eumachia montana* (Blume) I.M.Turner	Soka Gunung	Shrub	Native
92	*Lasianthus stipularis* Blume	Kokopian	Shrub	Native
93	*Pavetta montana* Reinw. ex Blume	Angsoka	Shrub	Native
94	*Psychotria divergens* Blume	Soka Gunung	Shrub	Native
	Rutaceae			
95	*Melicope latifolia* (DC.) T.G.Hartley	Ki Sampang	Tree	Native
96	*Melicope lunu-ankenda* (Gaertn.) T.G.Hartley	Ki Sampang	Tree	Native
	Salicaceae			
97	*Flacourtia rukam* Zoll. & Moritzi	Rukem	Tree	Native
	Selaginellaceae			
98	*Selaginella plana* (Desv.) Hieron.	Paku Rane	Fern	Native
	Smilacaceae			
99	*Smilax zeylanica* L.	Bungkus	Tree	Native
	Solanaceae			
100	*Solanum torvum* Sw.	Takokak	Shrub	Introduced
	Staphyleaceae			
101	*Dalrympelea sphaerocarpa* (Hassk.) Nor-Ezzaw.	Ki Bancet	Tree	Native
	Tectariaceae			
102	*Tectaria* sp.	Paku Takta	Fern	Native
	Theaceae			
103	*Schima wallichii* (DC.) Korth.	Puspa	Tree	Native
	Urticaceae			
104	*Dendrocnide stimulans* (L.f.) Chew	Pulus	Tree	Native
105	*Elatostema strigosum* Hassk.	Katilapro	Herb	Native
106	*Oreocnide rubescens* (Blume) Miq.	Nangsi	Tree	Native
107	*Poikilospermum suaveolens* (Blume) Merr.	Mentawan	Liana	Native
	Vitaceae			
108	*Leea indica* (Burm.f.) Merr.	Girang	Shrub	Native
	Zingiberaceae			
109	*Alpinia scabra* (Blume) Náves(1)	Bangle	Herb	Native
110	*Etlingera coccinea* (Blume) S.Sakai & Nagam.	Tepus	Herb	Native

Notes: (1) Endangered (EN-IUCN); (2) Vulnerable (VU-IUCN); (a) Protected (P.106/2018); (*) Appendix II (CITES).

The families with the highest number of species were Arecaceae, Fagaceae, Melastomataceae, and Moraceae, each consisting of six species (Fig. 2). In contrast, the lowest number of species was only one species in the following families: Actinidiaceae, Altingiaceae, Anacardiaceae, Araliaceae, Asparagaceae, Aspleniaceae, Asteraceae, Cyatheaceae, Cyperaceae, Dilleniaceae, Dipterocarpaceae, Hydrangeaceae, Hypoxidaceae, Juglandaceae, Magnoliaceae, Marantaceae, Meliaceae, Myristicaceae, Nephrolepidaceae, Oleaceae, Pandanaceae, Pentaphylacaceae, Rhamnaceae, Rosaceae, Salicaceae, Selaginellaceae, Smilacaceae, Solanaceae, Staphyleaceae, Tectariaceae, Theaceae, and Vitaceae.

The number of families and species compared at each growth level. The growth stages are tree, pole, sapling, and understory (seedling and herb). The data shows that at each growth stage, there are differences in the number of families and species (Fig. 3). The highest were understory plants (36 families and 53 species) and the lowest number of families and species were in pole stage (22 families and 32 species). Fagaceae dominated plant species at the tree level and consist of five species. Fagaceae dominated the pole level and consists of four species. The sapling level was dominated by Arecaceae and Moraceae, each consisting of four species. In contrast, the understory was dominated by Acanthaceae, Arecaceae, Melastomataceae, and Poaceae, each consisting of three species.

Rare and endangered species were explained based on their conservation status (Table 1). Six species are included in the criteria for rare and endangered species that grow around the Gunung Salak Geothermal Power Plant unit. These species in the Endangered category (EN-IUCN) were *Alpinia scabra* (bangle), *Castanopsis argentea* (saninten), and *Dipterocarpus hasseltii* (palahlar/ keruing). *Castanopsis argentea* is also a protected species by the government of Indonesia through regulations from the Ministry of Environment and Forestry. One fern species in the CITES appendix is *Sphaeropteris glauca* (App II). Fig. 4 shows palahlar, one of the endangered tree species.

