# Vegetation Structure of Orangutan Habitat in Kerangas Forest within an Industrial Timber Plantation in Central Kalimantan

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## Abstract

The persistence of orangutan populations within industrial landscapes depends heavily on the availability of natural forest patches that provide essential resources for foraging, nesting, and other daily activities. PT Industrial Forest Plantation (PT IFP) is an industrial timber concession in Central Kalimantan that lies within the distribution range of the Bornean orangutan (*Pongo pygmaeus wurmbii*) and is characterized by a kerangas forest (or heath forest) ecosystem. This study aimed to evaluate the quality of orangutan habitat within PT IFP by analyzing vegetation structure and composition, with particular emphasis on the availability of food and nesting tree species. Vegetation surveys were conducted in three High Conservation Value Areas (HCVAs)—Gawing, Mangkutup, and Muruy—using a line-transect plot method. Five vegetation plots measuring 20 × 100 m were established across the study sites, and all trees with a diameter at breast height (DBH) ≥ 10 cm were recorded. A total of 87 tree species belonging to 29 families were identified, with the highest species richness observed in Muruy (64 species from 24 families), followed by Mangkutup (41 species from 22 families) and Gawing (36 species from 18 families). Importance Value Index (IVI) analysis revealed that species from the families Dipterocarpaceae and Myrtaceae dominated the stand structure across all sites. Sorensen Similarity Index values among the three HCVAs ranged from 44.0% to 53.33%, indicating moderate similarity in species composition. Of the total tree species recorded, 49.43% were classified as orangutan food trees and 60.92% as nesting trees, demonstrating that kerangas forests within the concession provide key resources required by orangutans. These findings emphasize the ecological importance of kerangas forests embedded within industrial timber landscapes and highlight their critical role in supporting the persistence of Bornean orangutan populations through habitat-based conservation management.

**Keywords**: Vegetation structure, heath forest, orangutan habitat, HCV, industrial timber plantation

## Introduction

Orangutans are among the largest forest-dependent mammals, relying almost exclusively on tropical rainforests to meet their ecological requirements for foraging, nesting, and movement (Delgado & van Schaik, 2000). Lowland tropical rainforests constitute the primary and most suitable habitat for orangutans (Husson et al., 2009). However, these ecosystems have experienced extensive loss and fragmentation across Borneo and Sumatra, primarily driven by logging, mining, plantation expansion, and fires (Wich et al., 2012). As a consequence, nearly all orangutan metapopulations have undergone severe declines, leading the International Union for Conservation of Nature (IUCN) to classify all extant orangutan species—Bornean, Sumatran, and Tapanuli orangutans—as Critically Endangered (Ancrenaz et al., 2016; Singleton et al., 2017; Nowak et al., 2017).

Within increasingly modified landscapes, the persistence of orangutan populations is strongly dependent on the availability and quality of remaining forested habitats, particularly those embedded within industrial concession areas (Spehar & Rayadin, 2017). In Indonesia, the High Conservation Value (HCV) framework has been widely adopted within oil palm and industrial timber plantations to identify and safeguard areas of exceptional biological, ecological, social, or cultural importance (HCV Resource Network, 1999). When appropriately managed, HCV areas play a critical role in maintaining ecological functions and biodiversity within the production landscapes (Areendran et al., 2020). For orangutans, remnant natural forest patches within concessions function as essential refugia, supporting daily activities such as feeding, resting, and nest construction, while also facilitating movement across fragmented landscapes (Meijaard et al., 2010; Ancrenaz et al., 2021).

Habitat quality for orangutans is closely linked to forest structure and vegetation composition, which together determine the availability of food resources, nesting trees, and overall ecosystem carrying capacity. Structural attributes such as tree density, basal area, and dominance reflect stand productivity and forest maturity, whereas species composition provides insights into the diversity and reliability of key resources required by forest-dependent fauna (Soegianto, 1994; Ramananantoandro et al., 2020). Numerous studies have demonstrated that variation in vegetation characteristics substantially influences the carrying capacity and habitat preference of orangutans (Mukhlisi & Gunawan, 2019; Budiana et al., 2021; Zautunah et al., 2021).

This study aims to assess orangutan habitat quality through an analysis of vegetation structure and composition within High Conservation Value Areas (HCVAs) dominated by kerangas forest (heath forest) ecosystems inside the concession of PT Industrial Forest Plantation (IFP), Central Kalimantan, Indonesia. The study area lies within the distribution range of the Bornean orangutan (*Pongo pygmaeus wurmbii*), particularly along the Gawing, Mangkutup, and Muruy rivers, which are the main habitats for orangutans in the region (Wich et al., 2012; Rayadin et al., 2025). River corridors were therefore used as a primary basis for site selection, given their importance in supporting orangutan movement, foraging, and nesting.

