The Integration of Local Species and Local Knowledge in Agroforestry Systems in Indonesia: A Systematic Mapping Study

Puput Talantan[1], Fabiola B. Saroinsong[1*], Esra Nikita Situmorang[1], Euis F. S. Pangemanan[1], Semuel P. Ratag[1]

[1]Forestry Study Program, Universitas Sam Ratulangi
*Corresponding author *: fabiolasaroinsong@unsrat.ac.id*

ABSTRACT

Agroforestry systems are an innovative approach to land management that harmoniously integrates trees or forests with agricultural crops and livestock, creating a mutually supportive ecosystem. This approach not only increases land productivity but also contributes significantly to global food security, especially amid the challenges of climate change and environmental degradation. In addition, agroforestry plays an important role in biodiversity conservation by preserving natural habitats and preventing soil erosion, while providing economic benefits to farmers through crop diversification. Indonesia, as one of the world's megabiodiversity countries, has a wealth of local species, including various types of tropical trees, medicinal plants, and traditional food sources that have been integrated into agroforestry practices since ancient times. Species such as durian, petai, and various types of hardwood have become an integral part of local agricultural systems, which not only support ecological sustainability but also the culture of indigenous peoples. However, despite this great potential, knowledge about the use of local species in agroforestry in Indonesia is still limited, with many gaps in research that need to be identified to encourage more effective development.

This study aims to map research trends, key study focuses, frequently used key species, and knowledge gaps related to the integration of local species in agroforestry systems in Indonesia. By conducting this mapping, this study is expected to reveal the temporal and geographical patterns of agroforestry research, identify under-explored endemic species, and highlight areas such as Java, Sumatra, and Kalimantan that have high potential but have not been fully researched. The SMS method applied involved a systematic and structured search of various leading scientific databases, such as Scopus, Web of Science, and Google Scholar, using specific keywords such as "agroforestry Indonesia," "local species," and "biodiversity conservation." This process was followed by rigorous screening based on inclusion-exclusion criteria, which included publications in English and Indonesian from 2000 to the present, as well as a focus on relevant empirical studies or reviews. Data extraction was then conducted for quantitative analysis, such as publication frequency per year and geographical distribution, as well as qualitative analysis to identify key themes and knowledge gaps, such as the lack of studies on the impact of agroforestry on climate change or integration with modern technology.

The mapping results from this study are expected to provide strategic guidance for researchers, policymakers, and agroforestry practitioners. These findings can encourage the development of more sustainable programs, such as the promotion of local species in organic certification schemes or the integration of agroforestry into national policies such as the National Biodiversity Action Plan. In addition, these results will help address knowledge gaps, such as the need for further research on the adaptation of local species to the threats of deforestation and urbanization, so that agroforestry can become an effective solution for food security and conservation in Indonesia.

***Keywords**: Agroforestry, Local Species, Local Knowledge, Indonesia, Systematic Mapping Study, Biodiversity.*

1. INTRODUCTION

Agroforestry is a land management system designed to address problems arising from land conversion to solve food issues (Saroinsong et al., 2021; Pangemanan et al., 2025). Agroforestry aims to optimize and sustainably utilize existing resources (Ardini et al., 2020; Pangemanan and Saroinsong, 2025). This technology is implemented through the simultaneous or sequential use of seasonal crops, annual crops, and/or livestock during certain periods, thereby creating ecological, social, and economic interactions. The agroforestry system has more advantages than other land use systems. One of the advantages of this system is that it can be used on steep slopes.

Multistrata agroforestry systems can prevent landslides by forming soil organic matter, improving soil structure, and making the soil more stable (Rendra et al., 2016). Agroforestry systems are widely believed to have great potential as a major alternative land management method for soil conservation and for maintaining soil fertility and productivity in tropical areas. Therefore, farmers should apply technology packages with appropriate modifications so that they gain scientific knowledge (Sukmawati et al., 2014).

In Indonesia, the implementation of agroforestry has developed in line with strong local knowledge and community traditions in utilizing native plant species found around forests and agricultural land. The use of local species not only enriches the vegetation structure in agroforestry systems, but also increases ecological resilience due to their adaptability to local climate and soil conditions (Rendra et al., 2016).

