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Sustainability of Durian Agroforestry in the Selat Area, Jambi: *Population Structure and Management Challenges in a Changing Landscape*

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Abstract

Background: *Agroforestry systems integrate agricultural production with environmental conservation, particularly in tropical regions. Although durian-based agroforestry practices have long been established in Jambi, comprehensive studies on their ecological structure, contribution to biodiversity, and sustainability strategies remain limited. This study aims to analyze the population structure of durian trees, agroforestry patterns, biodiversity, as well as the challenges and sustainability strategies of the system.* **Methodology:** *Data were collected through vegetation analysis and in-depth interviews conducted in durian agroforestry areas in Selat, Jambi Province.* **Findings:** *The results show that agroforestry systems in this region are dominated by old durian trees that have strong associations with other species such as* Jengkol (*Archidendron pauciflorum*), *Duku* (*Lansium domesticum*), and Rubber (*Hevea brasiliensis*). **Contribution:** *This research contributes to biodiversity conservation by providing habitats for local flora and fauna and maintaining ecosystem balance. However, the sustainability of this system faces significant challenges, including land conversion due to population pressure, oil palm plantation expansion, declining durian productivity, and the emergence of the "tasteless durian" phenomenon that reduces fruit quality. Therefore, management strategies focusing on species diversification, tree rejuvenation, and innovations in cultivation technology are essential to sustain durian agroforestry and improve community welfare, particularly in the Selat region.*

Keywords: *Agroforestry; Association; Biodiversity; Agroforestry Model; Durian*

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INTRODUCTION

Globally, landscape degradation caused by deforestation, intensive agricultural land conversion, and biodiversity loss has become an urgent environmental issue that must be addressed immediately. According to the FAO (2022) report, terrestrial ecosystem degradation not only threatens environmental sustainability but also affects food security, community welfare, and climate stability. These challenges demand nature-based solutions capable of restoring ecosystem functions while supporting the livelihoods of local communities.

Within the framework of the Sustainable Development Goals (SDGs)—particularly those related to zero hunger, climate action, and life on land—agroforestry is recognized as a strategic approach that bridges agricultural productivity and environmental conservation. This system contributes to climate change mitigation through increased carbon stocks, restoration of degraded lands, and provision of ecosystem services, while also strengthening the livelihoods of smallholder farmers (Jose, 2009). In the context of Southeast Asia, agroforestry plays a crucial role in maintaining local flagship commodities with high economic, social, and cultural values, such as durian (*Durio* spp.).

Durian, often referred to as the "king of fruits" (Siriphanich, 2011), holds significant social, economic, and cultural importance in the lives of Southeast Asian communities. It is a key commodity that contributes greatly to farmers' income and local economies. National durian production in 2024 reached 1.96 million tons, with an annual production growth rate of 14.8% over the past five years. Most of this durian is produced from smallholder plantations (BPS, 2024). The Selat area in Jambi Province, along with neighboring villages, has long been known as a center for high-quality durian production. Many of the durian trees in this region are heritage trees passed down through generations, known locally as *durian pusako*.

Durian possesses a distinctive taste and aroma derived from a combination of fats, sugars, and volatile compounds containing esters and sulfur (Aziz & Jalil, 2019). The flavor of durian varies depending on cultivar type and growing location (Habibah et al., 2019). Likewise, *Durian Selat* is known for its unique flavor and mild aroma (Zulkarnain et al., 2013), making it both a local icon and a symbol of the community's cultural tradition.

Durian trees in the Selat area are typically cultivated within agroforestry systems that integrate durian with various other plant species. These agroforestry systems offer economic, environmental, and socio-cultural benefits. Economically, they help improve community livelihoods and resilience to climate change (Fanish & Priya, 2012). Agroforestry also generates benefits through income diversification and reduced dependency on chemical inputs (Satish et al., 2024). Environmentally, it contributes to climate change mitigation through carbon sequestration, supports biodiversity conservation, enhances soil health, and improves air and water quality (Jose, 2019). Additionally, agroforestry increases biomass productivity, enhances soil fertility, and promotes nutrient cycling (Fanish & Priya, 2012). It also improves pollination success, enhances water retention, and reduces soil erosion and fire occurrence (Sollen-Norrlin et al., 2020). Socially, agroforestry empowers smallholders, strengthens adaptive capacity, and enhances community resilience (Satish et al., 2024).

Despite its numerous benefits, durian-based agroforestry in the Selat area faces multiple challenges threatening its sustainability. Land-use changes due to oil palm plantation expansion, housing development, and other sectors pose major threats. In addition, socio-economic factors such as population growth, migration, market fluctuations, and climate change impacts have led to declining durian productivity and hindered natural regeneration (Weiwei et al., 2014; Watts et al., 2022). Other barriers include high operation costs, limited financial incentives, restricted market access, and a lack of awareness regarding the importance of agroforestry (Rolo et al., 2020).

Durian is often integrated into agroforestry models alongside other economically valuable tree species that also help maintain carbon stocks (Nurrochmat et al., 2023). Such agroforestry approaches have proven effective in balancing agricultural productivity and environmental conservation by mimicking natural ecosystems, maintaining productivity, and supporting various ecosystem services (Smith et al., 2012; Wilson & Lovell, 2016; Raihan, 2023). Moreover, agroforestry addresses the need for food, fuel, and environmental protection while reducing the negative impacts of modern agriculture. This approach also contributes to improved food security and reduced environmental degradation (Smith et al., 2012; Raihan, 2023).