Structure of vegetation

The vegetation structure at Gunung Salak Geothermal Power Plant is shown in Fig. 5. The graph of individual density at each growth stage and the number of individuals in several diameter classes show an inverted J-shaped curve. The inverted J curve shows that the forest condition around the power plant is still balanced, and the regeneration process runs well at all growth stages.

Some species dominate the number of the individual at each growth stage. *Schima wallichii* (puspa) has the highest number of individuals with 23 individuals, followed by *Ficus padana* (hamerang badag) with 14 individuals. *Schima wallichii* is common in the Java mountains (van Steenis, 1971). At the pole stage, the species with the highest number of individuals were *Ficus fistulosa* (beunying) with 15 individuals, and *Eurya acuminata* (ki menir) with 11 individuals. The species most commonly recorded at sapling were *Calliandra houstoniana* (kaliandra beureum) with 12 individuals and *Macaranga triloba* (mara) with eight individuals. The understory was *Selaginella plana* (paku rane) with 115 individuals and *Barleria cristata* (landep) with 70 individuals. *Selaginella plana*, has a habitus as ferns with a wide distribution, in the lowlands and mountain forests (Rahmad & Akomolafe, 2018; Setyawan *et al*., 2018; Coritico & Amoroso, 2020). Trees with a more than 75 cm diameter around the Gunung Salak Geothermal Power Plant unit recorded as many as six individuals (Fig. 5B) of four species. The trees with the three largest diameters were the *Schima wallichii* (116 cm), followed by *Magnolia sumatrana* (97 cm) and *S. wallichii* (92 cm).

Importance Value Index (IVI) and diversity index

Plants with the highest Important Value Index (IVI) showed that these species have the most significant influence on a forest ecosystem and can control them through the dominance of their density and abundance. Table 2 shows the five plant species with the highest IVI at each growth stage. Based on the IVI analysis, seedling and herb were dominated by *S. plana* (29.74) and *Miconia crenata* (20.84). At the sapling, the dominant species were *Macaranga triloba* (20.59) and *Calliandra houstoniana* (17.18). At the pole, the high IVI were *Ficus fistulosa* (43.27), *Eurya acuminata* (36.91), and *S. wallichii* (33.35). At the tree, the high IVI was *S. wallichii* (54.90), *Maesopsis eminii* (30.27), and *Ficus padana* (22.04).

Analysis of Shannon-Wiener diversity index, species richness index, evenness index, and dominance index value calculated by total data. Analysis of the Shannon-Wiener diversity index (H') is 3.784. Based on the index value category H', the diversity of flora around Gunung Salak Geothermal Power Plant is classified as high diversity. The species richness index is 16.391, which indicates that the species are in the high category. The species evenness index is 0.802, and the dominance index value is low as 0.042.

DISCUSSION

The forest ecosystem around the power plant can be considered the lower mountain forest of Java due to its plant diversity characteristics. The forest ecosystem is overgrown by natural trees typical of the flora of the Java Mountains. *Castanopsis argentea*, *Schima wallichii*, *Sloanea sigun*, *Lithocarpus* spp., *Quercus lineata*, and