Kerangas forests represent a distinctive tropical forest ecosystem characterized by sandy, highly acidic, and nutrient-poor soils, resulting in unique vegetation structure and species assemblages (Hilwan, 2015; Ikbal et al., 2023). Although these forests generally exhibit lower productivity compared to lowland dipterocarp forests (Rahman, 2010), they can still provide critical habitat resources for orangutans, particularly within fragmented and human-modified landscapes. Despite their ecological significance, studies examining the structure and composition of kerangas forests in relation to orangutan habitat requirements remain limited. By integrating vegetation structural analysis with the identification of food and nesting tree species, this study provides essential baseline information on the role of kerangas forests as functional orangutan habitat within industrial timber plantation landscapes, thereby supporting evidence-based conservation planning and management.

## Methods

### Study area and period

This study was conducted within kerangas forest (heath forest) ecosystems that also serve as orangutan habitat inside the High Conservation Value Areas (HCVAs) of PT Industrial Forest Plantation (PT IFP), an industrial timber plantation company administratively located in Kapuas Regency, Central Kalimantan Province, Indonesia (Figure 1). Primary field data were collected in December 2024 at three HCVAs, namely Gawing HCVA, Mangkutup HCVA, and Muruy HCVA.


**Figure 1. Study area within the PT IFP concession: (A) Kalimantan Island, (B) location of PT IFP in Central Kalimantan, and (C) High Conservation Value Areas (HCVAs) within the PT IFP concession.**

## Field data collection

Vegetation surveys were conducted using the line transect plot method with plot dimensions of 20 × 100 m (2,000 $m^2$). A total of five plots were established across the three study sites, comprising two plots in Gawing HCVA, two plots in Mangkutup HCVA, and one plot in Muruy HCVA. Each plot was subdivided into 20 × 20 m subplots. Within each subplot, all tree individuals with a diameter at breast height (DBH) ≥ 10 cm were inventoried. For each recorded tree, species name and family were identified, and DBH and total tree height were measured. This approach was applied consistently across all study sites to ensure comparability of vegetation structure and composition.

## Vegetation analysis

Vegetation data were analyzed to calculate the Important Value Index (IVI) and the Sørensen Similarity Index (SSI) following the formulations proposed by Mueller-Dombois a1`2nd Ellenberg (1974) and Sørensen (1948), respectively. The calculated parameters included:

- Tree density (D): the number of individuals per unit area, and Relative Density (RD): the percentage contribution of a given species to the total tree density.

$$Density\ (D) = \frac{Number\ of\ individuals\ of\ a\ species}{Total\ plot\ area}$$

$$Relative\ Density\ (RD) = \frac{Density\ of\ a\ species}{Total\ density\ of\ all\ species} \text{ x } 100$$

- Frequency (F): the proportion of subplots in which a species occurs, and Relative Frequency (RF): the percentage contribution of a species' frequency to the total frequency of all species.

$$Frequency\ (F) = \frac{Number\ of\ subplot\ found\ of\ a\ species}{Total\ number\ of\ subplots}$$

$$Relative\ Frequency\ (RF) = \frac{Frequency\ of\ a\ species}{Frequency\ of\ all\ species} \text{ x } 100$$

- Dominance (Do): the basal area of a species per unit area, and Relative Dominance (RDo): the percentage contribution of a species' basal area to the total basal area of all species.

$$Dominance\ (Do) = \frac{Basal\ area\ of\ a\ species}{Total\ plot\ area}$$

$$Relative\ Dominance\ (RDo) = \frac{Dominance\ of\ a\ species}{Total\ dominance\ of\ all\ species} \text{ x } 100$$

- Important Value Index (IVI): a quantitative measure representing the ecological importance and dominance of a species within the community, calculated as the sum of RD, RF, and RDo. Higher IVI values indicate stronger dominance within the vegetation structure.

$$INP = RD + RF + RDo$$

- Sørensen Similarity Index (SSI): a measure of compositional similarity between two vegetation communities, expressed as a percentage ranging from 0 to 100%. Similarity levels were classified following Krebs (1985) as low (1–30%), moderate (31–60%), high (60–91%), and very high (>91%).

$$SSI = \frac{2c}{a+b} x\ 100$$

where c is the number of species shared between two sites, a is the total number of species at site 1, and b is the total number of species at site 2.

## Results and Discussion

### Vegetation Structure and Composition (DBH ≥ 10 cm)

Based on vegetation surveys conducted across the three study sites, a total of 87 tree species (DBH ≥ 10 cm) belonging to 346 individuals were recorded from all sampling plots. The highest species richness was observed in Muruy, with 64 species representing 24 families, followed by Mangkutup with 41 species from 22 families, and Gawing with 36 species from 18 families. In terms of stand structure, Muruy exhibited the highest tree density and basal area, reaching 278.3 trees ha and 26.8 m² ha, respectively, followed by Mangkutup (247.5 trees ha; 16.4 m² ha) and Gawing (200 trees ha; 16.2 m² ha).