To date, most agroforestry research has focused either on the general benefits of the system or on agronomic aspects of durian cultivation (Yan, 2024; Huang et al. 2023; Ketsa et al., 2020; Thorogood et al. 2022; Murniati et al. 2022; Elizabeth & Syawal 2021). Studies that specifically explore the population structure of durian trees within agroforestry systems and the challenges of their management in changing landscapes remain scarce. A deeper understanding of the structure, composition, and governance of durian agroforestry systems is essential for developing adaptive management guidelines that are both ecologically and economically viable (Legesse & Negash, 2021; Wilson & Lovell, 2016). Therefore, this study seeks to fill this gap by analyzing the population structure and sustainability challenges of durian agroforestry in the Selat area. Furthermore, it aims to identify management strategies that can help conserve heritage durian orchards (*durian pusako*) while supporting the well-being of local communities.

METHOD

Time and Location

The study was conducted from June 2024 to November 2024 in durian agroforestry systems located in the Selat area, Batanghari Regency, Jambi Province. The soil types in the study area are predominantly *inceptisols* and *ultisols* (Samsidar et al., 2025). In general, the research site consists of flat to slightly undulating terrain with low elevation (below 100 m above sea level) (Batanghari, 2025). The agroclimatic conditions fall within the B1 agroclimatic zone, with an average monthly rainfall of 207 mm and an average of 14 rainy days per month. The mean monthly temperature is 26.4°C, with an average humidity of 26.45%. Monthly rainfall exceeding 200 mm occurs during the November–April period, while rainfall below 200 mm per month occurs between May and October (Saidi & Suryani, 2019). Vegetation observations were conducted in Ture Village, located at approximately 1°33′12″S and 103°24′8″E. Additional supporting data were collected from surrounding villages, including Pulau Betung, Lopak Aur, and Selat (Figure 1). Plant sample analyses were carried out at the Laboratory of Agroindustry for Medicinal Plants and Biotechnology, Faculty of Science and Technology, Universitas Jambi.

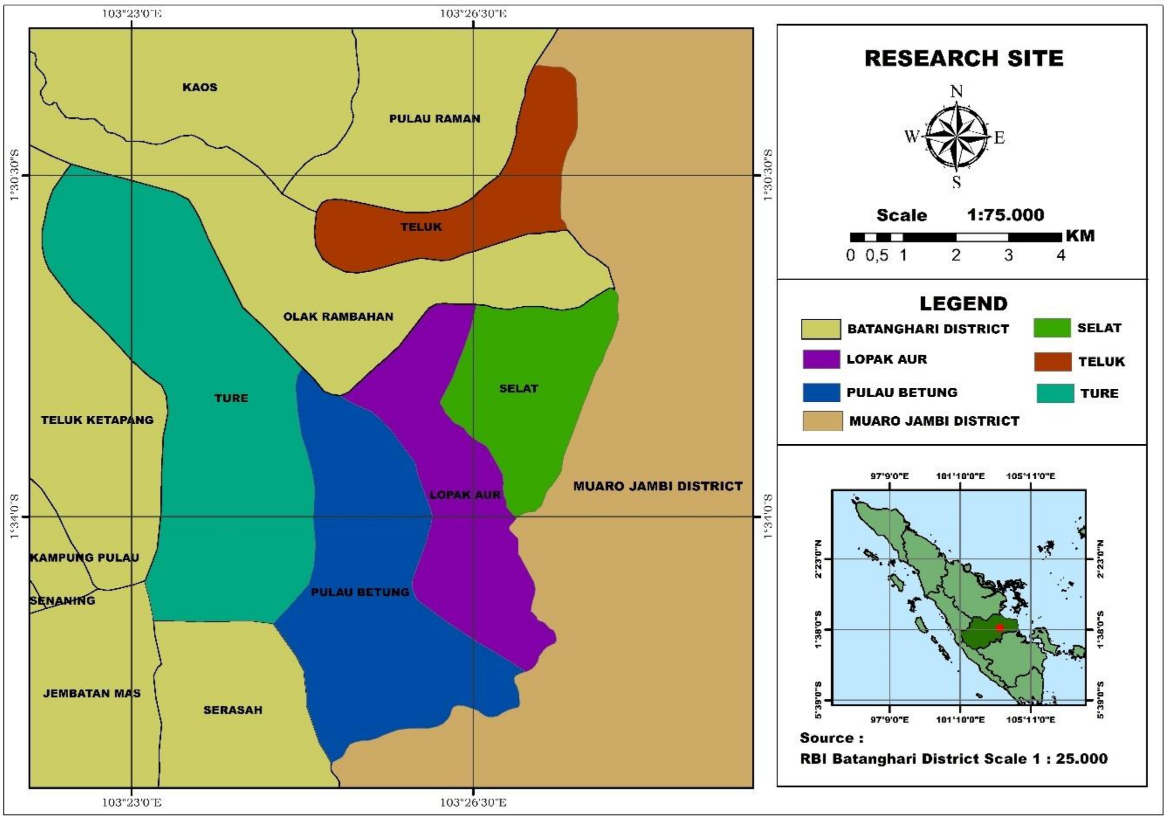

Figure 1. Research Site

Tools and Materials

The equipment used to collect data on the socio-cultural aspects of durian agroforestry included interview guidelines, stationery, a voice recorder, and a camera. Tools used for vegetation analysis consisted of stationery, a GPS, a camera, and a Deli range finder (type EDL41XX, range 0.05–100 m, 1.7-inch display, dual laser projection, accuracy ± 3 mm). Equipment for plant sample collection and identification included stationery, a camera, pruning shears, herbarium presses, and an oven. Materials used for specimen collection and identification included hanging labels, newspaper sheets, 70% alcohol, black cloth, clear adhesive tape, specimen plastic bags, and herbarium paper.

Methods

The methods used to obtain information on durian agroforestry included direct observation and in-depth interviews with 12 key respondents. Vegetation structure data for the durian agroforestry system were obtained through vegetation analysis.

This study employed a qualitative approach aimed at identifying socio-cultural aspects consistent with the maintenance of ecosystem services, including cultural services (Carlsen & Glenton, 2011).

