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Ecological characterization and conservation strategy of binjai (*Mangifera caesia*) in South Kalimantan, Indonesia

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Abstract. *Malik MA, Leksono AS, Gunawan, Abdullah SA. 2025. Ecological characterization and conservation strategy of binjai (*Mangifera caesia*) in South Kalimantan, Indonesia. Biodiversitas 26: 3827-3842.* Binjai (*Mangifera caesia*), a member of the Anacardiaceae family native to Southeast Asia, faces severe threats from timber extraction and habitat loss in South Kalimantan, Indonesia, while limited ecological data have hindered targeted conservation. This study assessed the distribution, ecological characteristics, and conservation strategies of binjai through field observations, purposive and snowball sampling, and ecological surveys in 21 plots (20×20 m each). Environmental factors measured included elevation, air temperature, humidity, light intensity, soil temperature, soil moisture, and soil pH, while vegetation data were collected using nested subplots across understory to tree levels and analyzed using Principal Component Analysis (PCA), vegetation analysis, and SWOT analysis. A total of 21 binjai trees were recorded in home yards, rice fields, and mixed gardens, with PCA revealing that air humidity (70.00-82.33%) and soil moisture (52.78-63.89%) were the most influential habitat factors. Vegetation surveys identified 74 associated species from 38 families, with dominant taxa including *Cynodon dactylon* and *Oryza sativa* in the understory, *Caryota mitis* and *M. caesia* at seedling level, *Musa paradisiaca* and *Bambusa spinosa* at sapling and pole levels, and *Cocos nucifera* and *Durio zibethinus* at the tree level. Diversity indices (H′=1.53-2.81) indicated moderate diversity across vegetation layers, reflecting ecological stability. The SWOT analysis highlighted weaknesses such as low community awareness and reliance on aged trees, as well as threats from land conversion and limited legal protection. Accordingly, recommended strategies include in situ protection through sustainable management and agroforestry integration, ex situ germplasm preservation in botanical gardens, environmental education to raise awareness, and cross-sector collaboration to enhance the conservation and economic value of binjai.

Keywords: Binjai, conservation, ecology, SWOT

INTRODUCTION

Binjai (*Mangifera caesia*), a member of the Anacardiaceae family, is native to Southeast Asia and valued for its culinary, cultural, and ecological significance (Chabib et al. 2018). It typically grows in lowland areas, particularly along riverbanks and seasonally flooded swamps at elevations below 450 meters above sea level (Ledesma 2019). Its distribution includes remnant forests and home gardens across Kalimantan, Sumatra, and the Malay Peninsula (Ganguli et al. 2019; Tanbuda et al. 2025). Despite this broad geographic range, binjai populations in Kalimantan and Sumatra exhibit limited genetic variation, suggesting a close genetic relationship across these regions (Resida et al. 2023).

Binjai is primarily valued as a food source (Gerten et al. 2015). The fruit is appreciated for its sweet, sour, and refreshing taste and is commonly incorporated into traditional dishes such as chili sauces (Suryatinah et al. 2020; Trisdayanti et al. 2021; Suwardi et al. 2022). Beyond its culinary value, binjai also holds traditional medicinal importance. Among the Dayak communities of South Kalimantan, Indonesia, the fruit is used to treat swelling by burning it into charcoal, mixing the ash with water, and applying the mixture topically (Suryatinah et al. 2020). Phytochemical analyses have demonstrated that binjai exhibits the highest antioxidant activity among native *Mangifera* species, primarily due to its flavonoid content and free radical scavenging ability (Mirfat et al. 2016). The presence of α-glucosidase inhibitors further indicates its potential as a functional food with anti-diabetic properties (Yunus et al. 2021).

The International Union for Conservation of Nature (IUCN) Red List categorizes binjai (*M. caesia*) as Near Threatened (NT), reflecting a declining population trend (Ganesan 2021). The species is approaching the threshold for classification as threatened. A major contributing factor to this decline is the extensive use of binjai timber for construction, which has led to unsustainable harvesting and reduced natural regeneration (Gerten et al. 2015; Resida et

al. 2023). Habitat loss from plantation expansion and logging also contributes to population decline. In Kalimantan, habitat degradation is intensified by forest concessions, illegal logging, industrial plantations, and oil palm cultivation (Alamgir et al. 2019; Austin et al. 2019; Ganesan 2021). Mining operations and urban development further promote habitat fragmentation, placing additional pressure on native plant species, including binjai (Salles et al. 2019; Itani et al. 2020).

Low community awareness of the ecological and economic value of binjai largely drives these unsustainable practices. According to Akhter et al. (2022), low awareness significantly contributes to the decline of native plant populations. Sarkingobir and Miya (2025) highlight the integration of environmental education into conservation strategies to promote sustainable practices. The challenge is compounded by the biological characteristics of *Mangifera* species, which require approximately five to six years to begin fruiting and fifteen to eighteen years to reach peak productivity, conditions that often discourage long term cultivation (Meena and Asrey 2018). The lack of legal frameworks specifically designed to protect native species such as binjai further exacerbates the issue. Reversing its decline will require targeted policies and conservation approaches that address both the ecological traits of the species and the socio-economic realities of local communities.

Noor et al. (2015) reported the presence of binjai in several districts of South Kalimantan Province, including Banjar and Hulu Sungai Tengah. However, existing distribution data are broad in scope and outdated, lacking fine-scale mapping of population presence across the region. Despite the vulnerability of binjai to habitat disturbances, it remains absent from national Red List assessments and is frequently overlooked in in situ conservation programs. Native fruit tree species such as binjai are often excluded from local conservation planning, resulting in minimal protection measures. The species is also rarely cultivated by local communities. In certain areas of Kalimantan, such as Tumbang Talaken. only a single tree has been recorded in a household yard (Satriani et al. 2024), indicating its declining presence in managed landscapes. In South Kalimantan, both population and ecological information on binjai remains scarce. Existing populations are generally limited to mature trees inherited through generations, with no evidence of systematic cultivation or active management (Salma et al. 2015). The lack of ecological information has contributed to habitat neglect and degradation. Such information remains essential for identifying suitable areas for binjai cultivation and for guiding conservation efforts. Furthermore, understanding the actual conditions of the species within local communities can support the development of more effective conservation strategies within local communities can support the development of more effective conservation strategies. Therefore, this study aimed to explore the distribution, ecological characteristics, and conservation strategies for binjai in South Kalimantan.

MATERIALS AND METHODS

Study period and area

The study was conducted from February to July 2024 in South Kalimantan, Indonesia, covering 21 sites across four districts. The study sites were selected based on a previous report by Noor et al. (2015) and preliminary field surveys in five districts. Field surveys involved interviews with native fruit vendors and tribal elders to identify the presence of binjai. Of the five districts surveyed, binjai was found in four districts: Banjar (1 site), Tapin (5 sites), Hulu Sungai Selatan (6 sites), and Hulu Sungai Tengah (9 sites) (Table 1). The study area spans approximately from 2°27′08.76″S to 3°43′43.86″S latitude and from 114°29′55.77″E to 115°49′17.44″E longitude (Figure 1).

Procedures

Distribution and ecological characteristics

Distribution data for binjai were collected through field surveys using a purposive sampling method. Tree locations were identified through local informants using a snowball sampling approach. Geographic coordinates were recorded using a Garmin 76CS GPS device. Ecological data included environmental factors and vegetation structure, collected from March to June 2024.

Table 1. Description of study sites

Location	Coordinate	Elevation (m asl.)	Description
1	3˚17'30.696" S 115˚18'19.249" E	173	Mixed garden
2	2˚55'28.289" S 115˚10'11.711" E	15	Mixed garden
3	2˚56'16.657" S 115˚07'15.475" E	14	Mixed garden
4	2˚54'48.930" S 115˚07'18.166" E	7	Rice field
5	2˚53'50.448" S 115˚07'14.901" E	9	Mixed garden
6	2˚55'37.610" S 115˚05'36.313" E	10	Home yard
7	2˚47'53.731" S 115˚15'54.614" E	24	Home yard
8	2˚47'11.739" S 115˚13'29.731" E	17	Rice field
9	2˚47'15.647" S 115˚14'03.853" E	17	Home yard
10	2˚43'12.670" S 115˚18'35.351" E	18	Mixed garden
11	2˚42'52.387" S 115˚18'13.329" E	10	Rice field
12	2˚42'33.991" S 115˚18'07.883" E	15	Home yard
13	2˚42'30.408" S 115˚21'30.208" E	27	Rice field
14	2˚42'25.143" S 115˚21'25.021" E	33	Home yard
15	2˚36'32.251" S 115˚21'52.452" E	23	Rice field
16	2˚36'10.651" S 115˚22'06.923" E	16	Home yard
17	2˚36'21.578" S 115˚18'42.841" E	16	Home yard
18	2˚33'23.086" S 115˚22'00.125" E	20	Home yard
19	2˚34'13.135" S 115˚22'40.496" E	17	Rice field
20	2˚33'42.356" S 115˚23'38.860" E	18	Rice field
21	2˚30'02.391" S 115˚28'49.090" E	38	Home yard

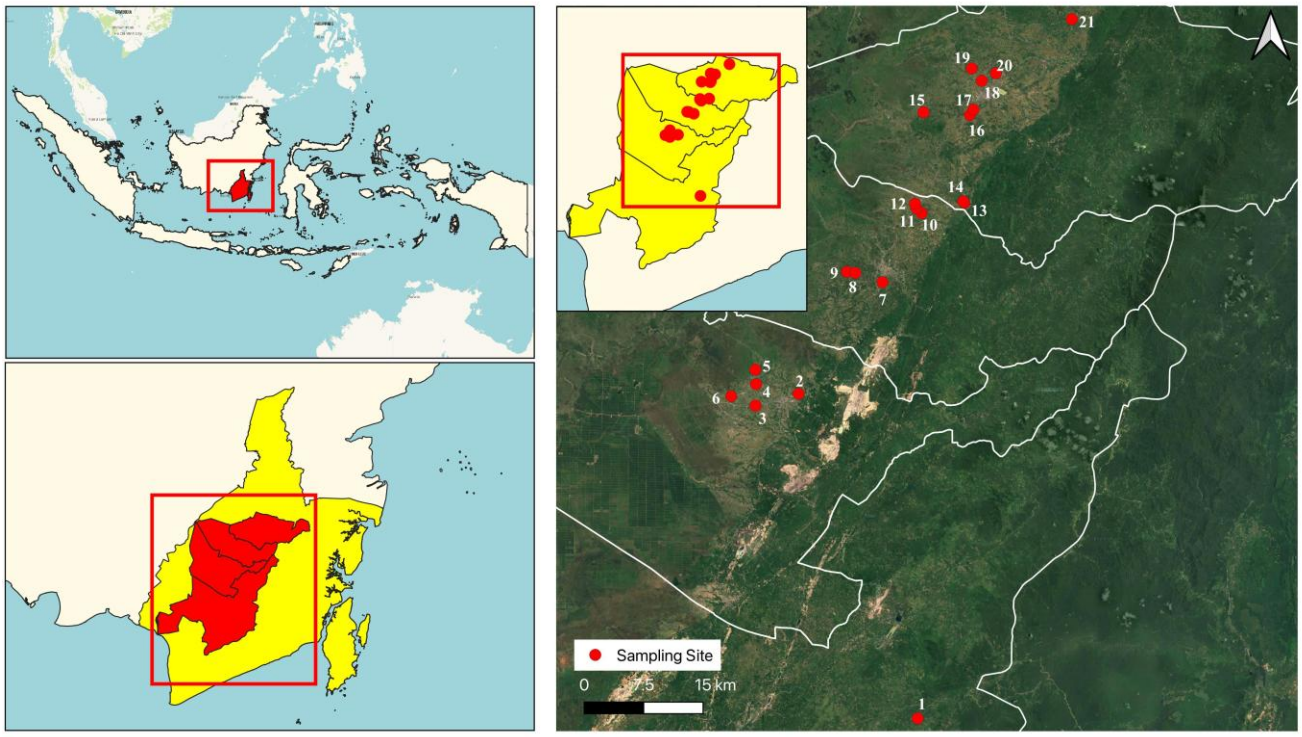


Figure 1. Study area covering four districts in South Kalimantan, Indonesia: 1. Banjar (BJR), 2-6. Tapin (TPN), 7-12. Hulu Sungai Selatan (HSS), 13-21. Hulu Sungai Tengah (HST)

