Jurnal Pro-Life, Volume 13 Nomor 2, Juli 2026

Pro-life
Jurnal Pendidikan Biologi, Biologi, dan Ilmu Serumpun
https://ejournal.uki.ac.id/index.php/prolife

Structure and Dominance of Secondary Forest Vegetation at the Coal Mine Plan Location, East Kalimantan, Indonesia

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Article History

Received:15 May 2026
Approved: 10 July 2026
Published:15 July 2026

DOI: https://doi.org/10.33541/pro-life.v13i2.8160

Keywords
Vegetation structure, species dominance, Importance Value Index, secondary forest.

ABSTRACT

This study documents vegetation biodiversity in the secondary forest area of the PT Alhasanie coal mining concession, East Kalimantan, Indonesia, as part of the pre-mining environmental baseline survey. Surveys were conducted in 2024 using a systematic nested plot design, "strip plot," across four vegetation strata: tree DBH ≥20 cm; pole DBH 10–19.9 cm; sapling height ≥1.5 m; DBH <10 cm; and seedling (height <1.5 m). Species composition and community structure were quantified using the Importance Value Index (IVI). A total of 32 plant species were recorded. Paraserianthes falcataria dominated the tree stratum (IVI = 149.98), Macaranga gigantea dominated both the pole (IVI = 97.59) and sapling (IVI = 115.45) strata, and Eupatorium odoratum dominated the seedling stratum (IVI = 44.57). Across all strata, the vegetation is overwhelmingly composed of pioneer, disturbance-adapted, and invasive species; Dipterocarpaceae are virtually absent from the upper strata and represented only by a single Shorea leprosula individual in the sapling layer. These findings confirm a severely disturbed young secondary forest with a clear history of shifting cultivation and land encroachment—no protected species under Indonesian Ministry of Environment and Forestry Regulation No. P.106/MENLHK/SETJEN/KUM.1/12/2018 were recorded. The survey results serve as the reference condition for environmental impact assessment and provide the ecological foundation for post-mining land rehabilitation planning.

INTRODUCTION

East Kalimantan is one of the regions on the island of Borneo with the highest tropical forest biodiversity in Southeast Asia, with thousands of plant and animal species and very high levels of endemism (Myers et al., 2000; Gaveau et al., 2016). The island of Borneo contains more than 15,000 species of vascular plants, about 6,000 of which are endemic, as well as hundreds of species of trees in the family Dipterocarpaceae that dominate the lowland forests and are the main ecological markers of the region (Whitmore, 1998). In East Kalimantan alone, lowland dipterocarp forests, peat swamp forests, and riparian ecosystems together support tremendous biodiversity, including many plant species that have not yet been fully documented (MacKinnon et al., 1996).

On the other hand, East Kalimantan is also the largest coal-producing province in Indonesia, with the area of mining concessions that continues to grow from year to year. Mulyana et al. (2011) noted that mining expansion in this region has been a major driver of deforestation and forest degradation over the past three decades. It has resulted in thousands of hectares of forested areas being converted into active mining areas, most of which pass through the secondary forest phase before being fully opened, thereby making the pressure on biodiversity and ecosystem functions at the landscape level more pronounced (Chazdon, 2014).

Secondary forests are forests that regrow on land previously cleared or damaged by human activities and are now the dominant vegetation type in most of the lowlands of Borneo (Rozendaal et al., 2019). Chazdon (2014) emphasised that tropical secondary forests continue to provide a real ecological role, including carbon storage, water system regulation, soil protection, and corridor functions for wildlife in fragmented landscapes. However, the recovery ability of secondary forests is largely determined by the history of disturbances: Chazdon & Guariguata (2016) show that lands that experience repeated clearing tend to be locked in conditions of aggressive pioneer dominance, while Martínez-Ramos et al. (2021) add that the dynamics of early-stage succession communities are strongly shaped by the specific disturbance history at each site.

Under Law Number 32 of 2009 on Environmental Protection and Management, every large-scale mining activity in Indonesia must prepare an EIA that includes a biodiversity survey. Indriyanto (2006) explained that vegetation data collected before mining serve as a reference for initial conditions, for protected species detection tools, and as a foundation for land rehabilitation design based on real field conditions. Soerianegara & Indrawan (1998) added that the use of standardised survey methods is a prerequisite for data to be consistently compared across locations and over time.