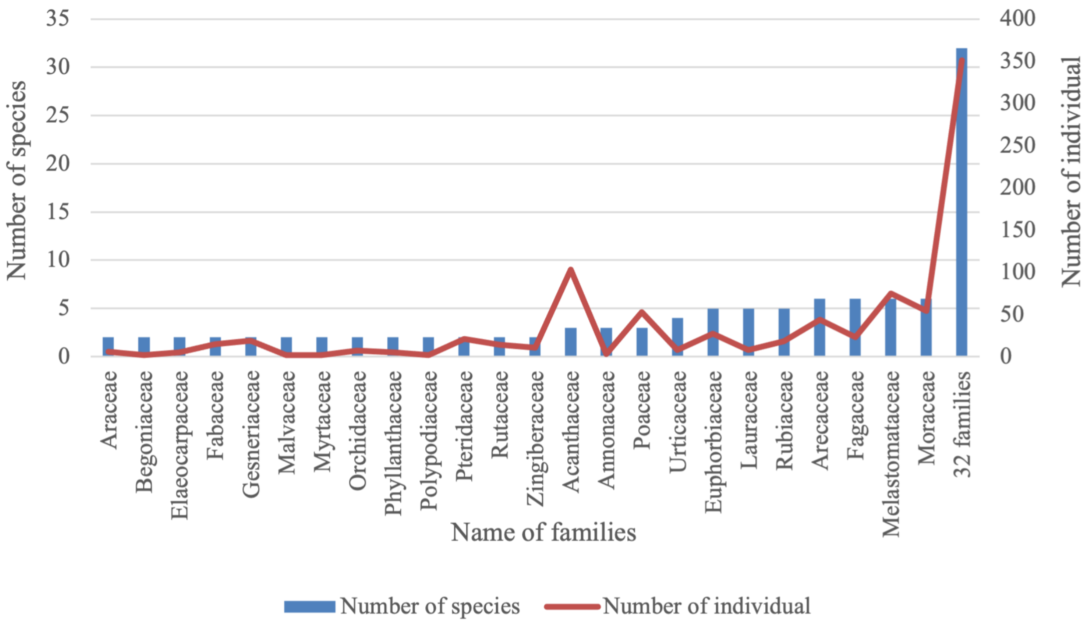


Fig. 2. Floristic composition of the study area.

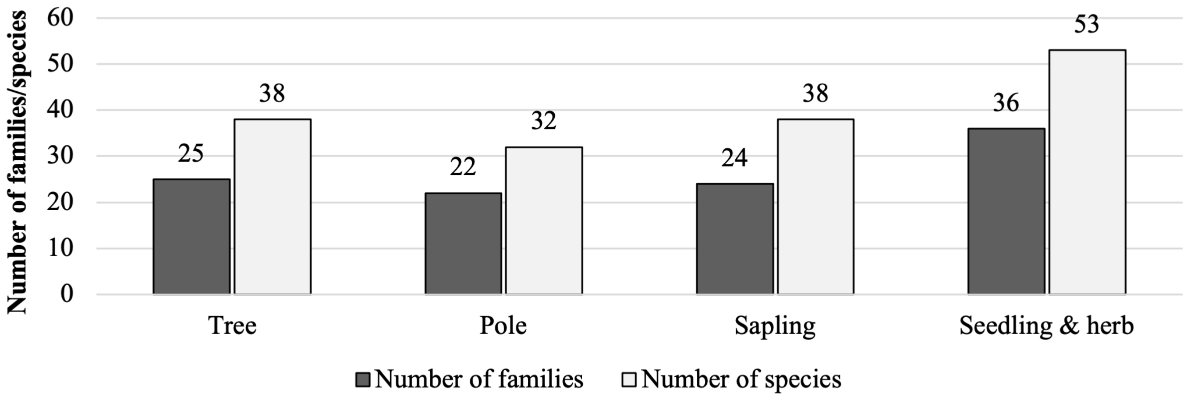


Fig. 3. Number of families and species at each growth stage.

Fig. 4. Palahlar/Keruing (*Dipterocarpus hasseltii*). Photos by Afri Irawan

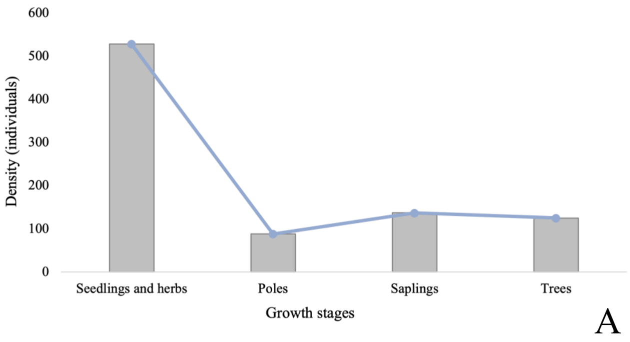
Engelhardia spicata are common species found in the mountainous regions of Java (Backer & van den Brink Jr, 1963; Backer & van den Brink Jr, 1965; Backer & van den Brink Jr, 1968; van Steenis, 1971; Toyama *et al*., 2018).