**Table 1. Number of species, number of families, number of individuals, tree density, and basal area at each HCVA within the PT IFP concession.**

| HCVA | n of species | n of family | n of tree | Tree Density (n/ha) | Basal Area (m²/ha) |
|---|---|---|---|---|---|
| Gawing | 36 | 18 | 80 | 200 | 16,2 |
| Mangkutup | 41 | 22 | 99 | 247,5 | 16,4 |
| Muruy | 64 | 24 | 167 | 278,3 | 26,8 |
| **Total** | 87 | 29 | 346 | | |

Differences in vegetation parameters among sites indicate variation in the structure and composition of kerangas forests, reflecting differences in ecological conditions and successional stages at each location. Kerangas forests are generally characterized by distinctive structural attributes that are strongly influenced by soil properties, moisture availability, and disturbance (Proctor, 1999; Zoletto & Cicuzza, 2022). The higher species richness, tree density, and basal area observed in Muruy compared to the other two sites suggest that this area has relatively more favorable edaphic conditions supporting vegetation growth (Din et al., 2015; Sellan et al., 2019).

***Important Value Index (IVI)***

Vegetation dominance is shaped not only by environmental conditions but also by interspecific competition within plant communities (Lohbeck et al., 2014). Analysis of the Important Value Index (IVI) at each HCVA revealed variations in dominant species and vegetation structure, reflecting differences in ecological conditions, disturbance intensity, and ecosystem stability (Riswan & Kartawinata, 1991; Mitchell et al., 2000; Sellan et al., 2019; Zoletto & Cicuzza, 2022).

At Gawing, the forest stand was strongly dominated by *Syzygium salicitoides* (IVI = 72.7%), followed by *Shorea balangeran* (34.2%) and *Planconella* sp. (22.9%). The genus *Syzygium* is widely recognized as a dominant component of kerangas forests in Borneo (Syuharni et al., 2014; Purwaningsih & Kartawinata, 2018). The pronounced dominance of only a few species suggests that Gawing experiences relatively extreme environmental conditions, favoring species with high tolerance to acidic and nutrient-poor soils (Proctor, 1999; Sellan et al., 2019).

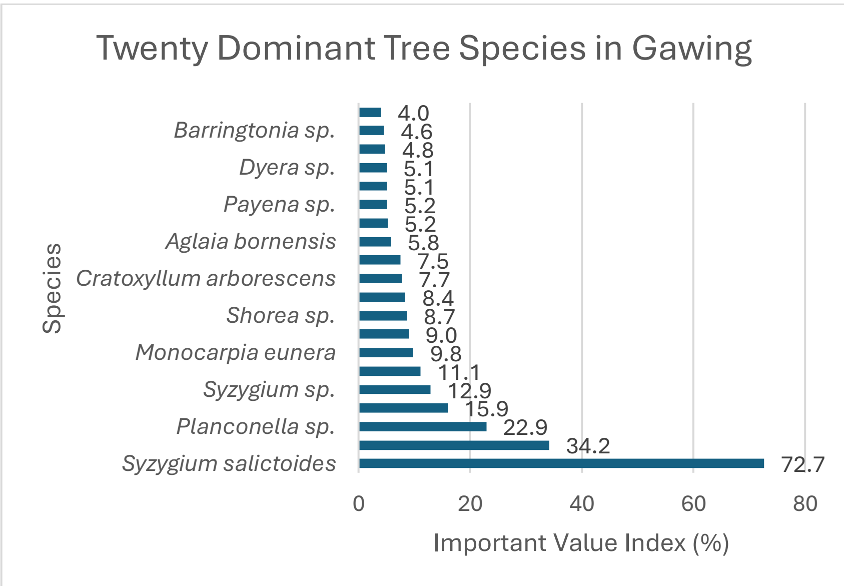


**Figure 2. Twenty dominant tree species in Gawing**

In Mangkutup, vegetation structure was more heterogeneous than in Gawing, with three dominant species, namely *Shorea balangeran* (36.7%), *Tristaniopsis* sp. (26.3%), and

*Planconella* sp. (24.1%). The more evenly distributed IVI values indicate a relatively balanced stand structure. Dominance of species from the Dipterocarpaceae and Myrtaceae families is consistent with kerangas forest communities reported from other sites in Central Kalimantan, such as KHDTK Mungku Baru (Maimunah et al., 2019).