Some previous studies provide important context for this research. Karmini et al. (2021) report that 50-year-old secondary forests in East Kalimantan show a significant increase in species richness, with native species gradually shifting dominance from pioneers. Yamada et al. (2000) found that shade tolerance is a key factor that determines the success of tree seedling recruitment under a pioneer canopy. Slik et al. (2003) emphasised that the presence of Dipterocarpaceae can be used as an indicator of the ecological quality of forests, as this family is highly susceptible to fire and logging disturbances; therefore, its absence is consistently a strong marker of degradation.

Although the importance of pre-mine vegetation surveys has long been recognised, quantitative data on the composition of secondary forest vegetation in East Kalimantan coal mining concessions are rarely published in open scientific journals. Most of the data is stored in internal *Analisis Mengenai Dampak Lingkungan*, or AMDAL documents that cannot be verified by other researchers, hindering the development of a robust knowledge base on the ecological conditions of pre-mining areas. This gap is important to address because without adequate comparative data, the design of evidence-based post-mining ecosystem recovery strategies will always face serious empirical limitations (Curtis & McIntosh, 1951; Karmini et al., 2021).

Based on the previous explanation, this study aims to document the composition and community structure of vegetation across four growth stages: trees, poles, saplings, and seedlings. It also aims to calculate the Importance Value Index (IVI) for each species at each growth stage to identify dominant species and to interpret the successional stage and ecological condition of the forest. Furthermore, this study assesses the conservation status of the recorded protected species and provides ecological information to support environmental management and ecosystem restoration planning.

RESEARCH METHODS

Study Design

This study uses a quantitative field survey approach to characterise the structure and composition of vegetation in the secondary forest area included in PT Alhasanie's coal mine operation plan in East Kalimantan. The survey will be conducted in 2024 as part of the biodiversity study required for the EIA, before the start of mining activities in the 2025–2029 period. The variables observed included individual density per species, frequency of species presence on each plot, and basal area-based dominance, all three of which were integrated in the calculation of the Important Value Index (INP) as a measure of the relative dominance of each species in its community (Curtis & McIntosh, 1951; Soerianegara & Indrawan, 1998). The research was conducted in the PT Alhasanie coal mine concession area, East Kalimantan Province, Indonesia (Figure 1).

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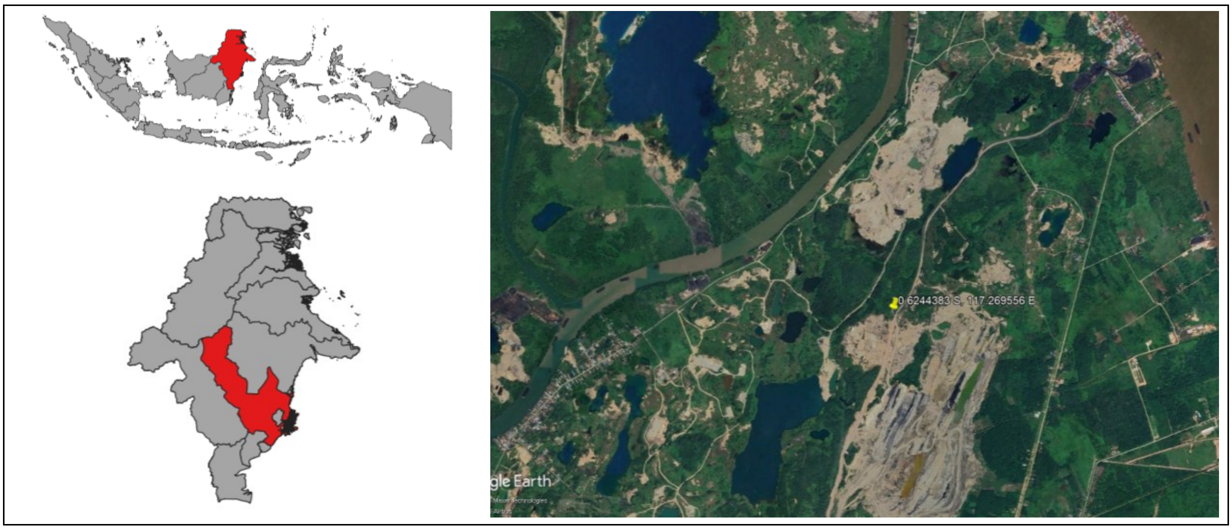

Figure 1. Research location

The main survey plot (Plot 1) is located at −0.6244383° S and 117.269556° E. Based on satellite image interpretation and field verification, the plot was classified as a young secondary forest. The area has previously experienced shifting agriculture and land encroachment, so the vegetation reflects the early stages of ecological succession. The climate of the region is humid tropical (Köppen Af), with annual rainfall of 2,000–3,000 mm, average temperatures of 26–28°C, and high humidity year-round. The soil is dominated by Ultisol and Oxisols, which are nutrient-poor and susceptible to compaction if vegetation cover is lost.