Some introduced plant species can become Invasive Alien Plant Species (IAPS). If not handled properly, IAPS can defeat the native flora (Tjitrosoedirdjo *et al*., 2016). Introduced plant species that were found and had potential as IAPS include *Calliandra houstoniana*, *Asystasia gangetica*, *Bellucia pentamera*, *Miconia crenata*, *Maesopsis eminii*, and *Solanum torvum*. Invasive alien plant species found in abundant populations at the study site were *C. houstoniana* and *M. eminii*. *Calliandra houstoniana* native to Central America. Despite the ability of this species to fixing nitrogen (Izerimana & Hirwa, 2019) that was important for the forest community, *Calliandra* has been reported to have a rapid growth rate and high densities that will increase its invasiveness (Yudaputra, 2020). While, *M. eminii,* an African exotic species, has been reported as fast-growing species and disturbed forest indicator in Bodogol forest, Gunung Gede Pangrango National Park (Helmi *et al*., 2009). *Maesopsis eminii* seeds are dispersed by birds and primates, thus accelerating their distribution (Sambas *et al.,* 2018).

Based on conservation status analysis, some plant species are categorized as rare, threatened, and endangered (RTE) species. These species listed in the Endangered category (EN-IUCN) were *Alpinia scabra* (bangle), *Castanopsis argentea* (saninten), and *Dipterocarpus hasseltii* (palahlar/keruing). *Castanopsis argentea* is also a protected species based on the Minister of Environment and Forestry Regulation No. 106 of 2018. *Castanopsis argentea* is a species listed in the 2019-2029 national priority tree conservation strategy (Hamidi *et al*., 2019). Other species in the Vulnerable category (VU-IUCN) were *Lithocarpus indutus* (Pasang) and *Macropanax concinnus* (Pangpung). The species is not protected, but is included in the Appendix 2 category of CITES, *Sphaeropteris glauca* (paku tiang) from the Cyatheaceae. *Sphaeropteris glauca* trades as an ornamental plant. Without regulation in its exploitation, this species will become extinct. All important plants species are native to Java and the western part of Malesia. *Castanopsis argentea*, *Dipterocarpus hasseltii*, *Lithocarpus indutus*, and *Macropanax concinnus* are rare tree species according to the IUCN red list. *Castanopsis argentea* was found in only four stands in the study plots. *Castanopsis argentea* can grow on arable land and dry, and rocky soils, but its population will decrease at higher elevations (Hilwan & Irfani, 2018). These stands grow in sloping areas. *Dipterocarpus hasseltii* and *L. indutus* grew in the forest on the west side of the power plant. *Dipterocarpus hasseltii* is found naturally in lowland areas in Sumatra and Kalimantan (Ashton, 1982) but rarely in the Java mountains. Apart from Mount Salak, *D. hasseltii* remains on Mount Halimun (Uji, 2002; Yusuf, 2004). *Dipterocarpus hasseltii* was also located in the Situ Gunung, Gunung Gede Pangrango National Park, but in subsequent studies, it was not found anymore at that location (Kalima & Wardani, 2013). In lowland forest at West Java, *D. hasseltii* is found in Leuweung Sancang Nature Reserve, Garut (Sidiyasa *et al*., 1985; Wardani *et al*., 1988; Kalima *et al*., 1988; Usmadi, 2015) and Yanlapa Nature Reserve, Bogor (Wardani, 2011). In relatively large numbers, *Macropanax concinnus* was found in the power plant forest area in relatively large number (± 20 ind/ha). This tree species is a high-density species in the mountain forests of Java (Kartawinata & Sudarmonowati, 2022).