Respondent Selection

Respondents were selected using the snowball sampling method (Espinosa et al., 2012). The criteria for respondents included village residents who possessed knowledge and direct experience related to durian agroforestry and durian utilization. Interviews were conducted through in-depth discussions with key informants (Bernard, 2017) using a structured interview guide. Information gathered included general knowledge about durian agroforestry (management practices, cultivation techniques, local durian varieties, and durian utilization), local ecological knowledge, and community activities related to durian.

Vegetation Structure

Data on vegetation structure were collected using 15 main plots, each measuring 20 × 20 m, with a 10-meter distance between plots for tree-level observations. Within each main plot, subplots were established: 10 × 10 m for poles, 5 × 5 m for saplings, and 2 × 2 m for seedlings, each with one replication. Tree diameters were categorized as follows: trees > 20 cm; poles $10 < D \leq 20$ cm; and saplings > 2 cm. The design of the vegetation analysis plots is illustrated in Figure 2.

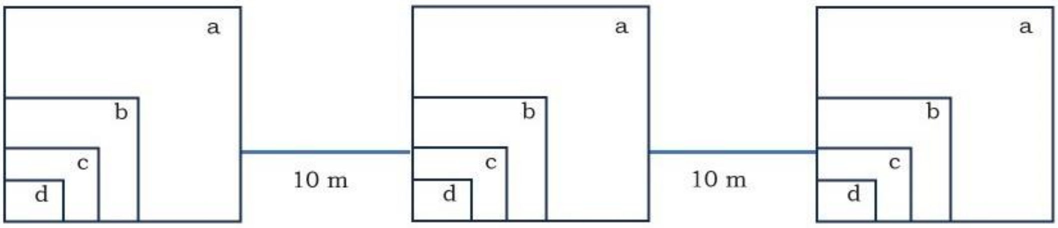

Figure 2. Plot Design for Vegetation Analysis; a. 20 x 20 m; b. 10 x 10 m; c. 5 x 5 m; and d. 2 x 2 m.

Plant Data Collection

Plant data collected included diameter at breast height (DBH) for trees and poles, as well as the number of individuals for saplings and seedlings. Plant identification was carried out directly in the field. Some unidentified specimens were preserved as herbarium samples (Queensland Herbarium, 2016; Rosleine et al., 2024) for further analysis. Identification was conducted using several reference sources, including Whitmore (1972); Priyadi et al., (2010); Kew Royal Botanic Garden (2025); GBIF (2025); Slick, (2025); and Inaturalist website (https://www.inaturalist.org/).

Observation of Agroforestry Patterns

Observations of agroforestry patterns were conducted through a combination of field observations and interviews with local farmers. In each plot, the plant species growing alongside durian were recorded, along with the functional roles of these companion plants. Additional information on the reasons for plant selection, economic objectives, and cultivation practices was obtained through farmer interviews. The agroforestry pattern was determined based on the combination of dominant plant species found within each orchard.

Data Analysis

Qualitative data analysis from interviews followed the approach of Miles et al., (2014) to describe the durian agroforestry system. Quantitative analysis was conducted descriptively to identify the characteristics of durian agroforestry. The association between durian and other plant species was analyzed using the Ochiai Index (OI) as described by Ludwig & Reynolds (1988) (Formula 1). The Ochiai Index ranges from 0 to 1, with higher values indicating a stronger level of species association.

$$\text{OI} = \frac{a}{\sqrt{a+b}\ \sqrt{a+c}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Description,
OI : Ochiai Index
a : Number of plots where both species are present
b : Number of plots where species A is absent and species B is present
c : Number of plots where species A is present and species B is absent

RESULT AND DISCUSSION

Selat Village is one of the main durian production centers in Jambi Province, located in the river side of Batanghari. This area holds a strategic position as it is connected to other durian-producing villages such as Ture, Lopak Aur, Pulau Betung, and Teluk. Collectively, the durian production from these villages is known as “Durian Selat,” which has long been recognized for its high quality both locally and regionally.

Durian Selat holds significant economic and cultural value. The consistency of farmers in maintaining durian trees, including *durian pusako*—trees inherited from previous generations—has given this region a distinctive identity. This reflects that the durian agroforestry system in Selat is not solely based on production aspects but is also deeply rooted in the community’s social and cultural heritage.

This study aims to describe the vegetation structure within the durian agroforestry systems practiced by the Selat community, including variations in vegetation diversity at both tree and understory levels. It also examines the existing patterns of durian agroforestry and the degree of interspecies association observed. The ecological and socio-economic implications of these agroforestry patterns are further discussed to provide a comprehensive understanding of the system’s role within the local community.

Durian Agroforest Vegetation

The vegetation inventory in the Selat durian agroforestry system recorded a total of 33 species distributed across different growth strata. The number of individual plants recorded consisted of 74 trees, 38 poles, 49 saplings, and 207 seedlings. At the tree stratum, durian (*Durio zibethinus*) dominated with 69 individuals, accounting for approximately 93% of the total trees, while other species were recorded in smaller numbers such as jengkol (*Archidendron jiringa*) (3 individuals), duku (*Lansium domesticum*) (1 individual), and candlenut (*Aleurites moluccana*) (1 individual). At the pole and sapling strata, the dominant species were betle nut (*Areca catechu*) and duku, whereas at the seedling stratum, the most abundant species were *L. gracile* (40 individuals) and *A. conyzoides* (32 individuals). These results indicate that although durian is the main crop, other species contribute to maintaining vegetation diversity in the lower strata.

The distribution of individuals across strata showed a notable contrast between the tree and seedling layers. The number of trees was relatively low compared to the more than 200 seedlings recorded, indicating a good potential for regeneration. However, comparison among strata also suggests regeneration pressure, as most dominant seedlings were not durian but rather pioneer herbs and shrubs. The density of durian trees reached 113 trees per hectare, a relatively high value compared to the recommended planting distance for superior durian varieties ranging between 8–12 meters (Ketsa et al., 2020), equivalent to a density of 69–156 trees per hectare. This condition shows that the community utilizes the land intensively for durian production, even though most of the trees are heritage trees passed down from previous generations.