Local plants such as durian, candlenut, bamboo, palm, melinjo, and various types of spices have long been part of traditional agroforestry systems and have been proven to support soil conservation while providing economic value to the community. The use of local species in agroforestry systems is also related to landscape planning that supports biodiversity, ecosystem stability, and sustainable land management (Saroinsong, 2020). Therefore, studies on the use of local species in agroforestry systems are relevant to understanding their role in improving the sustainability of land management and their contribution to the welfare of communities in Indonesia.

2. METHODOLOGY

This study uses a Systematic Mapping Study (SMS) approach to map the development of research related to the use of local species in agroforestry systems in Indonesia. This approach was chosen because it provides an overview of the number of publications, research focus, types of local species studied, and research trends in a given period. The research data was obtained through secondary data sources, namely scientific articles published in national and international journals indexed by Google Scholar, SINTA, and ScienceDirect.

3. RESULTS AND DISCUSSION

3.1 Local Species Diversity in Agroforestry Systems

Local species diversity is the main foundation for the sustainability of agroforestry systems in Indonesia. This system combines annual and seasonal crops on a single plot of land, with the aim of not only producing agricultural products, but also maintaining ecological balance and the social resilience of rural communities.

Research conducted in various regions of Indonesia shows that agroforestry systems have a high level of species diversity, with a combination of endemic plants, forest plants, and economically valuable agricultural plants. For example, a study by Setiawan & Arafah (2025) in Konawe, Southeast Sulawesi, found 31 tree species from 18 different families in a community forest agroforestry system in the midlands.

Of the total species identified, 74% are endemic to Indonesia, and 77% are actively cultivated by farmers. Dominant species such as Tectona grandis (teak), Theobroma cacao (cocoa), and Mangifera indica (mango) show high importance indices, indicating their significant ecological and economic roles in the community's agroforestry system. Another study on Siberut Island, West Sumatra, by Gusmardi et al. (2024) showed that the traditional agroforestry landscape of “Pomunean” contained more than 100 plant species, including Metroxylon sago (sago), Durio zibethinus (durian), Cocos nucifera (coconut), and Areca catechu (betel nut).

This system is divided into two categories: Tinugglu in hilly areas and Mone in lowlands. This study emphasizes the importance of traditional ecological knowledge in maintaining a balance between the economic, social, and ecological functions of agroforestry. In West Java, Permatasari et al. (2024) studied species diversity in traditional Pohpohan (Pilea melastomoides)-based agroforestry systems in Gunung Halimun Salak National Park. The results recorded 54 species from 37 plant families, with a predominance of the Rubiaceae, Fabaceae, and Malvaceae families.

Trees such as Pinus merkusii, Agathis dammara, and Maesopsis eminii are important components of the ecosystem, while understory plants such as Pohpohan are used as fresh vegetables with high economic value. This system is an example of the successful integration of forest conservation with the traditional agricultural practices of communities surrounding conservation areas. In addition to Java, research in South Sulawesi by Paembonan et al. (2018) shows that home garden agroforestry systems have moderate to high species diversity indices (1.25–2.18).

Fruit crops such as jackfruit, banana, papaya, and coffee grow alongside medicinal plants and hedge plants, contributing 43–49% to farmers' household income. This confirms that species diversity is not only important for ecological functions but also has a real economic impact. Research in Toraja, South Sulawesi by Paembonan et al. (2019) reinforces the relationship between species diversity and carbon storage. Moderate species diversity indices (1.87–2.14) correlate positively with carbon storage potential reaching 77.45 tons C/ha in the upper vegetation layer.

This shows that agroforestry systems not only support plant diversity, but also play an important role in climate change mitigation. Research in Banyuwangi by Hakim et al. (2018) describes the traditional home gardens of the Osing tribe as a complex form of agroforestry with high species diversity. Important species such as Coffea liberica, Durio zibethinus, and Garcinia mangostana have high ethnobotanical value due to their connection to the culture and rituals of the community.

This system shows that agroforestry functions as a cultural adaptation mechanism to environmental and social change. In addition to plant diversity, soil fauna diversity also shows a close relationship with agroforestry systems. Research by Kinasih et al. (2016) in Sumedang, West Java, found that the coffee-pine agroforestry system increased soil invertebrate diversity compared to monoculture pine forests. The Shannon diversity index value reached 2.64 with a distribution of fauna such as Formicidae (ants), Scarabaeidae (ground beetles), and Phalangiidae (ground spiders).