A conservation strategy for rare and endangered plant species needs to be developed. Practical conservation occurs in natural habitats. Forests are habitats for RTE species that need to protect from the threat of land clearing. The reduction of forests due to land conversion is a real threat to the existence of vulnerable species of flora and fauna (Banks-Leite *et al*., 2020). Sites designated as conservation areas should not be used for infrastructure development for power plants. In addition, other efforts to protect the RTE species include monitoring the regeneration of these species, such as with intensive care and monitoring. Mapping each RTE species location needs to be done for more accurate monitoring. In that study, biodiversity monitoring should be carried out by qualified consultants. The Conservation Strategy and Action Plan lists the conservation action strategy as prioritizing tree species within a certain period (Hamidi *et al*., 2019). Our study is expected to help add the encounter point of rare, threatened, and endangered species so that it can be used as a source of germplasm for alternatives in the propagation program of rare plant species.

Schima wallichii is one of the plant species that dominates mountainous forest areas in GHSNP, so it is common to find it growing in clumps and dominating an area (Mirmanto, 2014; Hilman & Rahman, 2021). Seedlings of *S. wallichii* are often found around the parent tree, so the individual resulting from natural regeneration and replanting can be distinguished. Meanwhile, *Magnolia sumatrana* is a native Java plant that can grow in mountainous areas with a few individuals (Cahyanto *et al.,* 2020; Tihurua & Sulistyawati, 2019). Other species with the next largest diameter were *M. eminii* with a diameter of 84 cm and 77 cm, then *Dalrympelea sphaerocarpa* with a diameter of 77 cm. The presence of *M. eminii* with its large size and ability to produce many fruits and seeds will threaten ecosystem sustainability because this



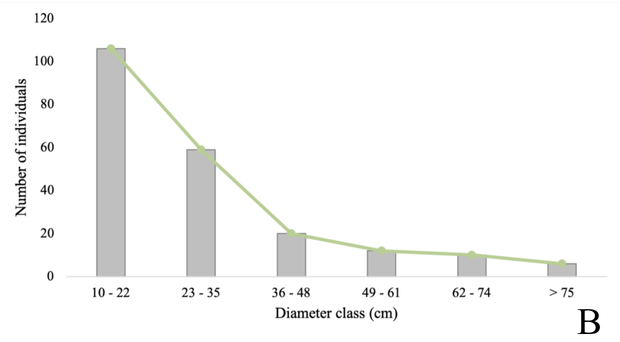


Fig. 5. Floristic structure. Density at each growth stage (A) and diameter class at the saplings and trees (B).

species is one of the invasive alien plant species (CABI, 2022). Not only in the forest around the Gunung Salak Geothermal Power Plant unit, but the presence of *M. eminii* has also become a concern for conservation area managers because of its good adaptability in relatively large numbers, in open areas, high growth speed, many fruits, and wide distribution, causing it to grow a lot and be invasive in the Salak-Halimun corridor (Rosleine *et al*., 2014).

The condition of the forest around the power plant shows that it is still in its growth stage, especially for pioneer and introduced species with a high growth rate. Meanwhile, the native species, including RTE species, have a slower growth rate. Open areas also cause forests around the power plants to take longer to climax. The mixed forest around the power plant was formed during early construction because some forest areas had to be cleared. The pioneer plant species initially outside the power plant area spread into the area due to human activity and seed dispersal assisted by wind and animals. Several areas are still open, especially those around roads and buildings. The production activities also increase the chances of the scattering of pioneer and alien plants into the power plant area, so the forest process towards climax will run more slowly. The importance value index (IVI) showed that the species could influence and control the forest ecosystem through the dominance of their density and abundance. Each growth shows a different importance value index. *Sellaginella plana* and *Miconia crenata* dominate the understory, which can grow and adapt in dense forest areas. The families and species with the highest composition were the seedlings and herbs, meaning that the understory in this forest ecosystem is still overgrown. Understory growth is supported by litter from the tree around there. The litter that decomposes quickly will provide sufficient nutrients for its growth (Ainiyah *et al*., 2017). In addition, sunlight that can penetrate to understory also affects the diversity of undergrowth (Setyawan *et al*., 2006; Dossa *et al*., 2013). *Sellaginella plana* had a high IVI because the research location is still shaded; this follows the living habitat of this species which likes shaded places and low light intensity (Krisnawati *et al*., 2021; Suryani *et al.,* 2023). *Miconia crenata*, a potentially invasive introduced species, also has a growing habitat in shaded areas (De Oliveira *et al.*, 2023). Locations with sufficient light intensity tend to have higher species diversity (Destarani *et al*., 2017).