A 20×20 m square plot was established at each site where a binjai tree was present, with the focal tree positioned at the center. This plot size is suitable for documenting mature tree species with a diameter greater than 20 cm (Hartoyo et al. 2024). A total of 21 plots were established, each containing one binjai tree. Plots were selected purposively based on community-owned trees. Environmental factors measured included elevation, air temperature, air humidity, light intensity, soil temperature, soil moisture, and soil pH. Measurements were taken three times daily (08:00, 12:00, and 16:00) and repeated across three separate days for each tree. Daily averages were calculated for each environmental factor. Vegetation data were collected across various growth levels, including understory (vegetation layer <1.5 m), seedling (sprouts to <1.5 m), sapling (≥1.5 m tall, diameter <10 cm), pole (diameter 10-20 cm), and tree (diameter >20 cm) (Paembonan et al. 2020; Deng et al. 2023). Subplot sizes were designated for each vegetation level: 2×2 m for understory and seedlings, 5×5 m for saplings, 10×10 m for poles, and 20×20 m for trees (Rambey et al. 2024). Vegetation data included species name, growth level, number of individuals, and Diameter at Breast Height (DBH) for poles and trees. Species identification was based on morphological characteristics (Setyawati et al. 2015; Tjitrosoepomo 2018).

Conservation strategy

Conservation strategy data were developed based on a preliminary study involving interviews with individuals knowledgeable about binjai, including tree owners, users, and sellers. The interviews aimed to collect information on binjai presence, historical planting motives, perceived benefits to the community, and current management practices that support binjai survival. Secondary data on the current status of binjai within local communities in South Kalimantan were also analyzed. The combined data were used to identify internal factors (strengths and weaknesses) and external factors (opportunities and threats) related to binjai conservation. These factors were tested for validity and reliability using responses from 30 participants selected through purposive sampling to assess the accuracy of the measurement instrument. The validity test was conducted at a significance level of α: 0.05, with an r-table value of 0.361 for N: 30, while the reliability test was conducted using a Cronbach's Alpha value greater than 0.60. The validity test confirmed that all items met the required standard (r-value >0.361), with internal factor scores ranging from 0.392 to 0.582 and external factor scores from 0.388 to 0.614. The reliability test demonstrated adequate internal consistency, with Cronbach's Alpha values of 0.656 for internal factors and 0.633 for external factors, both exceeding the minimum threshold of 0.60. Following these results, the finalized questionnaire was administered to a broader group of respondents (Gunawan et al. 2024). Respondents were binjai tree owners aged between 17 and 77 years. A total of 125 individuals participated, consisting of 6 (4.8%) from Banjar, 30 (24%) from Tapin, 35 (28%) from Hulu Sungai Selatan, and 54 (43.2%) from Hulu Sungai Tengah.

Data analysis

The distribution map was generated using ArcGIS version 10.8 based on coordinate data collected with a GPS device. Ecological data were analyzed through Principal Component Analysis (PCA) to determine key environmental factors influencing the presence of binjai (Gunawan et al. 2021). PCA is a statistical technique that reduces correlated variables into a smaller set of independent components. The analysis was conducted using Minitab 22 to identify the strongest linear associations between binjai distribution and environmental factors (Greenacre et al. 2022).

Vegetation data were analyzed by calculating the Important Value Index (IVI) and the Shannon-Wiener Diversity Index (H') to assess species dominance and diversity. IVI values were classified into three categories: low (<21.96), moderate (21.96-42.66), and high (>42.66). The Shannon-Wiener Index was also divided into three levels: low (H'<1), moderate (1≤H'≤3), and high (H'>3) (Fachrul 2007).

IVI = RD + RF (Understory, Seedling, and Sapling)

IVI = RD + RF + RDo (Pole and Tree)

$$\text{Density (D)} = \frac{\text{Total individual of species i}}{\text{Total area}}$$

$$\text{Relative Density (RD)} = \frac{\text{Total individual of species i}}{\text{Total area x 100\%}}$$

$$\text{Frequency (F)} = \frac{\text{Total plot of species i}}{\text{Total plot}}$$

$$\text{Relative Frequency (RF)} = \frac{\text{Total individual of species i}}{\text{Total plot x 100\%}}$$

$$\text{Dominance (D)} = \frac{\text{Total basal area of species i}}{\text{Total area}}$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Total individual of species i}}{\text{Total area x 100\%}}$$

$$H = - \sum Pi * Ln(Pi)$$

Where, H': Shannon-Wiener Diversity Indeks, pi: ni/N, ni: Total individual of species i, N: Total Individual, Ln: Natural logarithm. The conservation strategy was developed using a SWOT analysis, which evaluates internal factors (strengths and weaknesses) and external factors (opportunities and threats) associated with the presence of binjai in South Kalimantan. The analysis involved assigning weights to each factor, calculating the Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS), and constructing the SWOT Strategy Matrix (Agustin et al. 2023).

RESULTS AND DISCUSSION

Distribution and habitat

The exploration identified 21 binjai trees distributed across four districts in South Kalimantan, namely Hulu Sungai Tengah with 9 trees (42.86%), Hulu Sungai Selatan with 6 trees (28.57%), Tapin with 5 trees (23.81%), and Banjar with 1 tree (4.76%) (Figure 2). Hulu Sungai Tengah had the highest number of binjai trees, suggesting relatively stable environmental conditions that support binjai growth. This area appears to face fewer threats from land conversion compared to other regions, which supports binjai conservation**.** According to Irawan et al. (2019), the high population of binjai in this area may also reflect the active role of local communities in conserving and sustainably utilizing native species.

These findings indicate an uneven spatial distribution of binjai trees across the surveyed regions. The trees were found in home yards, rice fields, and mixed gardens (Figure 3). Soil texture in the binjai habitat varied from loam, sandy clay loam, clay loam, and clay. Most trees were not planted through intentional cultivation but were inherited as old trees passed down through generations. The species frequently occurs near residential areas and often grows alongside a variety of other plants, reflecting the local practice of cultivating of cultivating multiple species in home yards and mixed gardens. This arrangement allows easier access to the fruit. In rice fields, binjai trees also provide shade for farmers during agricultural activities.

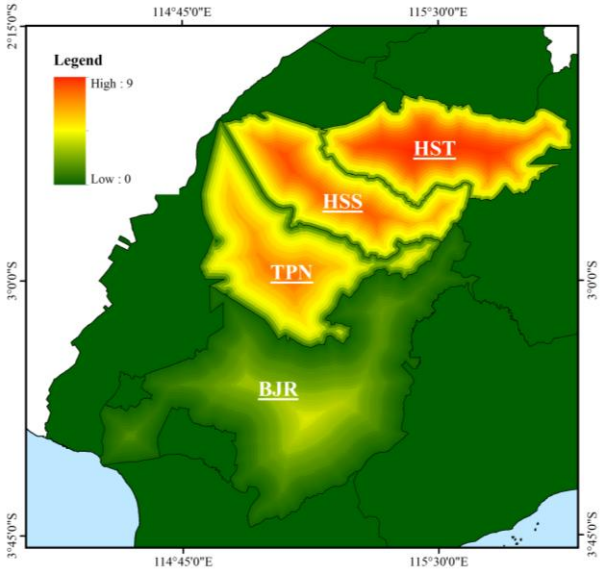


Figure 2. Distribution of binjai in South Kalimantan, Indonesia. Banjar (BJR), Tapin (TPN), Hulu Sungai Selatan (HSS), and Hulu Sungai Tengah (HST)

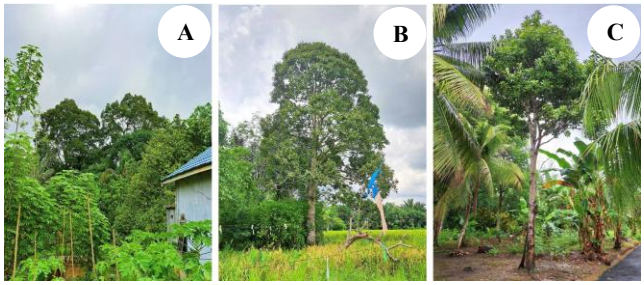


Figure 3. Binjai habitats in South Kalimantan, Indonesia. A. Home yard, B. Rice field, C. Mixed garden

Table 2. Environmental factors of binjai habitats in South Kalimantan, Indonesia

Environmental factor	Min	Max	Habitat types					
			Home yard		Rice field		Mixed garden	
			Min	Max	Min	Max	Min	Max
Elevation (m asl)	7	173	10	38	7	27	9	173
Air Temperature (˚C)	28.30	30.42	28.51	30.08	28.58	29.98	28.30	30.42
Air Humidity (%)	70.00	82.33	72.89	81.00	72.67	82.33	70.00	82.11
Light Intensity (lux)	11472	62870	15213	54470	21473	62870	11472	60426
Soil Temperature (˚C)	28.78	30.04	29.26	29.96	28.78	29.74	29.37	30.04
Soil Moisture (%)	52.78	63.89	53.33	60.00	55.00	63.89	52.78	58.89
Soil pH	4.56	6.89	4.65	6.71	4.56	6.87	5.35	6.89

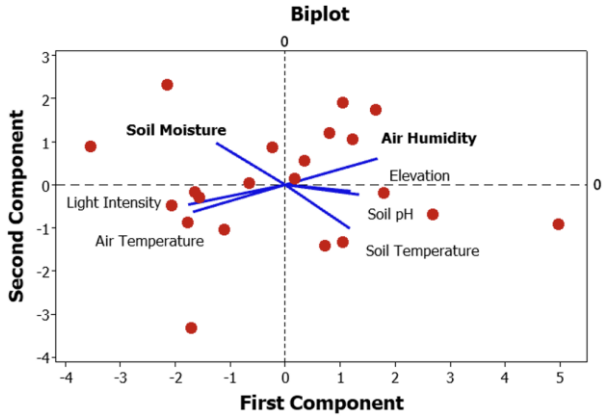


Figure 4. PCA biplot showing environmental factors of binjai habitats in South Kalimantan, Indonesia

Environmental factors

Binjai trees were found at elevation (7-173 m asl), air temperatures (28.30-30.42˚C), air humidities (70.00-82.33%), light intensities (11472-62870 lux), soil temperatures (28.78-30.04˚C), soil moistures (52.78-63.89%), and soil pH levels (4.56-6.89) (Table 2). These values show that binjai adapts well to lowland tropical environments, which feature moderately warm temperatures, high humidity, moderate to high light intensity, moist soils, and slightly acidic to near-neutral pH. Compared to kasturi (*M. casturi*) in South Kalimantan, binjai exhibits a slightly broader tolerance range. Kasturi has been recorded at elevations (35-109 m asl), air temperatures (27.90-33.10˚C), air humidities (64.30-86.90%), light intensities (19442-96938 lux), soil temperatures (27.10-32.80˚C), soil moistures (40.60-77.20%), and soil pH levels (5.4-6.80) (Gunawan et al. 2022).