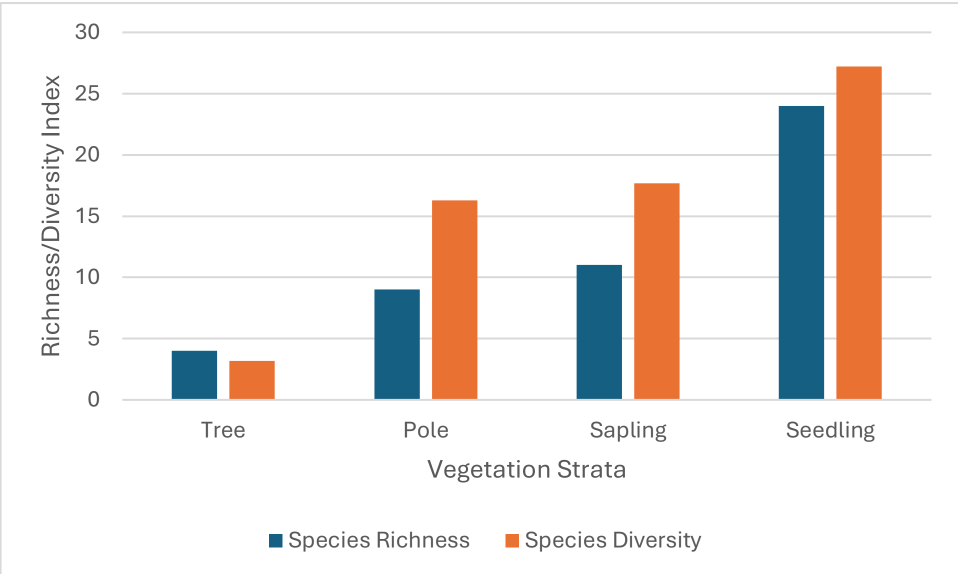

Figure 3. Species Richness and Diversity Across Vegetation Strata

The number of species found in each vegetation stratum exhibited a varied pattern. In the tree stratum, only four species were recorded, whereas nine species were found in the pole stratum, eleven in the sapling stratum, and twenty-four in the seedling stratum (Figure 3). The high number of species in the seedling stratum indicates strong regeneration potential, although not all species will survive to reach maturity. The Shannon–Wiener diversity index for the tree stratum was only 0.31, categorized as low, as the stratum was dominated by durian despite having a relatively large number of individual trees.

Durian serves as the key species shaping the agroforestry structure in the study area. Its dominance is evident, with durian trees comprising more than 90% of all trees (Figure 4). This system clearly reflects the community's focus on durian fruit production as a major economic commodity in Selat. Nevertheless, the presence of supporting species in other strata indicates that durian gardens are not entirely monocultural, instead, maintain a degree of vegetation diversity and contribute to specific ecological functions.

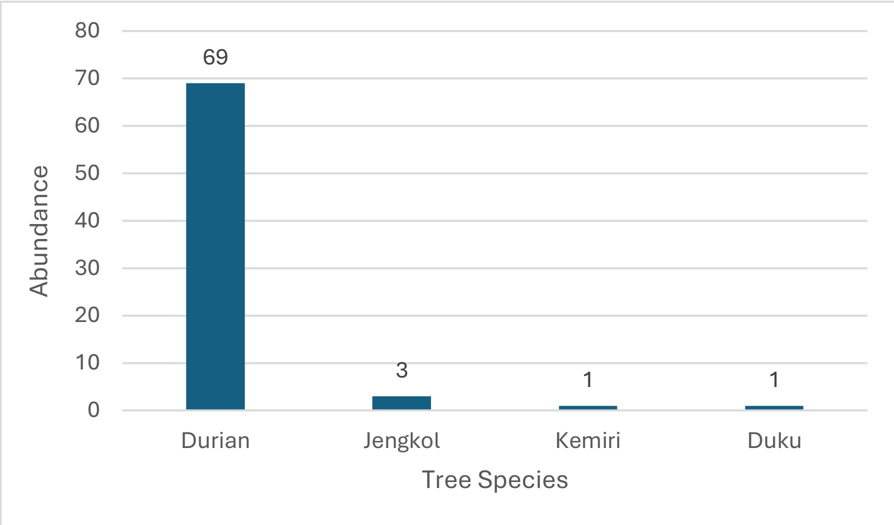

Figure 4. Tree Species Diversity in Durian Agroforests

Several non-durian species play important roles in the durian agroforestry ecosystem. Species such as jengkol, duku, betel nut, rubber, candlenut, and bamboo (*Bambusa* spp.) not only enrich tree diversity but also provide added value for local farmers. Ecologically, these species contribute to maintaining nutrient cycling, providing habitats for small fauna, and enhancing overall ecosystem functioning. Socio-economically, the presence of supporting plants contributes to diversifying food and income sources — for instance, chili and katuk (*Sauropus androgynus*) serve as daily vegetables, while betel nut, rubber, and cacao (*Theobroma cacao*) represent economically valuable commodities. Thus, although durian serves as the central element of the agroforestry system, supporting vegetation makes a significant contribution to both ecosystem sustainability and community well-being.

The dominant understorey species observed in the study area was jengkol (8 individuals), followed by *Macaranga tanarius* (6 individuals) and *Urena lobata* (5 individuals). Intermediate groups included *Amorphophallus* sp. (4 individuals), *Ficus* sp. (3 individuals), as well as *Bambusa* sp., duku, and katuk (each with 2 individuals). Species with lower abundance, such as *A. conyzoides*, *Asystasia gangetica*, and *Caryota mitis*, were represented by only one individual each. Despite their low abundance, these species play an important role in maintaining the diversity of understorey vegetation in the area.