Macaranga triloba as pioneer species dominated the sapling stage. It indicates that other sides of the forest around the geothermal area have opened, and the seed distribution has reached the study area. *Macaranga triloba*, at the seedling and sapling stage, is one of the dominant pioneer plant species associated with *Schima walichii* and *Liquidambar excelsa* in the GHSNP area, especially at an altitude of 1,000–1,400 m asl (Fauziah *et al.*, 2018; Denny *et al.*, 2021). *Macaranga triloba* in the secondary forest has a reasonably high ability to absorb CO_2, so it can reduce emissions in the air and has the highest transpiration rate compared to other pioneer plant species around GHSNP (Mansur, 2011). The introduced species, *C. houstoniana*, which is relatively common at the sapling stage, also needs to be a concern for the geothermal management area. This species has a high invasive ability, and although the population density will decrease from seedling to pole, some activities are needed to reduce the population because the dispersal of seeds in large numbers and quickly will increase the population of seedlings and saplings in a short time (Yudaputra, 2020).

Ficus fistulosa and *S. wallichii* dominated the pole and tree stages. Other species, such as *Eurya acuminata, M. eminii,* and *F. padana*, were also found in large numbers. The mountain of Java is habitat for *S. wallichii*, and this species dominates (van Steenis, 1971). The pole and tree stages are

Tabel 2. Importance Value Index each growth stage

No	Family	Species	Local name	RD	RF	RDo	IVI
			Seedling and herb				
1	Selaginellaceae	*Selaginella plana*	Paku Rane	21.78	7.96		29.74
2	Melastomataceae	*Miconia crenata*	Harendong Bulu	10.23	10.62		20.85
3	Acanthaceae	*Barleria cristata*	Landep	13.26	3.54		16.80
4	Nephrolepidaceae	*Nephrolepis biserrata*	Paku Pedang	7.01	6.19		13.20
5	Acanthaceae	*Strobilanthes filiformis*	Bubukuan	5.87	2.65		8.53
			Sapling				
1	Euphorbiaceae	*Macaranga triloba*	Mara	9.30	11.29		20.59
2	Fabaceae	*Calliandra houstoniana*	Kaliandra Beureum	13.95	3.23		17.18
3	Moraceae	*Ficus fistulosa*	Kondang	8.14	8.06		16.20
4	Theaceae	*Schima wallichii*	Puspa	8.14	6.45		14.59
5	Actinidiaceae	*Saurauia pendula*	Ki Leho	4.65	6.45		11.10
			Pole				
1	Moraceae	*Ficus fistulosa*	Kondang	18.07	8.20	17.00	43.27
2	Pentaphylacaceae	*Eurya acuminata*	Ki Menir	13.25	8.20	15.46	36.91
3	Theaceae	*Schima wallichii*	Puspa	12.05	11.48	9.83	33.35
4	Moraceae	*Ficus padana*	Hamerang Badag	4.82	6.56	6.56	17.93
5	Magnoliaceae	*Magnolia sumatrana*	Maglid	4.82	3.28	4.93	13.03
			Tree				
1	Theaceae	*Schima wallichii*	Puspa	18.55	13.83	22.56	54.90
2	Rhamnaceae	*Maesopsis eminii*	Kayu Afrika	8.06	5.32	16.89	30.27
3	Moraceae	*Ficus padana*	Hamerang Badag	11.29	6.38	4.37	22.04
4	Rutaceae	*Melicope lunu-ankenda*	Ki Sampang	5.65	5.32	4.59	15.59
5	Altingiaceae	*Liquidambar excelsa*	Rasamala	4.03	5.32	3.74	13.09

Note: RD: Relative Density; RF: Relative Frequency; RDo: Relative Dominance; IVI: Importance Value Index.