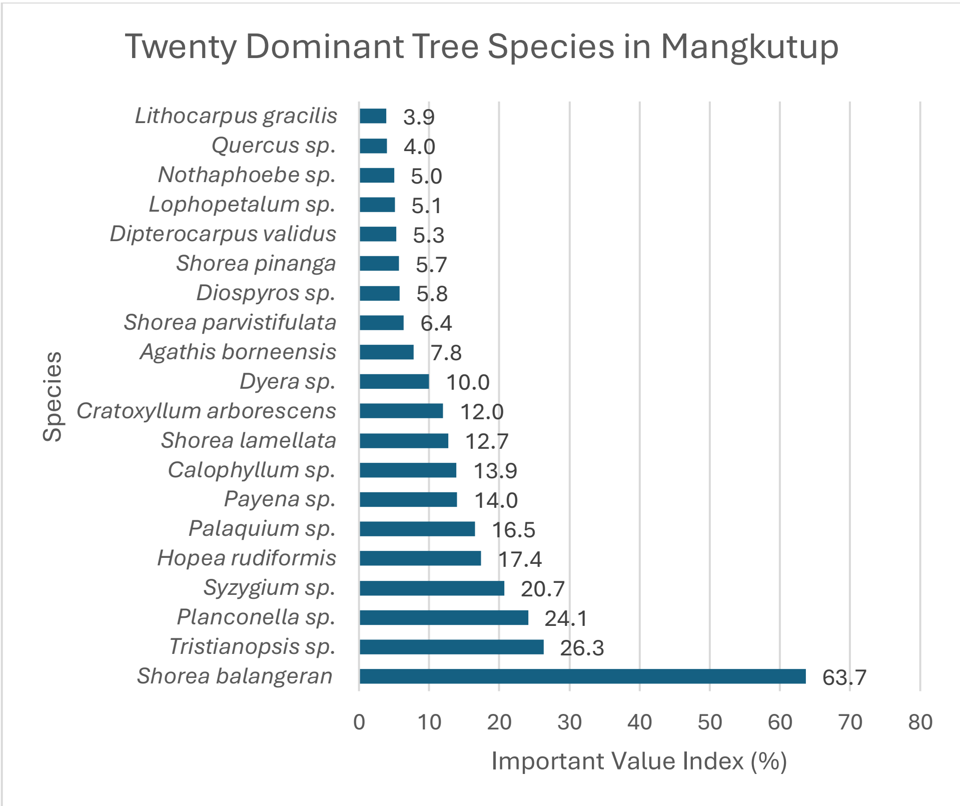


**Figure 3. Twenty dominant tree species in Mangkutup**

In contrast to the other two sites, Muruy HCVA exhibited a more evenly distributed dominance pattern, with no single species overwhelmingly dominant. The species with the highest IVI were *Shorea parvistipulata* (18.5%) and *Vatica umbonata* (15%), followed by *Diospyros* sp. (12.5%) and four additional Dipterocarpaceae species with IVI values exceeding 10%. Such evenly distributed dominance patterns are commonly associated with kerangas forests at more advanced successional stages (Ashton, 2015). This condition, combined with higher tree density, basal area, and species richness, indicates that Muruy has a relatively higher level of ecosystem stability compared to the other sites (Mitchell et al., 2000; Pratiwi & Garsetiasih, 2007).

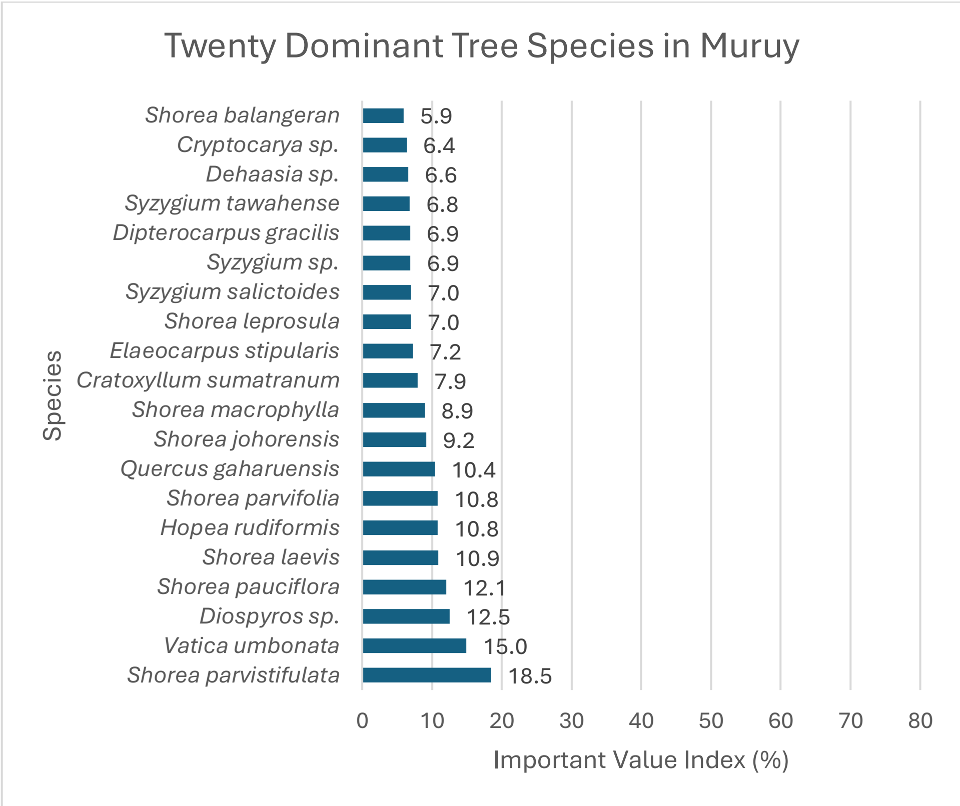


**Figure 4. Twenty dominant tree species in Muruy**

***Sørensen Similarity Index***

The Sørensen Similarity Index (SSI) values among study sites ranged from 44% to 53.33%. The highest similarity was observed between Mangkutup and Muruy (53.33%), followed by Gawing and Mangkutup (51.95%), while the lowest similarity occurred between Gawing and Muruy (44%). These results indicate that Mangkutup shares a more similar species composition with both Gawing and Muruy, whereas the lower similarity between Gawing and Muruy reflects greater differences in vegetation composition between the two sites.