The PCA results generated seven components that collectively accounted for 100% of the variance in environmental factors influencing the binjai habitat. The variance was distributed as follows: 55.30% (PC1), 24.80% (PC2), 10.00% (PC3), 8.20% (PC4), 0.90% (PC5), 0.60% (PC6), and 0.20% (PC7). Two principal components had eigenvalues greater than 1, with PC1 at 3.8693 and PC2 at 1.7370, indicating their importance in explaining environmental variability in binjai habitats in South Kalimantan. These findings align with Shrestha (2021), who noted that components with eigenvalues greater than 1 are considered significant, as such components account for more shared variance than unique variance. PC1 alone explained 55.30% of the total variance, demonstrating strong explanatory power. PC2 contributed an additional 24.80%, resulting in a cumulative explanation of 80.10% of the total variance. This suggests that the first two principal components sufficiently represent the majority of variation in the original environmental dataset.

The most influential environmental variables were air humidity (loading value: 0.435 on PC1) and soil moisture (loading value: 0.559 on PC2). The analysis indicates that binjai trees tend to occur within similar ranges of air humidity and soil moisture. Other environmental factors showed greater variability, making it difficult to define precise habitat conditions for binjai. Notably, the key environmental factors for binjai differ from those of kasturi (*M. casturi*), which is more strongly affected by air temperature (Gunawan et al. 2022).

The PC1 axis (55.30%) was defined by air humidity (0.435), soil pH (0.348), altitude (0.308), and soil temperature (0.304), whereas the PC2 axis (24.80%) was defined by soil moisture (0.559) and air humidity (0.032). These results indicate that binjai tends to thrive in habitats with high air humidity and soil moisture, while elevated light intensity and air temperature are less favorable for its growth. Figure 4 shows that air humidity axis is positively correlated with elevation, soil temperature, and soil pH. This implies that higher air humidity levels co-occur with increased elevation, soil temperature, and soil pH in binjai habitats. Conversely, air humidity shows a negative correlation with air temperature and light intensity, indicating that high air humidity typically occurs in cooler and more shaded environments. Soil moisture also exhibits a negative correlation with soil temperature, suggesting that higher soil moisture levels contribute to cooler soil conditions. Air humidity and soil moisture do not directly correlate because their relationship is orthogonal (90˚ angle) in the PCA plot (Greenacre et al. 2022), suggesting that each factor independently influences the binjai habitat.

Lobo and Sidhu (2017) reported that *Mangifera* species tolerate a wide range of air humidity, from 40% in winter to 85% in summer. Air humidity plays a crucial role in regulating photosynthesis. Higher air humidity reduces water loss through the stomata, helping to maintain leaf turgidity and ensuring optimal photosynthetic activity. Similarly, moist soil supports the development of shoots and young leaves by enhancing the availability, distribution, and mobility of nutrients, factors that significantly influence plant growth. A steady water supply to the root zone conserves nutrients by reducing leaching

and maintains optimal soil moisture (Damtie et al. 2022). Understanding these environmental factors can aid in identifying and prioritizing areas with similar ecological characteristics to support the targeted conservation and cultivation of binjai (Gunawan et al. 2023).

Structure and composition of vegetation

The results of observations in the binjai habitat showed the presence of 74 species belonging to 38 families, namely Acanthaceae, Anacardiaceae, Annonaceae, Araceae, Arecaceae, Asteraceae, Bromeliaceae, Caricaceae, Clusiaceae, Combretaceae, Davalliaceae, Dipterocarpaceae, Ebenaceae, Euphorbiaceae, Fabaceae, Geraniaceae, Loganiaceae, Malvaceae, Meliaceae, Mimosaceae, Moraceae, Musaceae, Myrtaceae, Oxalidaceae, Pandanaceae, Piperaceae, Poaceae, Polygonaceae, Rubiaceae, Rutaceae, Sapindaceae, Sapotaceae, Solanaceae, Sterculiaceae, Thelypteridaceae, Ulmaceae, Verbenaceae, dan Zingiberaceae. These species were distributed across 21 designated plots. The vegetation in these plots comprised 678 individuals of 29 species at understory level, 18 individuals of 8 species at seedling level, 97 individuals of 19 species at saplings level, 88 individuals of 19 species at pole level, and 102 individuals of 22 species at tree level. The lists of plant species are provided in Tables 3-7.

The vegetation composition within the binjai habitat was dominated by three families: Anacardiaceae, Asteraceae, and Poaceae, each comprising six different species. The proportion of individuals in each dominant family was Anacardiaceae (6.00%), Asteraceae (9.16%), and Poaceae (40.69%) (Figure 5). Anacardiaceae included *Bouea macrophylla*, *M. laurina*, *M. caesia*, *M. casturi*, *M. foetida*, and *Spondias dulcis*. This family dominated seedlings, saplings, poles, and mature trees level. Most members of this family are perennial plants, and grow in both dry and wet habitats, although the majority are found in drier conditions. This family is frequently utilized by communities for food, livestock feed, timber, medicine, and other purposes (Mitchell et al. 2022).

In contrast, Asteraceae and Poaceae dominated the understory layer. Asteraceae included *Ageratum conyzoides*, *Chromolaena odorata*, *Cyanthillium cinereum*, *Erigeron canadensis*, *Mikania micrantha*, and *Synedrella nodiflora*, while Poaceae comprised *Bambusa spinosa*, *Cynodon dactylon*, *Digitaria ciliaris*, *Oryza sativa*, *Paspalum longifolium*, and *Phragmites karka*. Several species from these families exhibit invasive characteristics. Asteraceae is among the largest families of flowering plants and is commonly found in dry and semi-arid areas. Its members include annual, biennial, or perennial herbs, subshrubs, and shrubs (Maroyi 2023). Many species are cultivated as ornamental plants due to their attractive flowers (Fitriyati et al. 2024). Poaceae consists of annual or perennial grasses and is the most globally distributed plant family (Veldkamp et al. 2019).

Table 3. Understory species recorded in binjai habitats in South Kalimantan, Indonesia

Scientific name	Local name	Family	Habitus	Origin	RD (%)	RF (%)	IVI (%)
Cynodon dactylon *	*Rumput Bermuda*	Poaceae	Graminoid	Non-native, invasive	17.70	13.04	30.74
Oryza sativa *	*Padi*	Poaceae	Graminoid	Native	17.70	13.04	30.74
Digitaria ciliaris	*Rumput Cakar Ayam*	Poaceae	Graminoid	Non-native, invasive	8.85	6.52	15.37
Paspalum longifolium	*Jukut Cariang*	Poaceae	Graminoid	Native	8.85	6.52	15.37
Caladium bicolor	*Keladi*	Araceae	Forb/herb	Non-native	2.36	6.52	8.88
Manihot esculenta	*Singkong*	Euphorbiaceae	Shrub	Non-native	1.47	4.35	5.82
Ageratum conyzoides	*Bandotan*	Asteraceae	Forb/herb	Non-native, invasive	2.95	2.17	5.12
Alpinia galanga	*Lengkuas*	Zingiberaceae	Forb/herb	Non-native	2.95	2.17	5.12
Asystasia gangetica	*Ara Sungsang*	Acanthaceae	Subshrub	Native, invasive	2.95	2.17	5.12
Chromolaena odorata	*Kirinyuh*	Asteraceae	Subshrub	Non-native, invasive	2.95	2.17	5.12
Geranium nodosum	*Geranium*	Geraniaceae	Forb/herb	Non-native	2.95	2.17	5.12
Mikania micrantha	*Sembung Rambat*	Asteraceae	Vine	Non-native, invasive	2.95	2.17	5.12
Phragmites karka	*Perumpung*	Poaceae	Graminoid	Native, invasive	2.95	2.17	5.12
Piper betle	*Sirih*	Piperaceae	Vine	Native	2.95	2.17	5.12
Polygonum cuspidatum	*Keludah*	Polygonaceae	Forb/herb	Non-native, invasive	2.95	2.17	5.12
Solanum carolinense	*Terong Duri*	Solanaceae	Forb/herb	Non-native, invasive	2.95	2.17	5.12
Synedrella nodiflora	*Jotang Kuda*	Asteraceae	Forb/herb	Non-native, invasive	2.95	2.17	5.12
Urena lobata	*Pulutan*	Malvaceae	Subshrub	Native, invasive	2.95	2.17	5.12
Euphorbia heterophylla	*Kate Mas*	Euphorbiaceae	Forb, herb	Non-native, invasive	1.47	2.17	3.65
Cyanthillium cinereum	*Sawi Langit*	Asteraceae	Forb/herb	Native, invasive	0.74	2.17	2.91
Davallia solida	*Pakis Kaki Kelinci*	Davalliaceae	Forb/herb	Native	0.74	2.17	2.91
Dieffenbachia seguine	*Blanceng*	Araceae	Forb/herb	Non-native	0.74	2.17	2.91
Elettaria cardamomum	*Kapulaga*	Zingiberaceae	Forb/herb	Non-native	0.74	2.17	2.91
Erigeron canadensis	*Memaku*	Asteraceae	Forb/herb	Non-native, invasive	0.74	2.17	2.91
Pandanus amaryllifolius	*Pandan Wangi*	Pandanaceae	Shrub	Native	0.74	2.17	2.91
Thelypteris noveboracensis	*Paku New York*	Thelypteridaceae	Forb/herb	Non-native	0.74	2.17	2.91
Ananas comosus	*Nanas*	Bromeliaceae	Forb/herb	Non-native	0.44	2.17	2.62
Amorphophallus paeoniifolius	*Suweg*	Araceae	Forb/herb	Native	0.29	2.17	2.47
Clerodendrum paniculatum	*Bunga Pagoda*	Verbenaceae	Shrub	Native	0.29	2.17	2.47

Note: *: Dominant species

Table 4. Species at the seedling level in binjai habitats in South Kalimantan, Indonesia

Scientific name	Local name	Family	Habitus	Origin	RD (%)	RF (%)	IVI (%)
Caryota mitis *	*Palem Sarai*	Arecaceae	Tree	Native	55.56	12.50	68.06
Mangifera caesia *	*Binjai*	Anacardiaceae	Tree	Native	11.11	12.50	23.61
Cananga odorata	*Kenanga*	Annonaceae	Shrub, Tree	Native	5.56	12.50	18.06
Carica papaya	*Pepaya*	Caricaceae	Shrub, Tree	Non-Native	5.56	12.50	18.06
Hevea brasiliensis	*Karet*	Euphorbiaceae	Tree	Non-Native	5.56	12.50	18.06
Livistona chinensis	*Palem Kipas*	Arecaceae	Tree	Non-Native	5.56	12.50	18.06
Psidium guajava	*Jambu Biji*	Myrtaceae	Tree	Non-Native	5.56	12.50	18.06
Theobroma cacao	*Kakao*	Sterculiaceae	Shrub, Tree	Non-Native	5.56	12.50	18.06

Note: *: Dominant species

Table 5. Species at the sapling level in binjai habitats in South Kalimantan, Indonesia