Durian Agroforestry Patterns

Durian trees in the Selat region are generally cultivated within agroforestry systems that integrate durian with other crops. In general, the observed agroforestry patterns can be categorized into four main types: (i) Durian–Food Crops, (ii) Durian–Rubber, (iii) Durian–betel nut, and (iv) Durian–Oil Palm (Table 1). In addition to these four major patterns, several other minor agroforestry combinations were also recorded. In practice, the boundaries between these patterns are not strictly defined, as many plant species occurring in one pattern are also found in other types of durian-based agroforests.

Table 1. Characteristics and Ecological and Socio-Economic Impacts of Durian Agroforestry Pattern

Agroforestry Pattern	Dominant Supporting Crops	Ecological Impact	Socioeconomic Impacts
Durian-Food Crops	Chili (*Capsicum* sp.), eggplant (*Solanum melongena*), katuk (*S. androgynus*)	Increases understorey plant diversification and enhances soil fertility	Provides household food sources and additional income
Durian-Rubber	Rubber	Reduces understorey diversity due to rubber dominance	Economically stable despite fluctuations in rubber prices
Durian-betel nut	Betel nut (*A. catechu*)	Serves as natural boundary markers and provides additional habitat	Reduces land boundary conflicts and adds income from betel nut sales
Durian-Oil Palm	Oil palm (*Elaeis guineensis*)	Decreases overall vegetation diversity; oil palm dominance suppresses understorey growth	Relatively profitable economically but reduces ecological value

Association of Durian with Other Species

The association analysis (using the Ochiai Index) revealed variations in the relationships between durian trees and other species. The highest association value was found for jengkol, with an index of 1.00, indicating a perfect and consistent co-occurrence with durian across all plots (Figure 5). This pattern reflects a long-standing local tradition in which farmers have cultivated durian and jengkol together within the same garden, both for household consumption and economic purposes.

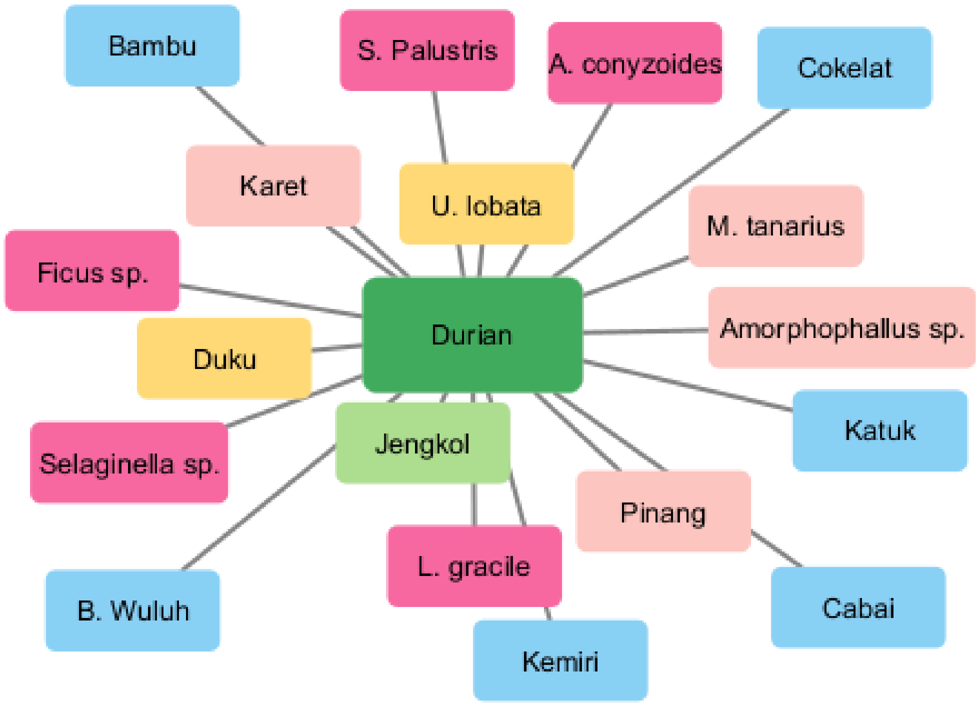

Figure 5. Association of Durian with Other Plant Species

Other species that exhibited very strong associations with durian were duku and *Urena lobata*, each with an index value of 0.89. The presence of duku around durian trees can be explained by both ecological compatibility and its economic value, while *U. lobata* tends to act as a pioneer species that occupies open spaces within the orchard. The coexistence of these species indicates that durian agroforestry systems are not monospecific but instead support the growth of various tree and understory species.

Moderate to strong associations (index value of 0.77) were found with several species such as *Macaranga tanarius*, *Amorphophallus* sp., rubber and areca palm (*Areca catechu*). These species reflect farmers' adaptive strategies in integrating cash crops into durian orchards. Rubber and areca palms, for instance, not only contribute to income diversification but also result in more complex vegetation structures. This suggests that durian agroforestry serves a dual function—maintaining durian productivity while supporting farmers' economic sustainability.

Several other species exhibited moderate associations (around 0.63), including *Ageratum conyzoides*, *Ficus* sp., *Leea indica*, *Lygodium gracile*, *Selaginella* sp., and *Stenochlaena palustris*. The occurrence of these species is more influenced by local ecological factors such as soil moisture and light availability under the durian canopy. Although not consistently found in all plots, these species contribute significantly to the diversity of the understory vegetation.

Low associations (0.45) were observed in species with relatively few individuals, such as candlenut, bamboo (*Bambusa* sp.), *Averrhoa bilimbi*, chili (*Capsicum* sp.), katuk (*S. androgynus*), and cacao (*T. cacao*). The presence of these species is generally complementary and not ubiquitous across all orchards. Nevertheless, their occurrence enhances vegetation diversity and enriches agroforestry ecosystem functions, for instance, as supplementary food sources or habitats for small fauna. Overall, these results emphasize that although durian is the dominant species, the presence of other species forms a diverse set of associations with significant ecological and socio-economic implications.