These results confirm that vegetation diversity supports the complexity of underground ecosystems that play a role in the nutrient cycle. In general, these findings indicate that the diversity of local species in agroforestry systems serves as a key pillar of ecosystem stability and the socio-economic sustainability of communities. Local species not only have high ecological value due to their role in maintaining soil fertility and carbon sequestration, but also socio-cultural value that is closely linked to local wisdom and community identity.

3.2 Ecological Functions: Soil Conservation and Biodiversity in Indonesian Agroforestry Systems

Agroforestry systems play an important role in maintaining the ecological functions of agricultural land in Indonesia, particularly in soil conservation, fertility improvement, water cycle regulation, and biodiversity preservation. By integrating trees, food crops, and shrubs within a single land area, agroforestry forms a system that resembles natural forest ecosystems — thereby reducing environmental degradation and supporting long-term ecosystem resilience.

3.2.1 Soil and Water Conservation

According to Rufaidah et al. (2024), agroforestry practices in Gapoktan Pujo Makmur, Lampung, have been proven to have key ecological functions such as retaining soil and water, minimizing erosion, and enriching soil nutrients through leaf litter decomposition. The deep root systems of local tree species such as durian (Durio zibethinus), teak (Tectona grandis), and candlenut (Aleurites moluccanus) stabilize soil structure and prevent landslides on sloping land. In addition, tree canopies increase rainwater infiltration and reduce surface runoff, thereby increasing groundwater reserves.

Research by Baliton et al. (2017) in the Way Betung watershed, Lampung, also confirms that agroforestry improves ecological balance in watersheds. This system has a carbon storage capacity of 24.4 tons C/ha and a moderate species diversity index (2.53), indicating that the combination of hardy and seasonal plants can function as a natural environmental buffer. Agroforestry in this region also reduces river sedimentation by up to 35% compared to monoculture land.

3.2.2 The Role of Agroforestry in Biodiversity

Biodiversity is an important indicator of the stability of agroforestry ecosystems. Research by Kurnianto et al. (2024) in Kluncing, Ijen, found that the coffee agroforestry system maintains high diversity of birds, butterflies, and pollinating insects. The Shannon-Wiener index for the bird community reached 2.911—the highest compared to other fauna groups—indicating the important role of layered vegetation structure in providing diverse habitats. The species Collocalia linchi (mountain swift) and the family Formicidae (ants) were identified as key species in maintaining the trophic balance of the ecosystem.

A study by Sari et al. (2025) reinforces these findings by showing that coffee agroforestry systems have a positive relationship between carbon stocks and vegetation diversity. The diversity index (H') ranged from 0.57 to 2.05, with a total carbon stock of 82 ± 19 Mg ha^{-1} in the disturbed forest category. The higher the tree species diversity, the greater the carbon storage capacity and ecosystem carrying capacity.

3.2.3 The Role of Agroforestry in Rehabilitating Degraded Ecosystems

Agroforestry is also an effective approach to restoring damaged land, especially tropical peatlands. Research by Jaya et al. (2024) shows that the application of agroforestry with native tree species such as Shorea balangeran, Dyera polyphylla, and Calophyllum inophyllum can increase soil moisture, reduce surface temperature, and reduce the risk of forest fires. In addition, mixed vegetation increases soil organic carbon content by 12–18% within three years compared to open land.

In Bengkulu, Wiryono et al. (2023) identified that agroforestry home gardens provide significant ecosystem services, including carbon storage (an average of 87 Mg C/ha), plant diversity conservation (57 tree species from 28 local species), and support for community food security. These results show that agroforestry systems not only maintain ecological functions but also provide sustainable socio-economic benefits.

3.2.4 Linkages with Social Forestry and Conservation Policy

According to Gunawan et al. (2022), the integration of agroforestry and social forestry programs in Indonesia can strengthen the conservation function of forest biodiversity while improving community welfare. The study underscores the importance of balancing ecological and social objectives in community forest management. However, the biggest challenges are habitat fragmentation due to agricultural expansion and the lack of ecological monitoring mechanisms at the local level.