Scientific name	Local name	Family	Habitus	Origin	RD (%)	RF (%)	IVI (%)
Musa paradisiaca *	*Pisang*	Musaceae	Forb/Herb	Native	27.84	19.57	47.40
Bambusa spinosa *	*Bambu*	Poaceae	Graminoid	Native	20.62	2.17	22.79
Mangifera laurina	*Hampalam*	Anacardiaceae	Tree	Native	5.15	10.87	16.02
Annona muricata	*Sirsak*	Annonaceae	Tree	Non-Native	4.12	8.70	12.82
Psidium guajava	*Jambu Biji*	Myrtaceae	Tree	Non-Native	4.12	8.70	12.82
Manihot esculenta	*Singkong*	Euphorbiaceae	Shrub	Non-Native	8.25	4.35	12.60
Citrus jambhiri	*Limau Kuit*	Rutaceae	Shrub, Tree	Non-Native	4.12	6.52	10.65
Averrhoa bilimbi	*Belimbing Tunjuk*	Oxalidaceae	Tree	Native	3.09	4.35	7.44
Carica papaya	*Pepaya*	Caricaceae	Shrub, Tree	Non-Native	3.09	4.35	7.44
Citrus aurantifolia	*Jeruk Nipis*	Rutaceae	Shrub, Tree	Native	3.09	4.35	7.44
Citrus sinensis	*Jeruk*	Rutaceae	Shrub, Tree	Non-Native	3.09	4.35	7.44
Nephelium lappaceum	*Rambutan*	Sapindaceae	Tree	Native	3.09	4.35	7.44
Arenga pinnata	*Aren*	Arecaceae	Tree	Native	2.06	4.35	6.41
Lepisanthes rubiginosa	*Kelalayu*	Sapindaceae	Tree	Non-Native	2.06	2.17	4.24
Trema orientalis	*Indarung*	Ulmaceae	Tree	Native	2.06	2.17	4.24
Archidendron pauciflorum	*Jengkol*	Mimosaceae	Tree	Native	1.03	2.17	3.20
Dimocarpus longan	*Lengkeng*	Sapindaceae	Tree	Native	1.03	2.17	3.20
Syzygium aqueum	*Jambu Air*	Myrtaceae	Tree	Native	1.03	2.17	3.20
Theobroma cacao	*Kakao*	Sterculiaceae	Shrub, Tree	Non-Native	1.03	2.17	3.20

Note: *: Dominant species

Table 6. Species at the pole level in binjai habitats in South Kalimantan, Indonesia

Scientific name	Local name	Family	Habitus	Origin	RD (%)	RF (%)	RDo (%)	IVI (%)
Musa paradisiaca *	*Pisang*	Musaceae	Forb/Herb	Native	47.73	22.45	45.77	115.95
Mangifera foetida *	*Hambawang*	Anacardiaceae	Tree	Native	9.09	14.29	10.41	33.79
Cocos nucifera *	*Kelapa*	Arecaceae	Tree	Native	6.82	10.20	10.02	27.04
Artocarpus heterophyllus	*Nangka*	Moraceae	Tree	Native	4.55	8.16	4.54	17.25
Mangifera laurina	*Hampalam*	Anacardiaceae	Tree	Native	4.55	8.16	4.54	17.25
Artocarpus altilis	*Sukun*	Moraceae	Tree	Native	4.55	4.08	3.74	12.36
Syzygium aqueum	*Jambu Air*	Myrtaceae	Tree	Native	2.27	4.08	3.05	9.40
Mangifera casturi	*Kasturi*	Anacardiaceae	Tree	Endemic	2.27	4.08	2.50	8.85
Annona muricata	*Sirsak*	Annonaceae	Tree	Non-Native	2.27	4.08	1.44	7.80
Nephelium lappaceum	*Rambutan*	Sapindaceae	Tree	Native	2.27	2.04	3.10	7.42
Hevea brasiliensis	*Karet*	Euphorbiaceae	Tree	Non-Native	3.41	2.04	1.70	7.15
Durio zibethinus	*Durian*	Malvaceae	Tree	Native	2.27	2.04	1.57	5.88
Ficus racemosa	*Loa*	Moraceae	Tree	Native	1.14	2.04	1.89	5.06
Bouea macrophylla	*Ramania*	Anacardiaceae	Tree	Native	1.14	2.04	1.47	4.64
Morinda citrifolia	*Mengkudu*	Rubiaceae	Shrub, Tree	Native	1.14	2.04	1.25	4.43
Spondias dulcis	*Kedondong*	Anacardiaceae	Tree	Non-Native	1.14	2.04	1.00	4.18
Strychnos nux-vomica	*Bidara Laut*	Loganiaceae	Tree	Native	1.14	2.04	0.87	4.04
Hopea odorata	*Merawan*	Dipterocarpaceae	Tree	Native	1.14	2.04	0.59	3.77
Sandoricum koetjape	*Kecapi*	Meliaceae	Tree	Native	1.14	2.04	0.56	3.73

Note: *: Dominant species

Table 7. Species at the tree level in binjai habitats in South Kalimantan, Indonesia

Scientific name	Local name	Family	Habitus	Origin	RD (%)	RF (%)	RDo (%)	IVI (%)
Mangifera caesia *	*Binjai*	Anacardiaceae	Tree	Native	20.59	30.00	46.40	96.99
Cocos nucifera *	*Kelapa*	Arecaceae	Tree	Native	14.71	11.43	6.08	32.22
Durio zibethinus *	*Durian*	Malvaceae	Tree	Native	9.80	7.14	5.94	22.89
Mangifera foetida	*Hambawang*	Anacardiaceae	Tree	Native	5.88	7.14	7.49	20.51
Hevea brasiliensis	*Karet*	Euphorbiaceae	Tree	Non-Native	11.76	2.86	4.64	19.26
Mangifera casturi	*Kasturi*	Anacardiaceae	Tree	Endemic	4.90	7.14	6.73	18.77
Arenga pinnata	*Aren*	Arecaceae	Tree	Native	6.86	5.71	3.06	15.64
Aleurites moluccana	*Kemiri*	Euphorbiaceae	Tree	Native	1.96	1.43	6.01	9.40
Mangifera laurina	*Hampalam*	Anacardiaceae	Tree	Native	2.94	2.86	2.58	8.38
Artocarpus heterophyllus	*Nangka*	Moraceae	Tree	Native	2.94	2.86	1.16	6.95
Artocarpus altilis	*Sukun*	Moraceae	Tree	Native	2.94	2.86	1.11	6.91
Diospyros blancoi	*Mentega*	Ebenaceae	Tree	Non-Native	1.96	2.86	1.44	6.26
Swietenia macrophylla	*Mahoni*	Meliaceae	Tree	Non-Native	1.96	1.43	2.33	5.72
Nephelium lappaceum	*Rambutan*	Sapindaceae	Tree	Native	1.96	2.86	0.77	5.59
Artocarpus integer	*Cempedak*	Moraceae	Tree	Native	1.96	1.43	1.23	4.62
Enterolobium cyclocarpum	*Sengon Buto*	Fabaceae	Tree	Non-Native	0.98	1.43	0.54	2.95
Ceiba pentandra	*Kapuk*	Malvaceae	Tree	Non-Native	0.98	1.43	0.52	2.93
Garcinia mangostana	*Manggis*	Clusiaceae	Tree	Native	0.98	1.43	0.47	2.87
Bouea macrophylla	*Ramania*	Anacardiaceae	Tree	Native	0.98	1.43	0.44	2.85
Manilkara zapota	*Sawo*	Sapotaceae	Tree	Non-Native	0.98	1.43	0.39	2.80
Syzygium aqueum	*Jambu Air*	Myrtaceae	Tree	Native	0.98	1.43	0.35	2.76
Terminalia catappa	*Ketapang*	Combretaceae	Tree	Native	0.98	1.43	0.34	2.75

Note: *: Dominant species

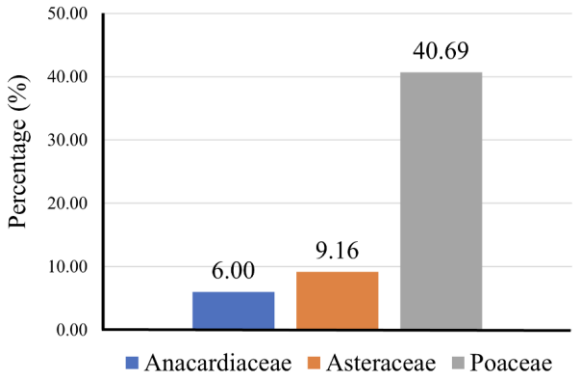


Figure 5. Dominant vegetation at the family level in binjai habitats

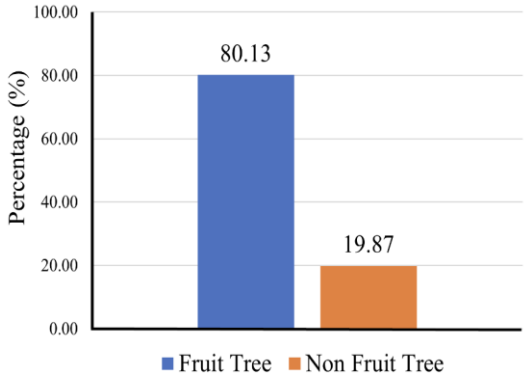


Figure 6. Composition of tree habitus in binjai habitats

Importance value index (IVI)

The Importance Value Index (IVI) reflects the ecological influence of specific vegetation types within the binjai habitat. Dookie et al. (2024) emphasized that species with high IVI are ecologically important due to their adaptability to diverse environmental conditions. As shown in Figure 7, banana (*M. paradisiaca*) emerged as the most dominant species and played a substantial role in shaping the vegetation structure of the binjai habitat. Its frequent coexistence with binjai likely results from their common cultivation in community yards alongside other crops, which also contributes to household food security for the local community. Species classified as dominant in this study were those with an importance value index (IVI) categorized moderate to high (≥21.96) (Fachrul 2007). The species with the highest IVI at each vegetation level in the binjai habitat were *C. dactylon* (30.74%) and *O. sativa* (30.74%) for understory; *C. mitis* (68.06%) and *M. caesia* (23.61%) for seedlings; *M. paradisiaca* (47.40%) and *B. spinosa* (22.79%) for saplings; *M. paradisiaca* (115.95%), *M. foetida* (33.79%), and *C. nucifera* (27.04%) for poles; and *C. nucifera* (32.22%) and *D. zibethinus* (22.89%) for trees (Figure 7). Invasive plants aggressively dominate the understory. Rice also dominates the vegetation, indicating the preference of binjai for rice field habitats. Fruit trees constitute the majority of dominant vegetation in the binjai habitat, accounting for 80.13%, while non-fruit trees represent 19.87% (Figure 6). These fruit trees occurred across the seedling, sapling, pole, and mature tree levels. In contrast, the vegetation composition in the tandui (*M. rufocostata*) habitat, also located in South Kalimantan, differs despite both being generally dominated by fruit trees. The species composition varies across growth levels: *S. aqueum*, *H. brasiliensis*, and *B. macrophylla* for seedling. *H. brasiliensis*, *S. aqueum*, and *G. renghas* for saplings. *H. brasiliensis*, *N. lappaceum*, and *P. canescens*

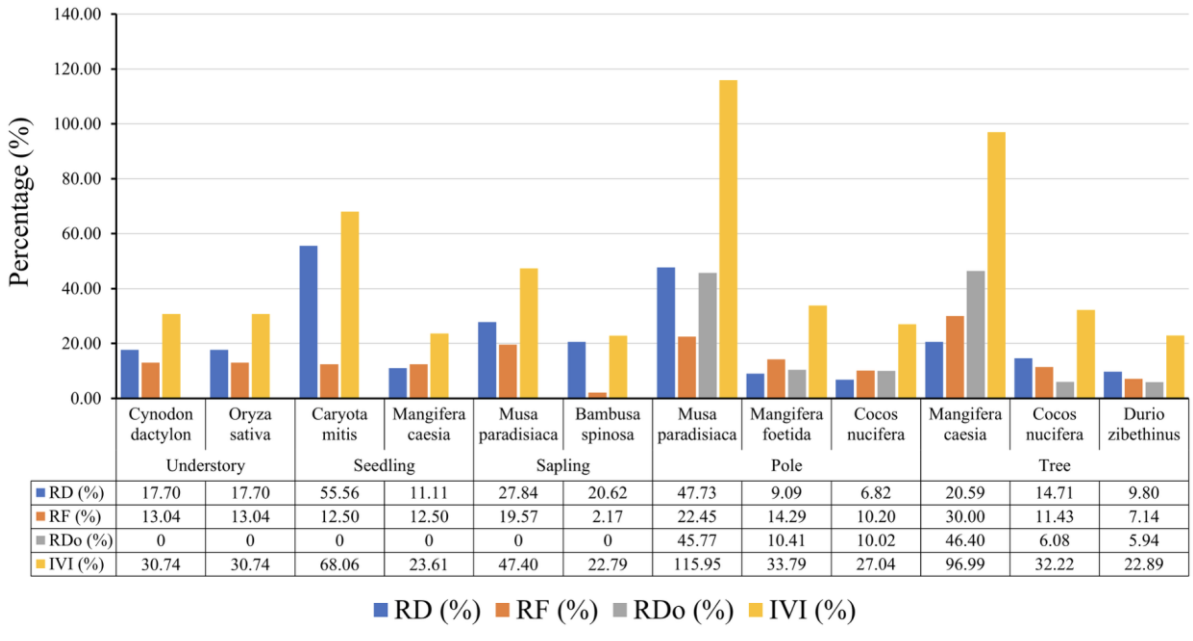
for poles. *Cocos nucifera*, *H. brasiliensis*, and *L. domesticum* for trees (Fitriani and Prihatiningtyas 2022). These patterns indicate that *Mangifera* species in South Kalimantan typically grow in association with other plants.