Discussion

The durian tree population in the Selat area is dominated by old trees with large trunk diameters, indicating that durian agroforestry in this region has been established for hundreds of years. Beyond its economic value, durian plays a vital role in the social and cultural life of local communities. Traditions such as *ngadang durian* (waiting for durian to fall) strengthen social bonds among community members. The durian fruiting season generates a unique social dynamic, characterized by intensified trading activities across villages within and around the Selat area.

Durian, known as the "king of fruits," holds significant cultural and economic value across Southeast Asia, where durian agroforestry not only contributes to farmers' livelihoods but also preserves cultural heritage linked to traditional farming systems (Thorogood et al., 2022). The sustainability of this agricultural practice supports the preservation of local traditions and cultural landscapes while promoting rural development (Khamung, 2015). Similar patterns are observed in the indigenous communities of Mount Wutai, Taiwan, where traditional agriculture sustains biodiversity, social institutions, and local cultural and environmental traditions (Ba et al., 2018). In several countries, such as Mexico, agroforestry systems have evolved into sacred cultural practices that connect spirituality and nature (Diemont et al., 2021). Agroforestry practices are often inherited across generations to maintain cultural identity and local institutions (Putra et al., 2020). In Cuba, traditional coffee agroforestry has proven effective in maintaining a balance between human needs and environmental conservation through the application of local knowledge (Agnoletti et al., 2022). Collectively, these examples demonstrate that agroforestry—including durian-based systems—provides not only economic benefits but also plays a crucial role in sustaining the social and cultural values of communities.

The durian trees planted by the ancestors several centuries ago have made Selat one of the most renowned durian-producing centers in the region. The current trees are largely managed by the descendants—grandchildren or great-grandchildren—of the original planters. To date, there have been limited efforts to regenerate aging durian trees. Only a small number of farmers have begun replanting by introducing new durian seedlings among existing trees. Some farmers facilitate natural regeneration by nurturing durian seedlings that germinate spontaneously between mature trees.

Durian-based agroforestry systems are developed by integrating durian with a variety of other crops, resulting in diverse patterns with distinct ecological characteristics and socio-economic impacts. The Durian–Rubber and Durian–Oil Palm patterns, for example, offer high long-term economic returns, whereas the Durian–Food Crop pattern is more oriented toward meeting farmers' subsistence needs. Meanwhile, the Durian–Betel Nut pattern is commonly practiced to demarcate farm boundaries while simultaneously providing additional income from betel nut production.

Species selection in agroforestry systems is influenced by multiple factors, including economic benefits, ecosystem services, and local knowledge. Economic factors often serve as the primary driver of farmers' decision-making (Ureta et al., 2016; Nguyen et al., 2020). In addition, farmers also consider ecological benefits such as soil quality improvement, shade provision, and mulch production, as well as other factors like market access and household needs (Nguyen et al., 2020). Optimal management techniques—such as tree density regulation, spatial arrangement, and pruning—are crucial for balancing positive and negative interactions between trees and intercrops (Basavaraju & Rao, 2000). By considering these factors, the development of sustainable agroforestry systems can be better ensured.

In the Selat region, durian agroforestry systems have evolved gradually through a combination of natural processes and human intervention. Initially, durian was cultivated as a monocrop in durian orchards. Open spaces between young durian trees were utilized for growing food crops such as rice. Over time, other plant species—such as duku, jengkol, and various others—began to establish naturally or were planted by farmers. As the system developed, farmers started managing and maintaining these additional species, resulting in a more complex agroforestry structure. The integration of timber trees into durian-based agroforestry not only enhances community welfare but also improves environmental conditions (Roshetko et al., 2007).

Beyond ecological benefits, durian agroforestry also contributes to food security by reducing dependence on external markets. Mixed patterns that combine durian with oil palm, for instance, can significantly increase farmers' income, although they require higher inputs in the form of fertilizers and pesticides compared to other patterns. Each durian-based agroforestry configuration presents distinct advantages and challenges, shaped by economic, ecological, and sociocultural factors. Therefore, locally adapted management strategies are essential to optimize the benefits of durian agroforestry for both communities and the environment.

The tree species found in durian agroforestry systems indicate that this model tends to resemble a monocultural plantation, characterized by the dominance of large durian trees with high stand density. This pattern suggests intensive land use with a primary focus on durian fruit production. Although durian remains the main species, the presence of secondary trees and diverse understory vegetation contributes to the overall biodiversity of the system. Minimal maintenance practices provide opportunities for various understory species to grow and develop, creating conditions that resemble those of secondary forests.

Tropical agroforestry systems have been shown to integrate biodiversity conservation with sustainable agricultural practices (Husband, 2020). Several studies have demonstrated that agroforestry can maintain plant diversity comparable to that of secondary forests while improving soil quality. The level of biodiversity within agroforestry systems varies depending on the type of agroforestry applied, where increased dominance of the main crop species, higher management intensity, and shorter cultivation cycles tend to reduce biodiversity (Sistla et al., 2016). For instance, in coffee-based agroforestry systems, biodiversity increases as the system becomes more complex, gradually shifting from intensive coffee monocultures to more diversified agroforestry structures (Gillison et al., 2004).

Durian represents one of the key elements in agroforestry systems, particularly in Southeast Asia. Several studies have reported that durian possesses a high importance value index in various regions (Rambey et al., 2022; Hidayat et al., 2022). Durian is also a common and economically valuable fruit species in the agroforestry practices of the *Orang Asli* communities in Malaysia (Keat et al., 2018). In Thailand, durian is frequently integrated into rubber-based agroforestry systems (Somboonsuke et al., 2011), providing greater economic returns compared to rubber monoculture plantations (Huang et al., 2023).

The existing durian agroforestry systems represent an advanced stage of development from previously monocultural durian orchards, which have gradually diversified through the inclusion of other species such as duku, jengkol, and candlenut. This diversification has led to more complex agroforestry systems with greater plant species richness. Agroforestry systems are known to enhance biodiversity compared to simpler agricultural systems due to their higher structural complexity (Santos et al., 2022).