Overall, SSI values fell within the "moderate" similarity category (Krebs, 1985), suggesting that although all three sites occur within the same landscape, each exhibit distinct ecological conditions and successional stages (Sellan et al., 2019; Zoletto & Cicuzza, 2022). Variation in species composition is likely influenced by differences in soil properties (e.g., texture, pH, nutrient availability), moisture regimes, and disturbance history, such as fire or other anthropogenic activities, which are known to strongly shape kerangas forest communities (Proctor, 1995; Anirudh et al., 2025; Zoletto & Cicuzza, 2022).

**Table 2. Sørensen Similarity Index (SSI) among study sites within the PT IFP concession**

| Study sites | N of species at each site | | N of species at both sites | N of shared species | Total Species | SSI (%) |
|---|---|---|---|---|---|---|
| | a | b | a+b | c | | |
| Gawing dan Mangkutup | 36 | 41 | 79 | 20 | 57 | 51,95 |
| Gawing dan Muruy | 36 | 64 | 102 | 22 | 78 | 44,00 |
| Mangkutup dan Muruy | 41 | 64 | 105 | 28 | 77 | 53,33 |

***Species Occurrence by Family***

Dipterocarpaceae was the most species-rich family across all study sites, with a total of 21 species recorded. Dipterocarpaceae is a dominant family in Southeast Asian tropical rainforests, including kerangas ecosystems (Whitmore, 1984; Sellan et al., 2019; Maimunah et al., 2019). The high representation of this family indicates that several species of *Shorea*, *Hopea*, and *Vatica* identified in the study area are capable of adapting to nutrient-poor and marginal edaphic conditions.

Other families with relatively high species richness and broad distribution across sites included Myrtaceae (6 species), Lauraceae (6 species), Fagaceae (5 species), Myristicaceae (5 species), Euphorbiaceae (4 species), Sapotaceae (4 species), Lecythidaceae (3 species), and Burseraceae (3 species). These families are also commonly reported from various kerangas forest types in Borneo (Brünig, 1974; Davies & Becker, 1996; Culverhouse, 2013; Ikbal et al., 2023).

**Table 3. Number of tree species by family at each study site.**

| No | Family | n species | | | Total |
|---|---|---|---|---|---|
| | | Gawing | Mangkutup | Muruy | |
| 1 | Anacardiaceae | 0 | 1 | 2 | 3 |
| 2 | Annonaceae | 1 | 0 | 3 | 3 |
| 3 | Apocynaceae | 1 | 1 | 0 | 1 |
| 4 | Aquifoliaceae | 0 | 0 | 1 | 1 |
| 5 | Araucariaceae | 0 | 1 | 1 | 1 |
| 6 | Burseraceae | 1 | 2 | 3 | 3 |
| 7 | Cannabaceae | 1 | 1 | 1 | 1 |
| 8 | Celastraceae | 0 | 1 | 0 | 1 |
| 9 | Clusiaceae | 1 | 2 | 2 | 2 |
| 10 | Dipterocarpaceae | 10 | 9 | 18 | 21 |
| 11 | Ebenaceae | 1 | 1 | 1 | 1 |
| 12 | Elaeocarpaceae | 0 | 1 | 1 | 1 |
| 13 | Euphorbiaceae | 1 | 1 | 3 | 4 |
| 14 | Fagaceae | 2 | 2 | 3 | 5 |
| 15 | Hypericaceae | 2 | 2 | 2 | 2 |
| 16 | Lauraceae | 4 | 3 | 4 | 6 |
| 17 | Lecythidaceae | 2 | 1 | 2 | 3 |
| 18 | Leguminosae | 0 | 1 | 0 | 1 |
| 19 | Malvaceae | 0 | 0 | 2 | 2 |
| 20 | Melastomataceae | 0 | 1 | 1 | 1 |
| 21 | Meliaceae | 1 | 1 | 1 | 2 |
| 22 | Moraceae | 1 | 0 | 2 | 3 |
| 23 | Myristicaceae | 1 | 2 | 3 | 5 |
| 24 | Myrtaceae | 4 | 3 | 4 | 6 |
| 25 | Olacaceae | 0 | 0 | 1 | 1 |
| 26 | Phyllanthaceae | 0 | 0 | 1 | 1 |
| 27 | Polygalaceae | 1 | 0 | 0 | 1 |
| 28 | Sapindaceae | 0 | 1 | 0 | 1 |
| 29 | Sapotaceae | 1 | 3 | 2 | 4 |
| | **N of Species** | **36** | **41** | **64** | **87** |
| | **N of Family** | **18** | **22** | **24** | **29** |

### *Food Tree and Nest Tree Species of Orangutans*

Orangutans are primarily frugivorous primates that rely heavily on fruit availability as the main component of their diet (Galdikas, 1978). In addition to fruits, orangutans also consume other plant parts such as leaves, flowers, young shoots, and bark (Galdikas, 1982), making the availability of food tree species a critical factor for their survival. Furthermore, orangutans construct arboreal nests daily for nocturnal sleeping and occasionally for daytime resting (Galdikas, 1978; Wich et al., 2009). Most nests are built near food trees, and in many cases, the same tree species is used both for feeding and nesting (Rahman, 2010). Although kerangas forests are generally considered lower-quality habitat compared to lowland dipterocarp or mixed swamp forests (Rahman, 2010), the presence of natural forest cover within industrial concessions remains crucial for supporting orangutan populations (Meijaard et al., 2010).