The vegetation in the binjai habitat corresponds with identified environmental factors, which include lowland tropical conditions characterized by relatively warm temperatures, high air humidity, moderate to high light intensity, moist soils, and slightly acidic to near-neutral pH. *Cynodon dactylon*, *O. sativa*, and *C. mitis* grow well at air temperatures of 23-35°C and relative humidity of 50-85%, matching the warm and humid conditions of the binjai habitat. *Cynodon dactylon* and *O. sativa* require full sunlight, while *C. mitis* tolerates shade but also grows in open areas. All three species grow well in soil temperatures of 20-33°C, soil moistures of 60-100%, and soil pH values of 5.50-7.0. These conditions reflect the soil characteristics in the binjai habitat (Rathnayake et al. 2016; Mandal et al. 2017; Quek et al. 2020). *Bambusa spinosa* commonly grows in tropical lowland areas, tolerates poor and rocky soils, and thrives under air temperatures of 20-35°C, consistent with the conditions recorded in the binjai habitat (Eyasu et al. 2024).

The presence of *M. paradisiaca*, *M. foetida*, *C. nucifera*, and *D. zibethinus* reinforces the ecological suitability between these tropical plant species and the binjai habitat. *Musa paradisiaca* prefers air temperatures of 31-32°C, soil temperatures of 27-28°C, and pH values of 4.5-7.5, which align with environmental conditions observed in the binjai habitat. *Mangifera foetida* grows well at temperatures of 24-30°C and air humidity below 80%, matching the local climate characteristics (Rao et al. 2016). *Cocos nucifera* tolerates air temperatures of 27-32°C and a soil pH of 5.5-7.0, and require full sunlight and well-drained soils, conditions that are present in the binjai habitat (Beveridge et al. 2022). *Durio zibethinus* grows best at air temperatures of 27-30°C, relative humidity of 75-80%, and elevations below 800 m (Ketsa et al. 2020). Although soil temperature in the binjai habitat is slightly higher, it remains within the tolerance range of durian. These dominant species show broad adaptability to the climatic and edaphic profile of the binjai habitat. Collectively, these environmental factors support the natural growth of binjai and create a stable habitat favorable for associated species. Such habitat characteristics not only reflect the ecological adaptability of binjai and its associated flora but also support its conservation by highlighting its ability to coexist with human communities across a broad ecological spectrum. These findings are consistent with the ecological preferences of *M. rufocostata*, which thrives in humid tropical environments with moderately fertile soils that also support the growth of surrounding tropical species (Fitriani et al. 2022; Fitriani and Prihatiningtyas 2022). Environmental adaptation also contributes to the dominance of wild nutmeg trees in association with various tropical fruit species, such as *Ficus benjamina*, *Mimusops elengi*, *Vitex cofassus*, *Melia iners*, *Pometia pinnata*, and *Euterpe edulis* (Mandea et al. 2024).

Diversity index (H')

The vegetation diversity index (H') in the binjai habitat was 2.81 for understory, 1.53 for seedlings, 2.40 for saplings, 2.08 for poles and 2.60 for trees. All values fell into the moderate diversity category (1≤H′≤3) (Table 8). Higher H′ values reflect greater species richness and evenness, while lower values indicate lower community diversity (Lahon and Sahariah 2022). Accordingly, the moderate diversity in the binjai habitat suggests a balanced community structure, which may enhance ecological stability under varying environmental conditions.



	Cynodon dactylon	Oryza sativa	Caryota mitis	Mangifera caesia	Musa paradisiaca	Bambusa spinosa	Musa paradisiaca	Mangifera foetida	Cocos nucifera	Mangifera caesia	Cocos nucifera	Durio zibethinus
	Understory		Seedling		Sapling		Pole			Tree		
RD (%)	17.70	17.70	55.56	11.11	27.84	20.62	47.73	9.09	6.82	20.59	14.71	9.80
RF (%)	13.04	13.04	12.50	12.50	19.57	2.17	22.45	14.29	10.20	30.00	11.43	7.14
RDo (%)	0	0	0	0	0	0	45.77	10.41	10.02	46.40	6.08	5.94
IVI (%)	30.74	30.74	68.06	23.61	47.40	22.79	115.95	33.79	27.04	96.99	32.22	22.89

Figure 7. Species with the highest IVI in binjai habitats in South Kalimantan, Indonesia

Table 8. Shannon diversity index (H') in binjai habitats in South Kalimantan, Indonesia

Vegetation level	Diversity index (H')	Category
Understory	2.81	Moderate
Seedling	1.53	Moderate
Sapling	2.40	Moderate
Pole	2.08	Moderate
Tree	2.60	Moderate

Conservation strategy

Socio-demographic characteristics

A total of 125 respondents participated in this study, comprising 73 males and 52 females. Their ages were classified according to the Ministry of Health Republic Indonesia (2025) into three categories: teenagers (10-18 years) for 4.00%, adults (19-59 years) for 92.80%, and elderly (60+ years) for 3.20%. Respondents had diverse educational backgrounds, ranging from elementary school to college-level attainment. Most had completed senior high school (44.00%), followed by junior high school graduates (35.20%), elementary school graduates (8.00%), and higher education graduates (7.20%). A small proportion (5.60%) reported having no formal education. Occupations also varied, with the majority working as farmers (38.40%), followed by traders (13.60%), laborers (12.00%), employees (4.8%), civil servants (4.00%), and entrepreneurs (2.40%). Others included the unemployed (10.40%), students (8.00%), and housewives (6.40%) (Figure 8).

SWOT analysis

The analysis of Internal Factors Analysis Summary (IFAS) (Table 9) and External Factors Analysis Summary (EFAS) (Table 10) identified a defensive strategy as the most suitable approach for binjai conservation in South Kalimantan, based on its position in the third quadrant (bottom-left) of the strategic matrix. The IFAS score was -0.32, while the EFAS score was -0.35 (Figure 9), indicating the need to address internal weaknesses while minimizing exposure to external threats (W-T strategy). The strategy should also consider the potential to strengthen existing strengths and opportunities (Jahanifar et al. 2017). The primary internal weakness is that communities have not prioritized binjai cultivation. Consequently, most of the remaining binjai trees consist of aged individuals that persist as part of ancestral heritage (Table 9) (Salma et al. 2015). Table 10 identified land conversion for agriculture and settlement as the main external threat. This transformation, typically initiated through logging activities for timber production, often results in the indiscriminate removal of non-target species such as binjai. According to Berhanu et al. (2023), land-use conversion further threatens vulnerable native and endemic species. To address the weaknesses and threats in binjai conservation in South Kalimantan, several conservation strategies are proposed (Table 11).

Protecting existing binjai trees

Conservation efforts should begin with preventing the unnecessary felling of existing binjai trees. This effort requires active participation from local farmers, including those who own trees. In South Kalimantan, wood remains widely used, and local communities have historically utilized binjai timber as an alternative construction material and firewood (Table 9) (Gerten et al. 2015). This long-standing practice has played a significant role in the decline of the species. Although binjai logging has become rare due to declining tree availability, its historical impact remains evident. Local farmers must adopt sustainable logging practices to ensure that harvesting does not threaten tree survival. They should also regularly plant binjai seeds to maintain population levels and support long-term conservation, including through the use of private land such as home gardens, which serve as a complementary conservation strategy (Table 9). A previous study has identified home gardens as effective in conserving native plants (Wahyuningtyas et al. 2024). These spaces contribute to biodiversity directly by increasing plant species richness and indirectly by supporting household livelihoods (Mathewos et al. 2018). Growing binjai in home gardens not only helps safeguard the species at the local level but also encourages its integration into everyday life, thereby reinforcing community-based conservation efforts.

Local farmers can incorporate binjai into agroforestry systems (Table 10), which offer a larger-scale alternative to mixed gardens, currently serving as the primary habitat for binjai. The system is well-suited for binjai, which naturally grows alongside crops such as rice, banana, coconut, durian, and horse mango (Figure 7). It involves strategic plant placement to ensure adequate light exposure and prevent excessive species density. In addition to spatial planning, conservation can be further strengthened by standardizing cultivation practices, ensuring access to high-quality planting materials, and expanding the potential uses of the species (Kour et al. 2018). The system not only supports plant growth but is also considered suitable for establishing small-scale conservation habitats outside protected areas (Rafaai and Abdullah 2024). A previous study in Cumilla District, Bangladesh, reported that *Mangifera* has successfully grown in an agroforestry system, coexisting with coconut, banana, guava, papaya, jackfruit, and lemon, alongside forest species such as bamboo, mahogany, and eucalyptus (Kamran et al. 2023). These findings demonstrate that agroforestry systems can contribute to binjai conservation while enhancing biodiversity.

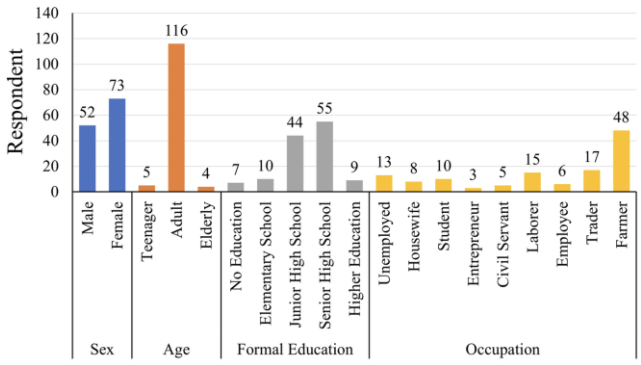


Figure 8. Demographic profiles of the respondents

Community land management also offers complementary conservation strategies, but Nurrahman et al. (2024) highlight that its success largely depends on the active participation of local communities. Despite its conservation potential (Table 9), community land often suffers from limited implementation of basic management practices, including maintaining water availability, controlling invasive weeds, applying fertilizers, and managing pests. Local farmers can adopt drip irrigation to ensure a consistent water supply. This method not only supports plant health but also improves productivity. A study has shown that drip irrigation increases yields in *M. indica* and allows precise water regulation based on plant age, weather conditions, and soil characteristics (Thirupathaiah et al. 2020). The habitat of binjai in South Kalimantan, which is predominantly lowland areas such as rice fields, suggests that the species can tolerate periodic flooding (Table 10). This ecological adaptation requires effective drainage systems to facilitate rapid water runoff after flooding. Choosing the right planting time can further reduce the risk of submergence during the early rainy season, which may damage or kill young seedlings. In response to these risks, post-flood management demands intensive care, including monitoring the health of roots and stems for signs of rot or disease, and pruning any affected parts.