In addition to intentionally planted species, several other tree species naturally grow among durian trees and are subsequently maintained by farmers. This practice reflects the accumulation of traditional ecological knowledge over time and involves multiple management strategies, such as protecting useful plants, attracting natural seed dispersers, and improving soil quality (Levis et al., 2018). The outcome is a more diverse and multilayered ecosystem capable of providing a wide range of products and ecosystem services (Michon et al., 2007).

Unlike other types of agroforestry, the tree diversity in durian-based systems is relatively low, with only a few species besides durian being recorded. This contrasts with rubber agroforestry systems in Sumatra, which host numerous non-rubber tree species and support a richer understory flora than monoculture plantations (Beukema et al., 2007). Similarly, agroforestry systems in Riau exhibit higher diversification, featuring species such as rubber, agarwood, meranti (*Shorea* spp.), bamboo, durian, jengkol, tampui, mangosteen, and oil palm (Insusanty et al., 2018). Agroforestry systems in West Kalimantan also demonstrate mixed planting of rubber, durian, and camphor (Winarni et al., 2018). Although tree diversity in durian agroforestry in the Selat area is relatively low, the system still supports higher biodiversity compared to surrounding monoculture plantations and agricultural lands (Udawatta et al., 2019).

Thus, durian agroforestry can be viewed as a system with substantial potential for biodiversity conservation, albeit to a lesser extent than more complex agroforestry models. Future efforts toward greater species diversification and sustainable management practices may further enhance both the ecological and economic benefits of durian-based agroforestry.

The analysis of durian associations with other plant species (using the Ochiai Index) revealed varying degrees of association between durian and other species. Jengkol exhibited the highest index value (1.00), indicating that the two species consistently co-occur in all durian plots. Other tree species showing strong associations with durian included duku, followed by betel nut rubber. Among understory species, *Urena lobata* had the highest association index, followed by *Amorphophallus* sp. and several others.

Jengkol was consistently found in all durian agroforestry plots observed. This finding indicates that the formation of agroforestry patterns is influenced not only by environmental factors but also by strong cultural and traditional practices. This condition aligns with previous ethnoecological studies on durian agroforestry, which show that local communities maintain combinations of fruit trees and companion plants for both subsistence and economic benefits as part of a sustainable agroforestry system (Mokoginta et al., 2025).

Jengkol is widely cultivated by local communities because it is a highly favored food source. Its distribution occurs not only through natural agents but also via human activities. For instance, farmers often bring jengkol as part of their meals while working in the orchard, and leftover seeds are frequently discarded, later germinating into trees. Similarly, seeds that fall and scatter during harvest can germinate naturally. The shaded conditions typical of durian orchards provide a favorable microclimate for jengkol seed germination (Zainal et al., 2024). Moreover, jengkol seedlings exhibit faster growth rates compared to several other tree species (Umer et al., 2021) and can thrive well in agroforestry systems that resemble secondary forest conditions (Oktavia et al., 2021).

In addition to jengkol, duku also shows a strong association with durian and is almost always present in durian orchards. The presence of duku provides additional economic benefits for farmers, both for household consumption and for fruit sales. Local farmers believe that durian and duku have a form of symbiotic relationship, although the specific ecological mechanisms remain unclear. However, in recent years, disease outbreaks have caused significant mortality among duku trees (Suwandi et al., 2021), leading to a drastic population decline and making them less abundant than jengkol.

Further analysis of species showing high association indices with durian indicates that these species generally possess smaller stature compared to durian trees. For instance, jengkol, duku, and rubber typically fall into the pole-size category (10–20 cm in diameter), much smaller than durian trees, which average around 70 cm in diameter. The mean diameter of jengkol trees is 22 cm—classified as a tree but only slightly above the minimum threshold for that category—while both duku and rubber fall entirely within the pole-size class. These differences in growth form are an important consideration when integrating species within durian-based agroforestry systems. In the Wan Abdul Rachman Grand Forest Park, Lampung, durian has also been reported to exhibit significant associations with several liana species, particularly black pepper (*Piper nigrum*) and betel vine (*Piper betle*), with Ochiai indices of 0.60 and 0.46, respectively (Sukra et al., 2021).

For the understory vegetation category, most of the species found in durian agroforests grow naturally, resulting in plant communities that more closely resemble secondary forests than monoculture agricultural systems. Species interactions within these ecosystems play an important role in shaping community structure and maintaining biodiversity (Ledo, 2015). Studies have shown that positive interactions are more common than exclusive competition in tropical forests, suggesting that species diversity in agroforestry systems is supported not only by habitat associations but also by facilitative mechanisms (Ledo, 2015; Burslem et al., 2005).

One of the understory plants showing a strong association with durian is *Urena lobata*. This species is widespread across tropical and subtropical regions, including Southeast Asia (Shelar et al., 2017; Mitchell et al., 2024). Its presence in durian agroforests may be linked to shifts in vegetation structure caused by agroforestry management practices that differ from those in primary forests. *U. lobata* contains a variety of phytochemicals—including alkaloids, glycosides, and flavonoids (Shelar et al., 2017)—which may contribute to its ecological success in agroforestry environments. Moreover, genetic studies indicate that *U. lobata* populations in Southeast Asia have local origins, supporting its status as an indigenous species in the region (Mitchell et al., 2024).

Durian agroforests in the Selat region of Jambi demonstrate that durian functions as a dominant species; however, its associations with jengkol duku, rubber, betel nut, and various understory species confirm that the system is not monodominant. The strong associations between durian and species such as jengkol and duku are influenced not only by ecological factors but also by cultural traditions that maintain specific species combinations as part of inherited agroforestry practices. Meanwhile, the presence of supporting species such as rubber, betel nut, and *U. lobata* enhances ecosystem functions through economic diversification, soil fertility improvement, and contributions to overall vegetation diversity. The high species diversity within durian agroforestry systems also contributes to greater ecosystem resilience against pests, diseases, and climate change compared to monoculture systems. Therefore, durian agroforestry management should aim to maintain and enrich the presence of other native species to promote ecological sustainability while ensuring long-term economic benefits for local communities.