Of the 87 tree species identified across the three HCVAs, 43 species (49.43%) were classified as food trees, while 53 species (60.92%) were categorized as nest trees. When examined by site, the number of food and nest tree species increased consistently from Gawing to Mangkutup and Muruy, paralleling the observed increase in vegetation structure and compositional complexity. Gawing recorded 17 food tree species and 26 nest tree species, Mangkutup supported 21 food tree species and 29 nest tree species, and Muruy exhibited the highest numbers, with 33 food tree species and 41 nest tree species. This pattern indicates that the availability of food and nesting resources increases with greater vegetation complexity, thereby enhancing habitat carrying capacity for orangutans (Russon et al., 2015).

**Table 4. Number and percentage of orangutan food tree and nest tree species at each HCVA.**

| Study Site | N of Species | Food Tree Species | | Nesting Tree Species | |
|---|---|---|---|---|---|
| | | n | % | n | % |
| Gawing | 36 | 17 | 47.22 | 26 | 72.22 |
| Mangkutup | 41 | 21 | 51.22 | 29 | 70.73 |
| Muruy | 64 | 33 | 51.56 | 41 | 64.06 |
| **Total** | **87** | **43** | **49.43** | **53** | **60.92** |

Several tree genera, including *Syzygium*, *Shorea*, *Diospyros*, *Palaquium*, and *Tristaniopsis*, play dual roles as both food and nest trees and were consistently recorded across all HCVAs. IVI analysis further revealed that species from these genera exhibited relatively high dominance and occurred consistently across sites. The canopies of these genera provide strong and stable branching structures suitable for nest construction, while also producing fruits and seeds that constitute important food resources for orangutans. Consequently, these species contribute substantially to habitat quality and carrying capacity.