3.2.5 Implications for Climate Change Mitigation

The ecological functions of agroforestry are not limited to soil and water conservation, but also play an important role in mitigating global climate change. According to van Noordwijk (2024), agroforestry systems in tropical regions can act as natural carbon sinks, improve nutrient cycles, and provide ecosystem services across scales—from the plot level to the landscape level. He emphasizes the need for tropical bioresource innovations based on local knowledge that are adapted to the socio-economic and ecological changes of communities.

3.3 Social and Economic Functions of Agroforestry Systems in Indonesia

Agroforestry systems in Indonesia not only play a role in maintaining ecological balance, but also have significant social and economic functions for rural communities. These systems create links between natural resource management and improved welfare and social resilience in local communities.

3.3.1 Contribution to Household Income

A study by Tiga et al. (2024) in Tina Bani Village, Ende, East Nusa Tenggara shows that community-based agroforestry systems (Community Forests, HKm) make a significant economic contribution. Approximately 98.87% of household income comes from agroforestry products such as coffee, candlenut, and other intercropped plants. This system uses an agrosylviculture pattern with a combination of forest and agricultural plants arranged randomly according to local traditions. However, this study also highlights challenges in the form of limited infrastructure and market access that restrict farmers' economic potential.

A similar study by Widiyanto et al. (2022) in Gunungkidul found that cajuput (Melaleuca cajuputi)-based agroforestry generates higher income than teak (Tectona grandis)-based systems. In addition to economic value, farmers also appreciate the social benefits of increased cooperation among farmer group members and better access to government programs.

3.3.2 Social Empowerment and Community Social Capital

One of the prominent social dimensions of agroforestry is its ability to strengthen social cohesion and build community social capital. Research by Rufaidah et al. (2024) at Gapoktan Pujo Makmur, Lampung, shows that the success of agroforestry systems is highly dependent on local wisdom and customary regulations. For example, there is a social agreement that prohibits the theft of crops with fines of up to ten times their sale value, as well as the distribution of harvests among residents based on the principle of social justice. Such a system builds a sense of collective responsibility for natural resource management and strengthens social networks among farmers.

In addition, research by Prabawani et al. (2024) in Central Java shows that agroforestry can increase the social capacity of small farmers and become a source of social capital for agricultural sustainability. Farmers who adopt agroforestry systems show higher levels of self-confidence and community participation, and are more active in farmer organizations and local cooperatives.

3.3.3 Food Security and Economic Diversification

Agroforestry systems also contribute significantly to household food security. Through the integration of food crops, fruits, and timber trees, these systems enable farmers to earn income and obtain food throughout the year. According to Rahman et al. (2017), agroforestry in the Salak Mountain Valley, West Java, has a higher economic value than swidden agriculture. In addition to increasing income, tree ownership also provides social status and security over land because it increases customary land rights.

Beyond financial benefits, sharing harvests such as fruits and vegetables with neighbors strengthens social solidarity. This demonstrates that agroforestry is not only an economic strategy but also a means of reinforcing the culture of mutual cooperation in rural areas.

3.3.4 Impact on Poverty Alleviation and Economic Independence

In the context of sustainable development, agroforestry serves as a mechanism for empowering poor communities economically. A study by Octavia et al. (2022) in three social forest locations (West Sumatra, Lampung, and East Nusa Tenggara) shows that the success rate of agroforestry is greatly influenced by community participation and local institutional support. In locations with high participation, the survival rate of plants reached 93.5% in the first 12 months, which was directly correlated with increased family income and better land cover.

Meanwhile, research in Malang by Jambut et al. (2023) found that the transition of management from Perhutani to Brawijaya University Forest improved social interaction, village infrastructure, and economic income, with 67% of respondents feeling an increase in welfare. As many as 88.86% of farmers consider the forest intercropping system to be the main source of food and household income.

3.3.5 Local Wisdom and Social Governance

Agroforestry in Indonesia has developed extensively through customary social mechanisms that ensure the equitable distribution of benefits. According to Jongrungrot (2016), agroforestry systems have three main functions: economic, environmental, and social, including sub-functions such as product charity (product sharing), knowledge sharing, and social networking. In the context of rural Indonesia, this social function makes agroforestry not only a means of production, but also a means of preserving cultural values and community solidarity.