Implementing ex situ conservation in botanical garden

The local community remains unaware of the importance of preserving binjai, resulting in the species being neglected and poorly managed (Table 9). Schrieber and Lachmuth (2017) state that unmanaged species are highly vulnerable to natural selection, genetic drift, and environmental pressures. These factors significantly threaten the success of future binjai reintroduction efforts and could lead to extinction. This situation underscores the urgent need for an integrated and collaborative conservation strategy, especially outside its natural habitat. Botanical gardens offer a promising solution for conserving binjai outside its natural range. They play a vital role in ex situ conservation by developing living collections and generating scientific knowledge that supports species identification, propagation, and habitat restoration (Donnell and Sharrock 2018). The Fairchild Tropical Botanic Garden exemplifies this, maintaining over 23 *Mangifera* species and serving as a research hub for interspecies mango breeding (Ledesma et al. 2017). This institution offers a viable model for advancing binjai conservation, especially considering its low regeneration rate in the wild. A study in India highlighted the value of systematic conservation efforts for underutilized fruit plants, including exploration, documentation, and utilization, carried out by research and conservation institutions. The Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi, India, has conserved approximately 440,000 accessions of 1,900 species in its gene bank, and 3,520 accessions of difficult-to-conserve species in its cryobank (Meena et al. 2022). Drawing from such successful models, implementing collaborative practices can significantly enhance efforts to preserve binjai.

A collaborative approach to ex situ conservation should begin with the exploration and identification of existing binjai populations, with universities conducting scientific assessments and species documentation. Botanical gardens, supported by regional agricultural offices, can advance this effort by inventorying germplasm from various sites in South Kalimantan. This process includes integrating genetic data and recording precise coordinates of original collection sites. Collaboration with local landowners and local community members remains essential to identify gaps and ensure that ex situ collections accurately represent the genetic diversity of in situ populations. NGOs can facilitate communication between researchers and communities, fostering participatory engagement and respect for traditional knowledge. Botanical gardens curate these collections as reservoirs of genetic material for future reintroduction and as reference sources to address threats in the natural habitats of binjai. Breman et al. (2021) emphasize that integrative conservation efforts reduce extinction risks and strengthen long-term biological resilience.

Table 9. Internal factor analysis matrix for binjai conservation strategy in South Kalimantan, Indonesia

Internal factor	Weight	Rating	Score
Strengths (S)			
Availability of community land supports binjai cultivation	0.11	3	0.36
Community-owned land promotes consistent maintenance	0.10	3	0.28
Communities use binjai for traditional medicinal purposes	0.07	2	0.16
Communities consume binjai fruits and process them into food products	0.10	3	0.31
Sale of binjai fruits provides an additional source of income	0.09	3	0.25
Score	**0.47**		**1.36**
Weaknesses (W)			**Score**
Communities remain unaware of the importance of preserving binjai	0.10	3	0.27
Communities have not prioritized binjai cultivation	0.12	4	0.42
Communities use binjai timber for construction purposes	0.11	3	0.34
Communities use binjai timber as firewood	0.09	3	0.23
Aged binjai trees persist as part of ancestral heritage	0.12	4	0.42
Score	**0.53**		**1.68**
Total	**1**		**3.04**
Difference			**-0.32**

Table 10. External factor analysis matrix for binjai conservation strategy in South Kalimantan, Indonesia

External factor	Weight	Rating	Score
Opportunity (O)			
Binjai can be cultivated in mixed gardens and agroforestry systems	0.12	4	0.42
Binjai shows resilience in periodically waterlogged areas	0.08	2	0.21
Native fruit markets support the commercial cultivation of binjai	0.10	3	0.27
Binjai conservation aligns with plant preservation and local ecological knowledge	0.09	3	0.25
Binjai is planted as a roadside tree in some communities	0.08	2	0.20
Score	**0.47**		**1.35**
Threat (T)			
Binjai cultivation areas are being converted into other agricultural lands	0.12	4	0.43
Expansion of residential areas reduces available land for binjai	0.12	3	0.41
Prolonged dry seasons increase the risk of land fires in binjai habitats	0.07	2	0.13
Communities prefer other mango species over binjai for cultivation	0.10	3	0.30
Lack of cross-sector collaboration hinders binjai conservation efforts	0.12	4	0.43
Score	**0.53**		**1.70**
Total	**1**		**3.05**
Difference			**-0.35**

Table 11. Binjai conservation strategies in South Kalimantan, Indonesia

No	Binjai conservation strategies in South Kalimantan
1	Protect binjai trees in their natural habitat (in situ) by preventing unnecessary logging, planting new seedlings, incorporating binjai into agroforestry systems, and practicing responsible land management.
2	Implement ex situ conservation efforts in botanical gardens, starting with the exploration, identification, and documentation of the origins and genetic resources of binjai.
3	Strengthen comprehensive environmental education to raise awareness of conservation and sustainability, targeting students at all education levels.
4	Foster cross-sector collaboration among government agencies, farmers, and local communities to highlight the cultural and economic value of binjai as a native fruit.

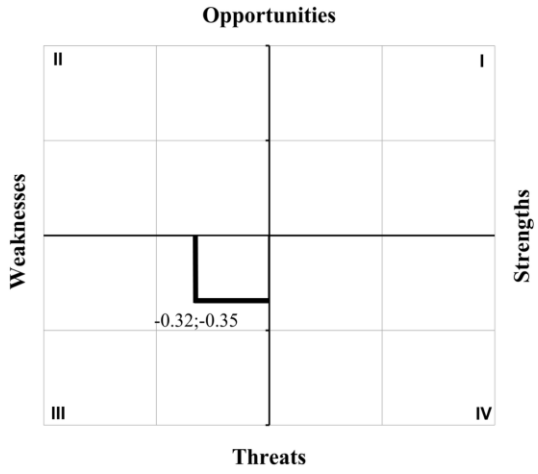


Figure 9. SWOT diagram showing binjai conservation strategy in South Kalimantan, Indonesia

Strengthening environmental education

Environmental education highlights the role of knowledge, experience, values, and local practices in sustaining biodiversity, including binjai. It utilizes various approaches, tools, and programs to foster environmental awareness, attitudes, and skills, enabling individuals to take informed conservation actions (Ardoin et al. 2020). A study in the Greater Accra Region of Ghana demonstrated the critical role of environmental education in biodiversity conservation. However, public awareness remains insufficient to influence daily conservation practices effectively (Eshun et al. 2022). Another study in China reveals that higher education levels positively affect public attitudes and understanding of the importance of conservation (Duan et al. 2022). The regional education office should integrate environmental education into binjai conservation efforts. Educators must deliver this education at all levels, from elementary to secondary schools and higher education institutions. They should actively develop and implement practical topics, such as conserving native plants and ecosystems. For example, Kim et al. (2020) demonstrated that garden-based curricular activities can effectively enhance learning. Schools that collaborate with NGOs should also provide environmental education in natural outdoor settings, with a specific focus on the conservation of binjai and its native ecosystems. Borsos et al. (2021) reported that outdoor education enhances students' plant identification skills. These educational approaches promote lasting attitudes toward environmental stewardship and foster greater awareness of local biodiversity. The lack of interest among the younger generation (Table 9), combined with insufficient supportive policies, poses significant challenges to environmental awareness, particularly in ethnobotany. Negi et al. (2018) reported that ethnobotanical knowledge predominantly resides with the older generation (aged 50 years and above). This study found that 12.80% of respondents in this

age group acknowledged the persistence of ethnobotanical knowledge but emphasized the need to promote it more widely. The low factor values regarding the use of binjai as traditional medicine (Table 9) further support this finding. Organizing educational trips to binjai habitats in South Kalimantan offers an effective way to increase environmental awareness and the understanding of binjai among the younger generation. Schools and local governments should coordinate these trips with community leaders and traditional knowledge holders to ensure cultural relevance and contextual depth. These activities should introduce the morphological features of binjai, explain its ecological roles, and highlight its cultural value from an ethnobotanical perspective. University researchers can contribute by documenting the uses of binjai and developing it into an educational resource for ethnobotany. Educational materials such as e-modules, printed books, and digital media play a vital role in preserving this knowledge for future generations. These resources must integrate local knowledge and community wisdom to ensure cultural relevance and promote sustainability.

Fostering cross-sector collaboration

Effective conservation of binjai in South Kalimantan requires active collaboration among three key stakeholders: the government, farmers, and local communities (Table 10). The declining population of binjai demands consistent government monitoring to assess its distribution and status. This study identifies the distribution of binjai across four districts in South Kalimantan (Figure 2), emphasizing the need for targeted and region-specific monitoring strategies. Agricultural offices at the district level should strengthen these efforts by utilizing their proximity and local knowledge. Government agencies must also monitor forest clearing near binjai habitats to prevent further degradation. This collaboration should aim to enhance the economic value of binjai fruit. Currently, binjai is sold at a relatively low price of 3,000 to 5,000 rupiah per fruit, significantly below the market value of commercial mangoes. Improving market access and promoting native fruit varieties can raise its perceived value. Local governments can create specialty markets that feature underrepresented species such as binjai (Table 10). These initiatives foster consumer awareness and demand, providing economic incentives for farmers through higher returns from binjai cultivation.

Agricultural offices and other government institutions must conduct outreach, training, and educational programs to raise awareness among farmers and local communities about binjai conservation, cultivation practices, and its ecological and economic significance. This collaboration empowers individual farmers and strengthens community resilience by encouraging innovation in sustainable binjai cultivation. Supporting these efforts requires the government to expand training on grafting techniques, enabling more effective binjai propagation and reducing the time to harvest. Akhter et al. (2022) reported successful grafting of *M. sylvatica*, demonstrating the broader applicability of the technique within the genus. The government can further support binjai cultivation by distributing fertilizers directly to farmers through organized groups and allocating distribution quotas based on the number of individual farmers or groups to ensure efficient resource management. In addition, the government can provide fertilizer subsidies and offer education to farmers, especially by promoting the use of organic fertilizers, which helps improve affordability and promotes sustainable agricultural practices. These measures will strengthen binjai resilience and align cultivation practices with environmental responsibility.

The government must formulate policies that preserve ethnobotanical knowledge. Within the Dayak community, traditional knowledge of binjai includes its medicinal use for treating swelling (Suryatinah et al. 2020), as well as other ailments such as itchiness, colds, bronchitis, and high blood pressure (Gerten et al. 2015). Current government policy does not explicitly address the conservation of ethnobotanical knowledge (Table 10). Existing regulations, such as Law No. 32 of 2024 on the Conservation of Natural Resources and Ecosystems, only make indirect references to traditional ecological knowledge. The law includes provisions relevant to ethnobotanical practices and recognizes the importance of community participation, particularly among indigenous peoples, in the conservation and sustainable use of native plant species. While it implicitly acknowledges the relationship between cultural heritage and plant utilization, it does not fully integrate ethnobotanical knowledge into conservation planning. The law promotes the protection of genetic resources and includes general regulations concerning traditionally used plant species, including those outside formal conservation areas. However, it lacks targeted measures to safeguard native species such as binjai. Local governments in South Kalimantan should establish policies that directly support the conservation of native plants and the preservation of ethnobotanical knowledge. These efforts should incorporate local cultural perspectives and emphasize the role of intergenerational knowledge transfer in sustainable conservation planning. By institutionalizing the cultural significance of binjai use and management, these policies will protect biodiversity and preserve the intangible heritage and identity of indigenous communities that rely on binjai for medicinal, spiritual, and ecological purposes.