Procedure

Vegetation surveys were carried out using the nested plot method in accordance with forestry vegetation inventory standards and tropical vegetation analysis methods commonly used in Indonesia (KLHK, 2017). The transect strip is located in a secondary forest area with five observation plots systematically arranged at 50 m intervals along the transect. Of the five observation plots, Plot 1 was designated as the main plot (research location) because its position is the most representative of the secondary forest area that will be directly affected by the mine operation plan. The other four plots serve as additional verification points in the AMDAL survey, and the data have not been integrated into the quantitative analysis.

Each observation point is made a nesting plot for the observation of all vegetation growth stages, namely: tree level (DBH ≥20 cm) in plots of 20 m × 20 m, pole level (DBH 10–19.9 cm) in plots of 10 m × 10 m, pile level (height ≥1.5 m; DBH <10 cm) in plots 5 m × 5 m, and seedling level (height <1.5 m) in plots 2 m × 2 m. Species were identified using Flora Malesiana and World Flora Online, while unidentified specimens were collected for herbarium verification.

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Data Collection

In each observation plot, the recorded data included the local and scientific names of each plant, the number of trunks per type per plot, and the chest-high diameter (DBH) for all individuals at the tree and pole levels, measured using millimetre-scale diameter bands. At the stake and seedling levels, recording is limited to the type name and the number of individuals. The equipment used in the survey includes measuring tapes and raffia ropes for making tiles, diameter tapes for DBH measurements, clinometers for confirming plant height, digital cameras for documentation, and standardised field data entry sheets. The protection status of each species is assessed in accordance with the Regulation of the Minister of Environment and Forestry No. P.106/MENLHK/SETJEN/KUM.1/12/2018, the IUCN Red List version 2024-1 (IUCN, 2024), and the CITES Appendix.

Data Analysis

The Essential Value Index (INP) is calculated for each type at each growth rate following the procedure described by Soerianegara & Indrawan (1998) and Indriyanto (2006). For the tree, pole, and stake level, INP is the sum of three relative components, with a maximum value of 300. For the seedling level, INP = KR + FR, with a maximum value of 200. The formula used is as follows.

INP (tree/pole/spike) = KR + FR + DR
INP (seeded) = KR + FR

Relative Density (KR) is calculated as KR = (Ki/ΣK) × 100%, Relative Frequency (FR) as FR = (Fi/ΣF) × 100%, and Relative Dominance (DR) as DR = (Di/ΣD) × 100%, where Ki is the density of type i-i per unit area, Fi is the frequency of the presence of type i on the observation plot, and Di is the total basal area of type i-type per unit area. The basal area of each individual is calculated from the diameter of the rod using the formula $LB = \pi(DBH/2)^2$. All calculations were performed separately for each growth rate to compare dominance patterns across levels, and the type with the highest INP was identified as the dominant type.

RESULTS AND DISCUSSION

Tree-level vegetation

Parasianthes falcataria, or *sengon laut*, has the highest dominance, with an INP of 149.98. This value shows KR at 49.51%, FR at 46.14%, and DR at 54.33%. This result is almost equivalent to the accumulation of INP of the other five types. *Gmelina arborea* ranked second with an INP of 60.83. Next, are *puspa* trees at 37.39, *simpur* trees at 21.41, *pulai* trees at 18.43, and *mahang* trees at 11.96. Six plant types are recorded at the tree level based on Table 1.

Table 1. Tree level vegetation important value index (dbh ≥ 20 cm) in plot 1, PT Alhasanie Concession, 2024

No.	Local Name	Species	KR (%)	FR (%)	DR (%) / INP
1	*Sengon Laut*	*Paraserianthes falcataria*	49.51	46.14	54.33 / 149.98
2	*Gmelina*	*Gmelina arborea*	22.25	20.41	18.17 / 60.83
3	*Puspa*	*Schima wallichii*	11.08	15.35	10.96 / 37.39
4	*Simpur*	*Dillenia* sp.	5.56	7.69	8.16 / 21.41
5	*Pulai*	*Alstonia* sp.	7.83	6.16	4.44 / 18.43
6	*Mahang Daun Lebar*	*Macaranga gigantea*	3.77	4.25	3.94 / 11.96

Description: KR = Relative Density; FR = Relative Frequency; DR = Relative Dominance; Maximum INP = 300. Source: Primary field data (2024).