commonly used as animal feed, such as *M. eminii*, *F. fistulosa*, and *F. padana* (Supartono *et al*., 2018; Nakabayashi, 2020; Priyono *et al*., 2020). *Ficus fistulosa* and *F. padana* were found to have high density and frequency, even though they have a small diameter. *Ficus fistulosa* had a diameter range of 11–29 cm, and *F. padana* had a diameter range of 14–35 cm. Their high fruiting ability supports these two species' high density and frequency levels. They can even bear fruit throughout the year, and several animals like their syconium, so the dispersal of these two species becomes widespread. *Ficus fistulosa* and *F. padana* are also foraging sources for the javan gibbon (*Hylobates moloch*), which has a home range around geothermal areas. Generally, the javan gibbon consumes the leaves and fruits of *F. fistulosa* and *F. padana* (Jang *et al*., 2021; Zulfa *et al*., 2021).

Schima wallichii has a good process of regeneration (Shrestha & Devkota, 2019). It relatively dominated the growth rate of saplings, poles, and trees, indicating that this species has relatively fast regeneration power and no disturbance from humans or animals around the power plant. The natural rejuvenation potential of *S. wallichii* in Mount Merapi National Park is recorded at up to 15,000 individuals/ha. In areas disturbed by this species, as many as 500 individuals/ha can be found (Baramantya *et al.,* 2016).

Analysis of the Shannon-Wiener diversity index (H') was 3.784. Based on the index value category H', the plant diversity around the Gunung Salak Geothermal Power Plant unit was classified as high diversity. The stability of the ecosystem of a place will increase along with the high value of the flora diversity index at that location (Michael, 1984). The species richness index of 16.391, indicates that the Gunung Salak Geothermal Power Plant unit species are in the high category. The number of species affects the value of the species richness index in a study area (Ismaini *et al*., 2015). The species evenness index was 0.802, and the dominance index value was low as 0.042. All diversity indices show that several species have the potential to be found growing evenly but have a very low population size, so they are not able to dominate in the study area.

Based on the results and discussion, the forest ecosystem in the Gunung Salak Geothermal Power Plant area is in a good category for the composition of flora and diversity index. However, invasive plant species' presence requires regular maintenance control. Regular monitoring is necessary for areas overgrown with invasive species. The mature rare, threatened, and endangered trees must be conserved to for growing well and become parent tree for plant conservation in that location. The presence of pioneer species also increases the diversity of plant species around the geothermal area, especially in preserving several plant species used as wild animal feed found at the study site.

CONCLUSION

In conclusion, the floristic composition and structure of vegetation on the Gunung Salak Geothermal Power Plant unit indicate good ecosystem conditions. Floristic composition is recorded in as many as 56 families of 110 species. The plants are found as native and introduced species. In addition, other native species were found, including Puspa (*Schima wallichii*) and Rasamala (*Liquidambar excelsa*). Introduced species around the study site include *Maesopsis eminii* and *Calliandra houstoniana*. Both introduced species have the potential to become invasive plants, so the spread of these species needs to be continuously monitored so that they do not become a threat to rare plants found in these locations, such as *Alpinia scabra* (EN), *Castanopsis argentea* (EN), *Dipterocarpus hasseltii* (EN), *Lithocarpus indutus* (VU), and *Macropanax concinnus* (VU). The vegetation structure around the study site also shows the good condition of forest regeneration, as indicated by the inverted J-curve shape for the growth stage and class diameter. The results of the IVI analysis showed that pioneer plants generally dominated the undergrowth and sapling stage. In contrast, mountain rainforest plants, such as *S. wallichii*, *Ficus padana*, and *L. excelsa*, dominated the pole and tree stages.

ACKNOWLEDGEMENTS

The authors would like to thank to Fikri Aziz Maulana for helping us to collect data. Also, thanks to Muhammad Rifqi Hariri, Zakaria Al Anshori, Arief Hamidi, and Muslim for helping us in identifying plants. Thank you to the reviewers who have provided corrections, suggestions, and input so that the information in this manuscript can be appropriately conveyed. Also, thank to Reyna Ashari, Nizza Nadya Rachmani, and Muhammad Rifqi Hariri for helping us proofread our manuscript.

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