In conclusion, this study documented 21 binjai trees growing in home yards, rice fields, and mixed gardens. The PCA results indicated the most influential environmental variables were air humidity (70.00-82.33%; loading: 0.435 on PC1) and soil moisture (52.78-63.89%; loading: 0.559 on PC2). Observations in binjai habitats identified 74 species from 38 families. Species with the highest Importance Value Index (IVI) at each vegetation level included *C. dactylon* (30.74%) and *O. sativa* (30.74%) for the understory; *C. mitis* (68.06%) and *M. caesia* (23.61%) for seedlings; *M. paradisiaca* (47.40%) and *B. spinosa* (22.79%) for saplings; *M. paradisiaca* (115.95%), *M. foetida* (33.79%), and *C. nucifera* (27.04%) for poles; and *C. nucifera* (32.22%) and *D. zibethinus* (22.89%) for trees. The species demonstrated adaptability to a wide range of vegetation diversity ($1 \leq H' \leq 3$), including the understory (2.81), seedlings (1.53), saplings (2.40), poles (2.08), and trees (2.60) levels. These findings indicate that binjai and

its associated species are ecologically flexible, supporting their conservation in human-influenced habitats. This study recommends an integrated approach to binjai conservation in South Kalimantan, including in situ protection, ex situ germplasm preservation, environmental education, and policy support. In situ efforts should focus on preventing logging, planting seedlings, integrating binjai into agroforestry systems, and promoting sustainable land management. Ex situ conservation involves storing genetic resources in botanical gardens. Environmental education can enhance community awareness, while government policies should foster collaboration among government agencies, farmers, and local communities to strengthen the cultural and economic value of binjai.

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REFERENCES

Agustin IY, Hakim L, Leksono AS. 2023. Mammals and bird conservation strategies through community-based wildlife watching ecotourism development in perhutani area in Poncokusumo, Malang District, East Java. Biotropika J Trop Biol 11 (1): 44-52. DOI: 10.21776/ub.biotropika.2023.011.01.06.

Akhter S, McDonald M, Jashimuddin M, Bashirul-Al-Mamun M, Sarker P. 2022. Agroforestry potential of a wild mango species (*Mangifera sylvatica* Roxb.). Trees, For People 7: 100194. DOI: 10.1016/j.tfp.2022.100194.

Alamgir M, Campbell MJ, Sloan S, Suhardiman A, Supriatna J, Laurance WF. 2019. High-risk infrastructure projects pose imminent threats to forests in Indonesian Borneo. Sci Rep 9 (1): 1-10. DOI: 10.1038/s41598-018-36594-8.

Ardoin NM, Bowers AW, Gaillard E. 2020. Environmental education outcomes for conservation: A systematic review. Biol Conserv 241: 108224. DOI: 10.1016/j.biocon.2019.108224.

Austin KG, Schwantes A, Gu Y, Kasibhatla PS. 2019. What causes deforestation in Indonesia? Environ Res Lett 14 (2): 024007. DOI: 10.1088/1748-9326/aaf6db.

Berhanu Y, Dalle G, Sintayehu DW, Kelboro G, Nigussie A. 2023. Land use/land cover dynamics driven changes in woody species diversity and ecosystem services value in tropical rainforest frontier: A 20-year history. Heliyon 9 (2): e13711. DOI: 10.1016/j.heliyon.2023.e13711.

Beveridge FC, Kalaipandian S, Yang C, Adkins SW. 2022. Fruit biology of coconut (*Cocos nucifera* L.). Plants 11 (23): 3293. DOI: 10.3390/plants11233293.

Borsos É, Borić E, Patocskai M. 2021. What can be done to increase future teachers' plant knowledge? J Biol Educ 57 (2): 252-262. DOI: 10.1080/00219266.2021.1909632.

Breman E, Ballesteros D, Castillo-Lorenzo E, Cockel C, Dickie J, Faruk A, O'donnell K, Offord CA, Pironon S, Sharrock S, Ulian T. 2021. Plant diversity conservation challenges and prospects-The perspective of botanic gardens and the millennium seed bank. Plants 20 (11): 2371. DOI: 10.3390/plants10112371.

Chabib L, Muhtadi WK, Rizki MI, Rahman RA, Suhendri MR, Hidayat A. 2018. Potential medicinal plants for improve the immune system from Borneo Island and the prospect to be developed as nanomedicine. Matec Web Conf 154: 04006. DOI: 10.1051/matecconf/201815404006.

Damtie BB, Mengistu DA, Waktola DK, Meshesha DT. 2022. Impacts of soil and water conservation practice on soil moisture in Debre Mewi and Sholit Watersheds, Abbay Basin, Ethiopia. Agriculture 12 (3): 417. DOI: 10.3390/agriculture12030417.

Deng J, Fang S, Fang X, Jin Y, Kuang Y, Lin F, Liu J, Ma J, Nie Y, Ouyang S. 2023. Forest understory vegetation study: Current status and future trends. For Res 2023 (3): 6. DOI: 10.48130/FR-2023-0006.

Donnell KO, Sharrock S. 2018. Botanic gardens complement agricultural gene bank in collecting and conserving plant genetic diversity. Biopreserv Biobank 16 (5): 384-390. DOI: 10.1089/bio.2018.0028.

Dookie S, Jaikishun S, Ansari AA. 2024. Comparative analysis of mangrove seedlings in natural, degraded, and restored. Geol Ecol Landsc 1-18. DOI: 10.1080/24749508.2024.2437189.

Duan W, Su N, Jiang Y, Shen J. 2022. Impacts of social trust on rural households' attitudes towards ecological conservation-Example of the giant panda nature reserves in China. Forests 13 (1): 1-16. DOI: 10.3390/f13010053.

Eshun F, Wotorchie RK, Buahing AA, Harrison-Afful AA, Atiatorme WK, Amedzake G, Adofo-Yeboah Y, Mante V. 2022. A survey of the role of environmental education in biodiversity conservation in the Greater Accra Region of Ghana. Conservation 2 (2): 297-304. DOI: 10.3390/conservation2020021.

Eyasu G, Gebrewahid Y, Darcha G, Kassa H. 2024. Adaptation and growth performance of different bamboo species in dryland areas of Northern Ethiopia. For Sci Technol 20 (2): 136-141. DOI: 10.1080/21580103.2024.2316723.

Fachrul MF. 2007. Metode Sampling Bioekologi 1st Ed. Bumi Aksara, Jakarta. [Indonesian]

Fitriani A, Arifin YF, Hatta GM, Wahdah R, Payung D. 2022. Suitability habitat model of *Mangifera rufocostata* under different climatic and environmental conditions. Biodiversitas 23 (9): 4570-4577. DOI: 10.13057/biodiv/d230924.

Fitriani A, Prihatiningtyas E. 2022. Struktur vegetasi sekitar jenis pohon tandui (*Mangifera rufocostata* Kosterm.) di Hulu Sungai Selatan. Jurnal Hutan Tropis 9 (2): 464-471. DOI: 10.20527/jht.v9i2.11298. [Indonesian]

Fitriyati U, Insani N, Ridhoi R, Hidajat HG, Aa'rachman FR, Hisyam Baidlowi M, Yozar Amrozi M, Ardiyanti RN. 2024. Boidiversity of asteraceae family in padusan ecotourism and natural laboratory area. BIO Web Conf 117: 01050. DOI: 10.1051/bioconf/202411701050.

Ganesan SK. 2021. *Mangifera caesia*. The IUCN red list of threatened species 2021: e.t31403a184586784. DOI: 10.2305/IUCN.UK.2021-3.RLTS.T31403A184586784.en.

Ganguli B, Narkhede1 S, Haldankar P, Bhattacharyya T. 2019. Wild mangoes-An incredible wealth for posterity. Indian J Fertil 15 (11): 1258-1264.

Gerten D, Salma I, Shafie MSM, Shariah U, Brooke P, Wong WWW, Norhayati MH. 2015. Traditional knowledge and practices related to genus *Citrus*, *Garcinia*, *Mangifera* and *Nephelium* in Malaysia. Oalib 2 (4): 1-11. DOI: 10.4236/oalib.1101453.

Greenacre M, Groenen PJF, Hastie T, D'Enza AI, Markos A, Tuzhilina E. 2022. Principal component analysis. Nat Rev Methods Prim 2 (1): 1-24. DOI: 10.1038/s43586-022-00184-w.

Gunawan, Anafarida O, Mahmudah N, Rizki MI. 2021. Autecology and distribution pattern of *Baccaurea macrocarpa* in South Kalimantan of Indonesia. Russ J Agric Soc-Econ Sci 117 (9): 117-124. DOI: 10.18551/rjoas.2021-09.13.

Gunawan, Anwar K, Gafur A, Hilaliyah R, Waro AA, Hikmah N, Sakinah, Erwansyah M, Susilawati D, Lestari RD, Triana D. 2023. Predicting the current potential geographical distribution of *Baccaurea* (*B. lanceolata* and *B. motleyana*) in South Kalimantan, Indonesia. Biodiversitas 24 (2): 930-939. DOI: 10.13057/biodiv/d240232.

Gunawan, Muhamat, Fadhila S, Farida OA. 2022. Habitat characteristics of *Mangifera casturi* Kosterm. in Banjar District of South Kalimantan, Indonesia. Russ J Agric Soc-Econ Sci 10 (130): 83-90. DOI: 10.18551/rjoas.2022-10.10.

Gunawan, Muhamat, Maghfiroh. 2024. Ethnobotany and conservation of kasturi (*Mangifera casturi* Koesterm.) by Banjar Tribe in South Kalimantan, Indonesia. Biodiversitas 25 (4): 1420-1426. DOI: 10.13057/biodiv/d250410.

Hartoyo APP, Mosa SA, Winata B, Rusniarsyah L, Peniwidiyanti, Izzbilhaq. 2024. Tree species diversity and management in agroforestry pohpohan (*Pilea Melastomoides*): The case in the traditional zone of Gunung Halimun Salak National Park, Indonesia. Biotropia-Southeast Asian J Trop Biol 31 (3): 380-390. DOI: 10.11598/btb.2024.31.3.2281.

Irawan B, Partasasmita R, Rahayu N, Setiawati T, Iskandar J. 2019. Indigenous knowledge of bamboos by naga community, Tasikmalaya District, West Java, Indonesia. Biodiversitas 20 (5): 1423-1434. DOI: 10.13057/biodiv/d200535.

Itani M, Al Zein M, Nasralla N, Talhouk SN. 2020. Biodiversity conservation in cities: Defining habitat analogues for plant species of conservation interest. Plos One 15 (6): 1-25. DOI: 10.1371/journal.pone.0220355.

Jahanifar K, Amirnejad H, Abedi Z, Vafaeinejad A. 2017. Estimation of the value of forest ecosystem services to develop conservational strategy management (strengths, weaknesses, opportunities and threats). J For Sci 63 (7): 300-312. DOI: 10.17221/137/2016-JFS.

Kamran MA Al, Sharif MO, Deb B, Prova SJ, Uddin MS. 2023. Homestead agroforestry and tree species diversity in Cumilla District of Bangladesh. J Agrofor Environ 16 (2): 80-86. DOI: 10.55706/jae1632.