Table 2. Important value index of pole level vegetation (dbh 10–19.9 cm) in plot 1, PT Alhasanie Concession, 2024

No.	Local Name	Species	KR (%)	FR (%)	DR (%) / INP
1	*Mahang Daun Lebar*	*Macaranga gigantea*	33.02	31.79	32.78 / 97.59
2	*Jelatang*	*Urtica dioica*	28.17	30.65	31.75 / 90.57
3	*Anggerung*	*Trema orientalis*	15.52	12.39	12.18 / 40.09
4	*Puspa*	*Schima wallichii*	12.12	12.49	10.28 / 34.89
5	*Mahang Putih*	*Macaranga hypoleuca*	6.51	8.42	7.10 / 22.03
6	*Kelampayan*	*Anthocephalus cadamba*	4.66	4.26	5.91 / 14.83

Description: KR = Relative Density; FR = Relative Frequency; DR = Relative Dominance; Maximum INP = 300. Source: Primary field data (2024).

The combined dominance of *sengon* and *gmelina* with a total INP of 210.81 out of 300 is not the result of natural regeneration. However, the existence of a planting system or agroforestry that has existed before, for example *sengon* is an exotic type from Maluku that has been widely cultivated in Kalimantan since the 1970s because of its growth that reaches more than 5 meters per year and its ability to associate with nitrogen-fixing bacteria (Charomaini & Suhaendi, 1997), while *gmelina* is also a fast-growing type of wood found in former Southeast Asian farmland (FAO, 2020).

This condition differs markedly from the natural succession pattern, in which the early canopy was formed by a mixture of diverse native pioneer species (Connell & Slayter, 1977). The complete absence of the Dipterocarpaceae family that usually dominates the fine lowland forest canopy of Borneo and is a major marker of the ecological integrity of the forest (Ashton, 2008; Slik et al., 2003) indicates that disturbances in this region are repeated and intense, so that no dipterocarp individuals have developed to mature tree size (Karmini et al., 2021).

Pole Level Vegetation

At the pole level, six plant types were identified, as shown in Table 2 There is a significant change in dominance compared to the tree level. *Mahang* is the most dominant type with an INP of 97.59. Followed by nettle with an INP of 90.57; Then followed by *anggerung, puspa, mahang putih*, and *kelampayan* with 14.83.

The absence of *sengon* and *gmelina* at this stage suggests unsuccessful natural regeneration, a pattern consistent with self-replacement failure during forest succession. However, confirmation requires long-term regeneration or demographic data, which were unavailable in this study. Both species are light-demanding and cannot regenerate under their own canopy (Brown & Lugo, 1990).

In contrast, regeneration under the canopy is entirely dominated by *mahang* and *jelatang*, two highly competitive aggressive pioneers in disturbed environments, *mahang* forms a mutualistic symbiosis with Crematogaster ants that protect it from herbivore and competition from vines (Davies et al., 2001), so that the combined INP of the two of them of 188.16 shows a highly concentrated dominance of species with similar ecological strategies that do not act as facilitators for species continued succession (Yamada et al., 2000).

Pire-level vegetation

A total of 10 types were recorded at the pile level, as shown in Table 3. This number is the highest among the levels. *Mahang daun lebar* is the most dominant species with an INP of 115.45. The value consists of KR 37.90%, FR 37.68%, and DR 39.87%. *Jelatang* are second with an INP of 66.70, followed by *anggelung* with an INP = 33.2, and seven other types with an INP below 25 each.

The increase in the INP of *mahang* from the pole level of 97.59 to the pile level of 115.45 indicates the continuous recruitment of *mahang* at this stage. This pattern has the potential to lead to a no-pioneer lock-in state, in which pioneer types lock down communities in the early stages of succession and actively prevent other types of succession from entering (Chazdon & Guariguata, 2016). However, definitive results on this phenomenon require temporal observation or a 10- to 20-year-long-term succession study outside the inventory survey area.