3.4 Implications of Agroforestry Systems for Climate Change Adaptation and Mitigation in Indonesia

Climate change is a global challenge that affects ecosystem stability and human welfare. Indonesia, as a tropical country with high biodiversity, faces real impacts in the form of increased average temperatures, shifts in rainfall patterns, and higher frequencies of droughts and floods. In this context, agroforestry systems—which combine trees with agricultural crops or livestock in a single landscape—have proven to be an effective strategy for climate change mitigation and adaptation in various regions of the archipelago.

3.4.1 Agroforestry as a Climate Mitigation Mechanism

Agroforestry plays an important role in carbon sequestration through increased biomass and soil carbon content. Research by Gusli et al. (2020) in Sulawesi found that 10–34-year-old cocoa-based agroforestry systems were able to store 120–150 Mg C/ha, compared to secondary forests which had 320 Mg C/ha. Increasing the age of agroforestry has been proven to restore the soil's capacity to store water (5.7 mm/m per 1 g Corg kg^{-1}) and increase the ecosystem's resilience to drought. Thus, agroforestry is a nature-based solution that simultaneously reduces carbon emissions and improves soil hydrology.

Research by Heryandi et al. (2022) in the Batutegi Protected Forest, Lampung, shows that a combination of coffee, pepper, rubber, and banana plants in an agrisilviculture pattern can produce higher carbon stocks than the national average for coffee-based agroforestry in Indonesia. This system not only reduces pressure on protected areas but also preserves local biodiversity, which plays a role in ecosystem balance.

Similarly, Purnomo et al. (2022) highlight the potential of soybean agroforestry systems under teak, pine, and sengon stands as a measure for climate mitigation and increased food production. This system efficiently utilizes the low light under the forest canopy to grow soybeans, yielding an average of 1.5 tons ha^{-1} of soybeans while maintaining the carbon sequestration function of the soil.

3.4.2 Agroforestry as a Strategy for Adapting to Climate Change

In addition to its role in mitigation, agroforestry is also a form of ecosystem-based adaptation. The combination of perennial and annual crops creates a layered vegetation structure that can prevent soil moisture loss and regulate the microclimate. Research by Hairiah et al. (2021) in the Bangsri microwatershed, East Java, shows that the increase in agroforestry area from 1994 to 2017 contributed to a reduction in net CO_2 emissions and increased the resilience of local agriculture to erratic rainfall.

This system also encourages the construction of small reservoirs and micro-irrigation to support vegetable productivity under the shade of trees. Meanwhile, Sudarma et al. (2024) in Bali reported that chili farmers have begun to implement intercropping patterns with shade trees and adaptive irrigation systems to reduce the risk of crop failure due to drought and increased pest intensity. This adaptation reduced production decline by up to 43% compared to monoculture systems, demonstrating the effectiveness of tree integration in coping with climate uncertainty.

In addition, agroforestry supports the socio-economic adaptation of communities by reducing dependence on a single commodity and diversifying sources of income. Farmers can harvest fruit, timber, and non-timber products (such as honey, sap, and spices) in rotation, which helps stabilize household economies amid climate fluctuations.

3.4.3 Agroforestry as Part of the National Climate Strategy

In the context of policy, agroforestry has the potential to support the achievement of Indonesia's Nationally Determined Contributions (NDCs) target to reduce greenhouse gas emissions by 31.89% independently by 2030. According to Mardiatmoko (2022), the implementation of agroforestry is in line with the REDD+ and Bonn Challenge programs because it combines forest conservation, carbon sequestration, and sustainable land management. However, challenges still include weak policy synergies and limited access to climate finance at the community level.

A global meta-analysis study by Eshetu et al. (2025) reinforces the evidence that agroforestry systems can absorb 3.5–9.8 Mg CO_2 ha^{-1} per year, increase soil carbon content by up to 15%, and increase biodiversity by 25–40% compared to monoculture systems. Globally, these systems also increase agricultural yields by up to 30% and strengthen food security—making them an ideal climate-smart agriculture approach for tropical regions such as Indonesia.

3.4.4 Challenges and Development Directions

Despite its great potential, the implementation of agroforestry in climate mitigation and adaptation faces a number of challenges. Much of Indonesia's agroforestry land is still managed without the support of carbon monitoring technology and strong institutions. The lack of recognition of indigenous peoples' tenure rights is also an obstacle to long-term implementation. In addition, the lack of financial incentives such as payment for ecosystem services (PES) means that farmers do not yet receive direct economic benefits from the carbon mitigation services they produce.