**Table 5. List of tree species (DBH ≥ 10 cm) and their classification as orangutan food and nest trees.**

| No | Species | Family | Tree Density (DBH ≥ 10 cm) | | | Food Tree | Nest Tree |
|---|---|---|---|---|---|---|---|
| | | | Gawing | Mangkutup | Muruy | | |
| 1 | *Agathis borneensis* | Araucariaceae | 0 | 7.5 | 3.3 | | √ |
| 2 | *Aglaia bornensis* | Meliaceae | 5 | 0 | 0 | | |
| 3 | *Aglaia odorata* | Meliaceae | 0 | 2.5 | 1.7 | √ | √ |
| 4 | *Alseodaphne bancana* | Lauraceae | 2.5 | 0 | 0 | | √ |
| 5 | *Artocarpus integra* | Moraceae | 0 | 0 | 1.7 | √ | |
| 6 | *Artocarpus lowii* | Moraceae | 2.5 | 0 | 0 | √ | |
| 7 | *Artocarpus* sp. | Moraceae | 0 | 0 | 1.7 | | |
| 8 | *Barringtonia pendula* | Lecythidaceae | 0 | 0 | 1.7 | | |
| 9 | *Barringtonia* sp. | Lecythidaceae | 2.5 | 0 | 3.3 | √ | √ |
| 10 | *Buchanania* sp. | Anacardiaceae | 0 | 0 | 1.7 | | |
| 11 | *Calophyllum* sp. | Clusiaceae | 5 | 15 | 3.3 | √ | √ |
| 12 | *Camnosperma* sp. | Anacardiaceae | 0 | 2.5 | 0 | | √ |
| 13 | *Canarium* sp. | Burseraceae | 2.5 | 2.5 | 1.7 | √ | √ |
| 14 | *Castanopsis argantea* | Fagaceae | 2.5 | 0 | 0 | | √ |
| 15 | *Castanopsis* sp. | Fagaceae | 0 | 0 | 3.3 | | √ |
| 16 | *Chaetocarpus castanocarpus* | Euphorbiaceae | 0 | 2.5 | 0 | | |
| 17 | *Cinnamomum javanicum* | Lauraceae | 0 | 0 | 3.3 | | |
| 18 | *Cratoxyllum arborescens* | Hypericaceae | 7.5 | 12.5 | 3.3 | √ | √ |
| 19 | *Cratoxyllum sumatranum* | Hypericaceae | 2.5 | 2.5 | 6.7 | | √ |
| 20 | *Cryptocarya costata* | Lauraceae | 2.5 | 0 | 0 | | |
| 21 | *Cryptocarya* sp. | Lauraceae | 2.5 | 2.5 | 6.7 | | √ |
| 22 | *Dacryodes rostrata* | Burseraceae | 0 | 2.5 | 6.7 | √ | √ |
| 23 | *Dacryodes rubiginosa* | Burseraceae | 0 | 0 | 5 | √ | √ |
| 24 | *Dehaasia* sp. | Lauraceae | 5 | 2.5 | 5 | | √ |
| 25 | *Diospyros* sp. | Ebenaceae | 7.5 | 2.5 | 11.7 | √ | √ |
| 26 | *Dipteracarpus* sp. | Dipterocarpaceae | 0 | 0 | 1.7 | | √ |
| 27 | *Dipterocarpus cornutus* | Dipterocarpaceae | 0 | 0 | 3.3 | √ | √ |
| 28 | *Dipterocarpus gracilis* | Dipterocarpaceae | 2.5 | 0 | 6.7 | | √ |
| 29 | *Dipterocarpus validus* | Dipterocarpaceae | 0 | 2.5 | 0 | | |
| 30 | *Durio griffithii* | Malvaceae | 0 | 0 | 1.7 | | √ |
| 31 | *Durio zibethinus* | Malvaceae | 0 | 0 | 1.7 | √ | √ |
| 32 | *Dyera* sp. | Apocynaceae | 5 | 10 | 0 | | |
| 33 | *Elaeocarpus stipularis* | Elaeocarpaceae | 0 | 2.5 | 8.3 | | |
| 34 | *Garcinia dulcis* | Clusiaceae | 0 | 2.5 | 3.3 | √ | √ |
| 35 | *Gironniera nervosa* | Cannabaceae | 2.5 | 2.5 | 1.7 | √ | √ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 36 | *Glochidion* sp. | Phyllanthaceae | 0 | 0 | 1.7 | √ | |
| 37 | *Gluta renghas* | Anacardiaceae | 0 | 0 | 5 | | |
| 38 | *Hopea mengarawan* | Dipterocarpaceae | 0 | 2.5 | 1.7 | | |
| 39 | *Hopea rudiformis* | Dipterocarpaceae | 2.5 | 15 | 10 | | √ |
| 40 | *Horsfielda grandis* | Myristicaceae | 0 | 0 | 1.7 | √ | √ |
| 41 | *Ilex cymosa* | Aquifoliaceae | 0 | 0 | 5 | √ | √ |
| 42 | *Knema elmeri* | Myristicaceae | 0 | 0 | 3.3 | √ | √ |
| 43 | *Knema latericia* | Myristicaceae | 0 | 2.5 | 3.3 | √ | √ |
| 44 | *Lophopetalum* sp. | Celastraceae | 0 | 5 | 0 | √ | √ |
| 45 | *Lithocarpus gracilis* | Fagaceae | 2.5 | 2.5 | 5 | | √ |
| 46 | *Macaranga gigantea* | Euphorbiaceae | 2.5 | 0 | 1.7 | √ | √ |
| 47 | *Macaranga hypoleuca* | Euphorbiaceae | 0 | 0 | 1.7 | | |
| 48 | *Madhuca* sp. | Sapotaceae | 0 | 2.5 | 0 | √ | √ |
| 49 | *Mallotus* sp. | Euphorbiaceae | 0 | 0 | 1.7 | | |
| 50 | *Memecylon* sp. | Melastomataceae | 0 | 2.5 | 1.7 | | |
| 51 | *Monocarpia eunera* | Annonaceae | 10 | 0 | 3.3 | √ | √ |
| 52 | *Myristica maxima* | Myristicaceae | 5 | 0 | 0 | √ | √ |
| 53 | *Myristica villosa* | Myristicaceae | 0 | 2.5 | 0 | | |
| 54 | *Nephelium* sp. | Sapindaceae | 0 | 2.5 | 0 | √ | √ |
| 55 | *Nothaphoebe* sp. | Lauraceae | 0 | 5 | 3.3 | | √ |
| 56 | *Ochanostachys amantacea* | Olacaceae | 0 | 0 | 1.7 | | √ |
| 57 | *Palaquium beccarianum* | Sapotaceae | 0 | 0 | 1.7 | √ | √ |
| 58 | *Palaquium* sp. | Sapotaceae | 0 | 12.5 | 1.7 | √ | √ |
| 59 | *Payena* sp. | Sapotaceae | 5 | 10 | 0 | √ | √ |
| 60 | *Planconella* sp. | Lecythidaceae | 12.5 | 17.5 | 0 | √ | √ |
| 61 | *Polyalthia glauca* | Annonaceae | 0 | 0 | 5 | | √ |
| 62 | *Quercus gaharuensis* | Fagaceae | 0 | 0 | 8.3 | √ | √ |
| 63 | *Quercus* sp. | Fagaceae | 0 | 5 | 0 | | √ |
| 64 | *Shorea assamica* | Dipterocarpaceae | 2.5 | 0 | 0 | | |
| 65 | *Shorea balangeran* | Dipterocarpaceae | 20 | 20 | 6.7 | | √ |
| 66 | *Shorea gratissima* | Dipterocarpaceae | 0 | 0 | 1.7 | | |
| 67 | *Shorea johorensis* | Dipterocarpaceae | 0 | 0 | 6.7 | | |
| 68 | *Shorea laevis* | Dipterocarpaceae | 10 | 2.5 | 10 | √ | √ |
| 69 | *Shorea lamellata* | Dipterocarpaceae | 2.5 | 10 | 6.7 | | |
| 70 | *Shorea leprosula* | Dipterocarpaceae | 0 | 0 | 3.3 | | |
| 71 | *Shorea macrophylla* | Dipterocarpaceae | 0 | 0 | 3.3 | | |
| 72 | *Shorea ovalis* | Dipterocarpaceae | 0 | 0 | 1.7 | | |
| 73 | *Shorea parvifolia* | Dipterocarpaceae | 2.5 | 2.5 | 10 | | |
| 74 | *Shorea parvistipulata* | Dipterocarpaceae | 7.5 | 5 | 11.7 | √ | √ |
| 75 | *Shorea pauciflora* | Dipterocarpaceae | 5 | 0 | 10 | | |
| 76 | *Shorea pinanga* | Dipterocarpaceae | 0 | 5 | 3.3 | | |
| 77 | *Shorea* sp. | Dipterocarpaceae | 7.5 | 0 | 0 | | |
| 78 | *Sindora wallichii* | Leguminosae | 0 | 2.5 | 0 | | |
| 79 | *Syzygium pearsonii* | Myrtaceae | 0 | 2.5 | 3.3 | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 80 | *Syzygium salictoides* | Myrtaceae | 12.5 | 0 | 6.7 | | √ |
| 81 | *Syzygium* sp. | Myrtaceae | 12.5 | 12.5 | 8.3 | √ | √ |
| 82 | *Syzygium tawahense* | Myrtaceae | 0 | 0 | 5 | √ | √ |
| 83 | *Syzygium zeylanicum* | Myrtaceae | 2.5 | 0 | 0 | | √ |
| 84 | *Tristianopsis* sp. | Myrtaceae | 12.5 | 20 | 0 | √ | √ |
| 85 | *Vatica umbonata* | Dipterocarpaceae | 0 | 0 | 10 | | |
| 86 | *Xanthophyllum* sp. | Polygalaceae | 2.5 | 0 | 0 | | |
| 87 | *Xylopia* sp. | Annonaceae | 0 | 0 | 1.7 | | √ |
| | **Tree Density** | | **200** | **247.5** | **278.3** | | |
| | **Total Species** | | **36** | **41** | **64** | **40** | **53** |