Table 3. Important value index of pire-level vegetation (Height ≥ 1.5 m; DBH < 10 cm) at plot 1, PT Alhasanie Concession, 2024

No.	Local Name	Species	KR (%)	FR (%)	DR (%) / INP
1	*Mahang Daun Lebar*	*Macaranga gigantea*	37.90	37.68	39.87 / 115.45
2	*Jelatang*	*Urtica dioica*	22.01	20.83	23.86 / 66.70
3	*Anggerung*	*Trema orientalis*	10.70	11.34	11.17 / 33.21
4	*Laban*	*Vitex pubescens*	6.85	8.29	9.48 / 24.62
5	*Sirih-sirih*	*Piper Aduncum*	5.71	4.96	3.91 / 14.58
6	*Mali-mali*	*Leea indica*	5.31	4.67	2.35 / 12.33
7	*Jambu-jambuan*	*Syzygium* sp.	3.25	3.60	2.70 / 9.55
8	*Meranti Merah*	*Shorea leprosula*	3.16	3.33	2.65 / 9.14
9	*Sendok-sendok*	*Endospermum malaccense*	2.97	2.94	2.05 / 7.96
10	*Gadung*	*Dioscorea hispida*	2.14	2.36	1.96 / 6.46

Description: KR = Relative Density; FR = Relative Frequency; DR = Relative Dominance; Maximum INP = 300. Source: Primary field data (2024).

Table 4. Important value index of seedling level vegetation (Height < 1.5 m) in plot 1, PT Alhasanie Concession, 2024

No.	Local Name	Species	KR (%)	FR (%) / INP
1	*Kirinyuh*	*Eupatorium odoratum*	22.20	22.37 / 44.57
2	*Karamunting*	*Melastoma malabathricum*	12.50	12.40 / 24.90
3	*Mahang Daun Lebar*	*Macaranga gigantea*	10.65	11.26 / 21.91
4	*Anggerung*	*Trema orientalis*	10.49	10.31 / 20.80
5	*Pakis Kawat*	*Dicranopteris linearis*	9.56	9.24 / 18.80
6	*Jelatang*	*Urtica dioica*	7.89	8.45 / 16.34
7	*Laban*	*Vitex pubescens*	7.42	8.08 / 15.50
8	*Lengkuas Hutan*	*Alpinia galanga*	7.06	7.02 / 14.08
9	*Akar Kuning*	*Arcangelisia flava*	6.86	6.78 / 13.64
10	*Acer Lokal*	*Sterculia* sp.	5.37	4.09 / 9.46

Description: KR = Relative Density; FR = Relative Frequency; Maximum INP = 200. Source: Primary field data (2024).

Behind this dominance, the discovery of a single individual*, Shorea leprosula* INP 9,14, is the most ecologically important finding of the entire survey, the only representative of Dipterocarpaceae at all levels of observation. Red meranti is more tolerant of partial shade than most other dipterocarps (Maycock et al., 2005), and its successful growth indicates that the ectomycorrhizal mycorrhizae required by this species is still available in local soils (Kettle, 2010), making it a prime candidate for post-mining enrichment planting programs in the region.

Seedling Vegetation

Ten types were found at the seedling level, with a maximum INP value of 200 (see Table 4). *Kirinyuh* was dominated, with an INP of 44.57, followed by *karamunting* with 24.90 and *mahang* with 20.80. The lowest INP value is for the local Acer, at 9.46. The presence of *kirinyuh* is the most concerning ecological indicator observed. This invasive Central American species grows rapidly, produces abundant seeds, and releases allelopathic compounds that inhibit the germination of other plant species (Yokota et al., 2021). Without active intervention, its dominance may persist for a decade or more (Pham et al., 2010).

The presence of *Dicranopteris linearis* also exerts additional pressure on forest regeneration. This fern forms a dense layer on the surface of nutrient-poor soils, reducing light availability and intensifying root competition, thereby inhibiting the establishment and growth of tree seedlings (Russell et al., 1998). This combination of chemical and physical barriers indicates a significant delay in forest succession compared with a 50-year-old secondary forest in East Kalimantan (Karmini et al., 2021). Without active rehabilitation, including invasive weed control, topsoil conservation, and meranti enrichment planting, post-mining ecological recovery is unlikely within a reasonable timeframe (Rozendaal et al., 2019).