Ketsa S, Wisutiamonkul A, Palapol Y, Paull RE. 2020. The Durian: Botany, Horticulture, and Utilization. Wiley, New York. DOI: 10.1002/9781119625407.ch4.

Kim KJ, Jung E, Han MK, Sohn JH. 2020. The power of garden-based curriculum to promote scientific and nature-friendly attitudes in children through a cotton project. J Res Child Educ 34 (4): 538-550. DOI: 10.1080/02568543.2020.1718251.

Kour S, Bakshi P, Sharma A, Wali VK, Jasrotia A, Kumari S. 2018. Strategies on conservation, improvement and utilization of underutilized fruit crops. Intl J Curr Microbiol Appl Sci 7 (3): 638-650. DOI: 10.20546/ijcmas.2018.703.075.

Lahon D, Sahariah D. 2022. Physico-chemical properties of water and its impacts on the species diversity of aquatic plants at Disangmukh wetland of Assam, India. Ecol Environ Conserv 28 (1): 203-207. DOI: 10.53550/eec.2022.v28i01.026.

Ledesma N. 2019. Distribution and use of *Mangifera caesia* Jack. in Bali, Indonesia. Acta Hortic 1244: 29-32. DOI: 10.17660/ActaHortic.2019.1244.4.

Ledesma N, Campbell RJ, Hass M, Campbell TB. 2017. Interspecific hybrids between *Mangifera indica* and related species. Acta Hortic 1183: 83-88. DOI: 10.17660/ActaHortic.2017.1183.12.

Lobo MG, Sidhu JS. 2017. Biology, postharvest physiology, and biochemistry of mango. In: Siddiq M, Brecht JK, Sidhu JS (eds). Handbook of Mango Fruit: Production, Postharvest Science, Processing Technology and Nutrition. Wiley, New York. DOI: 10.1002/9781119014362.ch3.

Mandal AK, Dheebakaran G, Banik M, Kumar A, Arul PS, Ajit KMC. 2017. Response of bermuda grass (*Cynodon dactylon*) growth under elevated temperature and moisture stress condition. Pharm Innov J 6 (12): 83-87.

Mandea AR, Parjanto, Yuniastuti E, Nandariyah, Melati R. 2024. The vegetation analysis of natural habitat of wild nutmeg (*Myristica* spp.) in Halmahera Forest, North Maluku. Intl J Adv Sci Eng Inf Technol 14 (6): 2053-2058. DOI: 10.18517/ijaseit.14.6.19085.

Maroyi A. 2023. Medicinal uses of the asteraceae family in Zimbabwe: A historical and ecological perspective. Ethnobot Res Appl 25: 1-30. DOI: 10.32859/era.25.46.1-30.

Mathewos M, Hundera K, Biber-Freudenberger L. 2018. Planting fruits and vegetables in homegarden as a way to improve livelihoods and conserve plant biodiversity. Agriculture 8 (12): 190. DOI: 10.3390/agriculture8120190.

Meena NK, Asrey R. 2018. Tree age affects postharvest attributes and mineral content in amrapali mango (*Mangifera indica*) fruits. Hortic Plant J 4 (2): 55-61. DOI: 10.1016/j.hpj.2018.01.005.

Meena VS, Gora JS, Singh A, Ram C, Meena NK, Pratibha A, Rouphael Y, Basile B, Kumar P. 2022. Underutilized fruit crops of Indian arid and semi-arid regions: Importance, conservation and utilization strategies. Horticulturae 8 (2): 1-29. DOI: 10.3390/horticulturae8020171.

Ministry of Health Republic Indonesia. 2025. Informasi Kategori Usia. https://ayosehat.kemkes.go.id/kategori-usia. [Indonesian]

Mirfat AHS, Salma I, Razali M. 2016. Natural antioxidant properties of selected wild *Mangifera* species in Malaysia. J Trop Agric Food Sci 44: 63-72. DOI: 10.5958/0976-1926.2015.00010.8.

Mitchell JD, Pell SK, Bachelier JB, Warschefsky EJ, Joyce EM, Canadell LC, da Silva-Luz CL, Coiffard C. 2022. Neotropical Anacardiaceae (cashew family). Rev Bras Bot 45 (1): 139-180. DOI: 10.1007/s40415-022-00793-5.

Negi VS, Pathak R, Sekar KC, Rawal RS, Bhatt ID, Nandi SK, Dhyani PP. 2018. Traditional knowledge and biodiversity conservation: A case study from Byans valley in Kailash sacred landscape, India. J Environ Plan Manag 61 (10): 1722-1743. DOI: 10.1080/09640568.2017.1371006.

Noor A, Ningsih RD, Hasbianto A, Sabur A. 2015. Sebaran dan keragaman plasma nutfah mangga di Kalimantan Selatan. Prosiding Seminar Nasional Sumber Daya Genetik. Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian, Jakarta. [Indonesian]

Nurrahman AD, Khusaini M, Leksono AS, Tarno H. 2024. Models for sustainable open access land management that integrate economic, social, and environmental balance. Trans Chinese Soc Agric Mach 55 (5): 1-13. DOI: 10.62321/issn.1000-1298.2024.05.01.

Paembonan SA, Bachtiar B, Ridwan M. 2020. Sustainable forest management through natural mangrove regeneration on Pannikiang Island, South Sulawesi. IOP Conf Ser Earth Environ Sci 486 (1): 012082. DOI: 10.1088/1755-1315/486/1/012082.

Quek ZBR, Chui SX, Lam WN, Fung TK, Sivasothi N. 2020. Autecology of the common fishtail palm, *Caryota mitis* (Arecaceae), in Singapore. Bot Lett 167 (2): 265-275. DOI: 10.1080/23818107.2020.1717612.

Rafaai NH, Abdullah SA. 2024. Developing a composite index of conservation value to determine the conservation status of protected areas: The case of the Krau Wildlife Reserve and Tasek Bera Ramsar Site, Peninsular Malaysia. J Nat Conserv 82: 126758. DOI: 10.1016/j.jnc.2024.126758.

Rambey R, Rahmawaty, Suratman MN, Gandaseca S, Rauf A, Nababan ESM, Delvian, Aththorick TA, Ismail MH, Saputra MH. 2024. Habitat preferences of *Amorphopahllus* sp. Silaiya Village, Sayur Matinggi District, North Sumatra, Indonesia. E3S Web Conf 519: 03020. DOI: 10.1051/e3sconf/202451903020.

Rao NKS, Shivashankara KS, Laxman RH. 2016. Abiotic Stress Physiology of Horticultural Crops. Springer India, Bengaluru. DOI: 10.1007/978-81-322-2725-0.

Rathnayake WMUK, De Silva RP, Dayawansa NDK. 2016. Assessment of the suitability of temperature and relative humidity for rice cultivation in rainfed lowland paddy fields in Kurunegala District. Trop Agric Res 27 (4): 370-388. DOI: 10.4038/tar.v27i4.8214.

Resida E, Chikmawati T, Ariyanti NS, Fitmawati. 2023. *Mangifera kemanga* Blume (Anacardiaceae) taxonomic assessment for genetic diversity based on molecular substantiation. Sabrao J Breed Genet 55 (1): 175-186. DOI: 10.54910/sabrao2023.55.1.17.

Salles DM, Do Carmo FF, Jacobi CM. 2019. Habitat loss challenges the conservation of endemic plants in mining-targeted Brazilian Mountains. Environ Conserv 46 (2): 140-146. DOI: 10.1017/S0376892918000401.

Salma I, Shariah U, Pearlycia B, Wong WW, Shukor A, Norhayati H, Camellia NAN. 2015. Community contribution towards conservation of tropical fruit trees in Malaysia. Oalib 2 (1): 1-7. DOI: 10.4236/oalib.1101146.

Sarkingobir Y, Miya YY. 2025. Nutritional (health) and other values of plants: Overview of conservation and strategies for protecting. Kashf J Multidiscip Res 3 (3): 1-13. DOI: 10.71146/kjmr338.

Satriani I, Panjaitan D, Sunariyati S. 2024. Keanekaragaman jenis mangga (*Mangifera* spp.) di Tumbang Talaken Kecamatan Manuhing Kabupaten Gunung Mas Kalimantan Tengah. J Biotrop Res Nat Technol 2 (2): 69-78. DOI: 10.52850/borneo.v2i2.11387. [Indonesian]

Schrieber K, Lachmuth S. 2017. The genetic paradox of invasions revisited: The potential role of inbreeding×environment interactions in invasion success. Biol Rev 92 (2): 939-952. DOI: 10.1111/brv.12263.

Setyawati T, Narulita S, Bahri IP, Raharjo GT. 2015. A Guide Book to Invasive Alien Plant Species in Indonesia. Research, Development and Innovation Agency, Ministry of Environment and Forestry, Republic of Indonesia, Jakarta.

Shrestha N. 2021. Factor analysis as a tool for survey analysis. Am J Appl Math Stat 9 (1): 4-11. DOI: 10.12691/ajams-9-1-2.

Suryatinah Y, Budiarti MS, Wijaya RN, Tjandrarini DH. 2020. Exploration and inventory of local medicinal plants with potential as anti-inflammatory in three dayak tribes, South Kalimantan. Buletin

Plasma Nutfah 26 (1): 63-67. DOI: 10.21082/blpn.v26n1.2020.p63-76.

Suwardi AB, Navia ZI, Harmawan T, Syamsuardi S, Mukhtar E. 2022. Importance and local conservation of wild edible fruit plants in the East Aceh Region, Indonesia. Intl J Conserv Sci 13 (1): 221-232.

Tanbuda C, Sulaiman M, Yong PLP, Rusdi NA, Sathiya SJ, Yeaw NS, Hasnidah SF, Rajagopal M, Pang TPN, Garcia MM. 2025. Medicinal plants of Sabah (North Borneo): Lest we forget. Pharm Biol 63 (1): 288-332. DOI: 10.1080/13880209.2025.2487557.

Thirupathaiah G, Bhagwan A, Kumar AK, Kumar KA, Vijaya D. 2020. Response of irrigation and mulching on yield, water use efficiency, nutrient use efficiency and economy of mango Cv. Banganpalli in (semiarid region) Southern Telangana Region. Intl Res J Pure Appl Chem 21 (23): 215-224. DOI: 10.9734/irjpac/2020/v21i2330320.

Tjitrosoepomo G. 2018. Morfologi Tumbuhan 21st Ed. Universitas Gadjah Mada Press, Yogyakarta. [Indonesian]

Trisdayanti NPE, Pujawan AAKA, Putu N. 2021. Organoleptic and nutritional quality of wani fruit (*Mangifera caesia*) sorbet. J Gastron Tour 8 (1): 12-20. DOI: 10.17509/gastur.v8i1.35843.

Veldkamp JF, Duistermaat H, Wong KM, Middleton DJ. 2019. Poaceae (gramineae). Flora Singap 7: 219-501. DOI: 10.26492/fos7.2019-07.

Wahyuningtyas RS, Humaida N, Hani A, Aziza LN, Gunawan, Fitriani A. 2024. Potential and challenges of utilizing *Artocarpus odoratissimus* (binturung) fruit in Kalimantan. IOP Conf Ser Earth Environ Sci 1315 (1): 012026. DOI: 10.1088/1755-1315/1315/1/012026.

Yunus SNM, Abas F, Jaafar AH, Azizan A, Zolkeflee NKZ, Ghafar SZA. 2021. Antioxidant and a-glucosidase inhibitory activities of eight neglected fruit extracts and uhplc-ms/ms profile of the active extracts. Food Sci Biotechnol 30 (2): 195-208. DOI: 10.1007/s10068-020-00856-x.