***Conservation recommendations***

Kerangas forests are generally characterized by lower productivity and simpler stand structure compared to other tropical forest types. Nevertheless, kerangas forests within the PT IFP concession possess significant ecological value as natural habitat for the Bornean orangutan (Pongo pygmaeus wurmbii). The results of this study demonstrate that these forests are capable of providing essential food and nesting tree species, underscoring their important role in maintaining the viability of orangutan populations within the concession area. Therefore, the protection and management of HCVAs should be prioritized to maintain vegetation integrity and minimize the risks of habitat degradation, deforestation, fragmentation, and anthropogenic disturbances such as hunting and encroachment. Effective protection of HCVAs represents a fundamental step toward sustaining the ecological functions of orangutan habitat.

In addition to habitat protection, enhancing connectivity among HCVAs represents another critical conservation strategy. Habitat fragmentation is a major threat to orangutan populations in multifunctional landscapes, as it restricts individual movement and limits access to food resources. Accordingly, improving connectivity among HCVAs, as well as between PT IFP HCVAs and surrounding forested areas outside the concession, is essential to support orangutan mobility and maintain landscape-level habitat continuity.

Conservation efforts should also be supported by long-term monitoring programs. The establishment of permanent transects and regular monitoring of HCVAs are essential for tracking changes in orangutan populations and habitat conditions over time. Such monitoring data can be used to evaluate the effectiveness of conservation programs and to develop adaptive, evidence-based management strategies.

The success of orangutan conservation depends not only on internal company initiatives but also on strong multi-stakeholder collaboration. Enhanced coordination among government agencies, academic institutions, research organizations, local communities, and conservation practitioners is needed through the development of a structured long-term conservation roadmap. Furthermore, the establishment of dedicated institutions focusing on orangutan conservation, HCVA management, and human–orangutan conflict mitigation is crucial to ensure the sustainability and effectiveness of conservation programs on the ground.

## Conclusions

This study was conducted in three High Conservation Value Areas (HCVAs) within the concession of PT Industrial Forest Plantation (PT IFP), namely Gawing, Mangkutup, and Muruy, which comprise kerangas forest ecosystems and represent important habitat for the Bornean orangutan (*Pongo pygmaeus wurmbii*). The study focused on analyzing the structure and composition of tree vegetation with DBH ≥ 10 cm and its relationship with the availability of orangutan food and nesting tree species. The results indicate that all three HCVAs possess relatively good habitat potential, as reflected by the proportion of food tree species ranging from 47.22% to 51.56% and nesting tree species from 64.06% to 72.22% of the total tree species recorded. Stand structure across all sites was predominantly composed of the families Dipterocarpaceae, Myrtaceae, and Ebenaceae, whose member species play critical roles as key food resources and nesting trees for orangutans. Given the limited number of studies examining the relationship between kerangas forest vegetation structure and the ecological requirements of orangutans, the findings of this research provide a significant scientific contribution to improving our understanding of the role of kerangas forests as important orangutan habitat. Furthermore, the conservation management recommendations developed based on these results are expected to support the strengthening of sustainable habitat management and protection strategies for orangutans within the PT IFP concession.

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