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Table 5. Complete List of Plant Species at All Levels, PT Alhasanie Secondary Forest, East Kalimantan (2024)

No.	Local Name	Species	Family	Ecological Record
1	*Kirinyuh*	*Eupatorium odoratum*	*Asteraceae*	Invasive Pioneer Herbs
2	*Karamunting*	*Melastoma malabathricum*	*Melastomataceae*	Disturbed land shrubs
3	*Sirih-sirih*	*Piper aduncum*	*Piperaceae*	Check out the pioneers
4	*Kayu Buta-buta*	*Homalanthus populneus*	*Euphorbiaceae*	Pioneer tree
5	*Sendok-sendok*	*Endospermum malaccense*	*Euphorbiaceae*	The original pioneer tree
6	*Kelampayan*	*Anthocephalus cadamba*	*Rubiaceae*	The original pioneer tree
7	*Anggerung*	*Trema orientalis*	*Cannabaceae*	Pioneer tree
8	*Mahang Daun Lebar*	*Macaranga gigantea*	*Euphorbiaceae*	Dominant pioneer tree
9	*Mahang Semut*	*Macaranga triloba*	*Euphorbiaceae*	Pioneer tree, myrmecophilous
10	*Mahang Putih*	*Macaranga hypoleuca*	*Euphorbiaceae*	Pioneer tree
11	*Jambu-jambuan*	*Syzygium* spp.	*Myrtaceae*	Native trees
12	*Bengkal*	*Nauclea* sp.	*Rubiaceae*	Native riparian trees
13	*Mali-mali*	*Leea indica*	*Vitaceae*	Disturbed forest bushes
14	*Puspa*	*Schima wallichii*	*Theaceae*	Native tree, wide adaptive
15	*Kayu Ara*	*Ficus erecta*	*Moraceae*	Native fig tree
16	*Merembung*	*Vernonia arborea*	*Asteraceae*	Pioneer tree
17	*Ara*	*Ficus* sp.	*Moraceae*	Native fig tree
18	*Secang*	*Caesalpinia bonducella*	*Fabaceae*	Climbing bush
19	*Jahe-jahean*	*Zingiber* spp.	*Zingiberaceae*	Herbs in the shade
20	*Pakis Kawat*	*Dicranopteris linearis*	*Gleicheniaceae*	Broken Ground Indicator Nail
21	*Darah-darah*	*Myristica* sp.	*Myristicaceae*	Native trees
22	*Rengas*	*Gluta renghas*	*Anacardiaceae*	Native trees, poisonous sap
23	*Kedangbelum*	*Milletia* sp.	*Fabaceae*	Native tree/liana
24	*Balik Angin*	*Mallotus penangensis*	*Euphorbiaceae*	Pioneer tree
25	*Terap*	*Artocarpus odoratissima*	*Moraceae*	Native tree, edible fruit
26	*Simpur*	*Dillenia* sp.	*Dilleniaceae*	Native trees
27	*Kaliandra*	*Calliandra* sp.	*Fabaceae*	Check nitrogen binders
28	*Senduduk*	*Macrolenes muscosa*	*Melastomataceae*	Native bush
29	*Tula-tula*	*Mallotus floribundus*	*Euphorbiaceae*	Pioneer tree
30	*Sengon Laut*	*Paraserianthes falcataria*	*Fabaceae*	Pioneer plant trees (exotic)
31	*Laban*	*Vitex pubescens*	*Lamiaceae*	Secondary forest trees
32	*Gmelina*	*Gmelina arborea*	*Lamiaceae*	Tree plant (exotic)

Description: There are no protected types based on the Minister of Environment and Forestry Regulation No. P.106/MENLHK/SETJEN/KUM.1/12/2018 or with the status of CR/EN (IUCN, 2024). Source: Primary field data (2024).

CONCLUSION

A total of 32 plant species were identified across four growth levels in the secondary forest area of PT Alhasanie's concession in East Kalimantan. The dominance pattern shows that sengon dominates at the tree level, wide-leaf mahang at the pole and stake level, and kirinyuh at the seedling level. This combination shows the condition of young secondary forests that are highly degraded, with vegetation dominated by pioneer, gang-tolerant, and invasive types. The lack of presence of Dipterocarpaceae, except for one individual, the red meranti, indicates low ecological integrity and limited natural regeneration ability. In addition, no plant species were found that included the protected category. Overall, condition ii indicates that the recovery of rehabilitation efforts is active to accelerate the succession process and improve the quality of the ecosystem.

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