Sustainable management of durian agroforestry requires a holistic approach that integrates species diversification and ecosystem optimization. Species diversification not only enhances resistance to disturbances but also supports ecological efficiency by optimizing the use of natural resources such as water, light, and soil nutrients. Ecosystems with high biodiversity tend to recover more effectively after disturbances (Schmitt et al., 2020). In addition, species-rich systems are generally more resilient to extreme climatic events, whereas monocultures are more vulnerable to high mortality rates during prolonged dry periods (Hutchison et al., 2018).

Agroforestry systems involving multiple plant species have been proven to enhance crop yields, improve soil organic matter content, and reduce pest attacks (Ji et al., 2024). The proper selection of companion species plays a crucial role in the success of such systems, as demonstrated by several previous studies (Rao et al., 2002). The durian-based agroforestry system in Selat should be enriched with additional tree species to increase both vertical and horizontal diversity, while simultaneously improving soil structure and microclimatic quality within durian orchards.

The sustainability of durian agroforestry in the Selat region faces multiple challenges—ecological, social, and economic. One major challenge is land conversion driven by increasing demand for settlements and infrastructure. Population growth and improved economic conditions have led to the conversion of many agroforestry lands, including durian orchards, into residential and infrastructural areas. In addition, migration from other regions has intensified pressure on already limited agricultural land, thereby reducing the ecological capacity and diversity of durian agroforestry systems.

Another critical factor affecting sustainability is the aging durian population. Most durian trees in this area are centuries old, leading to a significant decline in productivity. Although some farmers have begun replanting young durian trees among older ones, such rejuvenation efforts remain sporadic and unsystematic. Without a well-planned rejuvenation strategy, durian production in this area will become increasingly threatened, particularly in the face of climate change and soil degradation. The introduction of improved cultivation technologies, including the use of superior varieties, could therefore serve as an effective solution to increase productivity and maintain Selat as a competitive durian-producing region.

Beyond internal factors, the expansion of the oil palm industry has significantly affected land-use patterns in Jambi Province, including the Selat region. The higher economic value of oil palm compared to durian has encouraged many farmers to convert their durian agroforestry plots into oil palm plantations. While this expansion contributes to economic growth, it has negative impacts on social and environmental dimensions and threatens the sustainability of traditional farming systems (Qaim et al., 2020). Furthermore, oil palm expansion not only undermines traditional agricultural systems such as durian agroforestry but also drives deforestation and biodiversity loss (Bhagwat et al., 2012).

Another emerging challenge over the past decade is the phenomenon of *"tasteless durian"*—durian fruits that lack flavor and aroma, making them undesirable to both humans and wildlife. Consequently, many of these fruits are left to rot in the fields. Local informants reported that this phenomenon affects approximately 10% of the durian population in the area.

In Thailand, climate change has been shown to threaten durian productivity, primarily due to increasing temperatures and unpredictable rainfall patterns (Lilavanichakul & Pathak, 2024). Climate-related factors such as water scarcity, salinity, and high temperatures can negatively affect fruit quality (Kishor et al., 2023). Moreover, the El Niño–Southern Oscillation (ENSO) phenomenon has been reported to decrease durian yield and shift peak harvest seasons, with La Niña exerting a more pronounced impact than El Niño (Sarvina & Sari, 2017).

To address these challenges, more sustainable management strategies for durian agroforestry systems are required. One possible approach is the integration of sustainable agricultural techniques emphasizing land conservation, tree rejuvenation, and product diversification. Introducing more diverse agroforestry systems—by combining durian with other economically valuable species—can reduce land-use pressure and improve resilience to climate change. Additionally, enhancing farmers' capacity through training in environmentally friendly durian management and adopting innovative technologies for durian rejuvenation are vital steps toward improving productivity and long-term sustainability.

This study was conducted at a single location with relatively low species diversity; thus, the findings may not fully represent areas with higher diversity. Environmental factors such as soil type and rainfall, which may influence interspecies associations, were not examined in detail. Other limitations include incomplete technical data on planting distances, the number of farmers, and diversity indices for each agroforestry pattern. External factors such as climate variability and orchard management were also not comprehensively analyzed. Since this research was limited to the Selat area, its results cannot yet be generalized to other regions with different agroforestry characteristics. Furthermore, the absence of quantitative data on durian yield and direct economic contribution, as well as limited exploration of socio-economic conflict dynamics within the durian agroforestry system, represent important areas for future research.

CONCLUSION

The results of this study indicate that the population structure of durian-based agroforestry systems in the Selat region is dominated by old trees, many of which are centuries old, with low regeneration rates—both natural and farmer-assisted. This condition may lead to a long-term decline in durian productivity if systematic rejuvenation efforts are not implemented. Durian exhibits strong ecological associations with other species such as jengkol, duku, and rubber, suggesting that the agroforestry systems in this area have evolved naturally with interaction patterns that promote ecosystem sustainability.

Findings from this study highlight the need for sustainable agroforestry management strategies that include systematic rejuvenation of durian trees through the periodic planting of superior seedlings, as well as maintaining supporting species diversity to preserve ecological balance. Furthermore, this study recommends integrating companion species with both economic and ecological value (such as nitrogen-fixing legumes, soil-protecting plants, and fruit trees like duku or jengkol, optimizing planting distances to enhance regeneration growth, and providing incentives or training for farmers to manage agroforestry systems adaptively in response to environmental changes and market pressures. Through the implementation of these measures, durian agroforestry in the Selat region is expected to remain productive while maintaining local ecosystem sustainability.

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