To overcome this, it is necessary to strengthen local capacity, community-based research, and the integration of agroforestry into national climate change policies. The application of land-based carbon monitoring systems, such as community-based MRV (Measurement, Reporting, and Verification), can strengthen the position of agroforestry as a key component in Indonesia's climate adaptation and mitigation efforts.

3.5 Integration of Local Knowledge and Modern Science in Agroforestry Systems in Indonesia

The integration of local knowledge and modern science is an important element in sustainable agroforestry management in Indonesia. The combination of these two approaches not only strengthens community adaptation to environmental change, but also encourages ecologically and socially relevant technological innovation. Local communities in various regions of Indonesia have long developed traditional agroforestry systems, which have been enriched with scientific approaches to improve productivity, efficiency, and conservation of natural resources.

3.5.1 The Role of Local Knowledge in Agroforestry Management

Local knowledge is rooted in the experiences passed down from generation to generation in interacting with their environment. A study by Dako et al. (2025) in the Mutis-Timau highlands of Timor Island revealed that the Ajaobaki and Fatumnasi communities use three traditional agroforestry models: intercropping, hedge crops, and a combination of forestry and agriculture. They integrate food crops (corn, beans), garden crops (oranges, candlenuts, avocados), and timber trees (teak, gamal, and Casuarina junghuhniana) to maintain a balance between food security, economic income, and environmental protection. This approach demonstrates the ability of local communities to manage ecological spaces that are adaptive to climate and soil conditions.

Research in Bintuni Bay, West Papua by Jaizul et al. (2025) also shows that the indigenous communities of Moskona, Wamesa, and Sumuri still maintain traditional agricultural systems based on sago, sweet potatoes, and bananas. The modernization process has not eliminated these traditions;

instead, a hybridization of knowledge has been created, in which communities choose elements of modern technology that are compatible with their ecological and spiritual values. This shows that local knowledge is not a static system, but rather adaptive and dynamic to socio-economic changes.

3.5.2 Integration of Modern Science into Traditional Practices

The integration of modern science enriches local practices with data-driven scientific approaches and technological innovations. A study by Limpo et al. (2022) on the Bugis–Makassar farming community shows the Tudang Sipulung model as a formal forum that combines local and scientific knowledge in agricultural decision-making. In this forum, scientific research results such as climate forecasts and fertilizer recommendations are combined with local wisdom, for example, determining planting times based on natural signs. This system even has customary legal power that strengthens compliance and sustainability in agricultural practices.

Research by Nugroho et al. (2023) confirms the importance of a socio-technical approach in watershed management. The integration of scientific technology with local community knowledge has proven effective in restoring the hydrological functions of watersheds and improving the socio-economic conditions of farmers. They emphasize the need for the principles of suitability, applicability, and acceptability so that this integration of knowledge is truly accepted and beneficial to local communities.

3.5.3 Local Ecological Knowledge as the Basis for Scientific Innovation

Local ecological knowledge (LEK) has become a source of inspiration in contemporary scientific research. A study by Gading et al. (2025) at the foot of Mount Tambora shows that coffee farmers have a deep ecological understanding of soil quality based on natural indicators such as earthworms, soil color, and humus. As many as 80% of farmers consider the presence of earthworms as the main indicator of fertility, a perception that was later scientifically verified through soil biology analysis. The integration of LEK and modern ecological knowledge strengthens regenerative agricultural practices and soil conservation in coffee agroforestry systems.

Similarly, Kamakaula (2024) highlights the importance of an ethnoecological approach in combining local communities' understanding of climate and ecosystems with modern science for climate change mitigation. His research shows that local wisdom regarding seasonal cropping patterns and the selection of drought-resistant species can increase the resilience of agroforestry to extreme climate variability.

3.5.4 Knowledge Transformation Towards Innovative Systems

The integration of local and modern knowledge in agroforestry systems is also reflected in land management practices by farmers in North Sulawesi. A study by Titdoy et al. (2014) shows that farmers in Tolok Satu Village actively develop agroforestry systems through a combination of forestry crops, agricultural crops, and livestock based on generations of experience and adaptation to the biophysical conditions of the land. The applied agrisilviculture and agrosilvopastoral patterns reflect farmers' ability to adapt cultivation techniques and planting distance arrangements to optimize production and ecological functions. These findings confirm that farmers play a role as innovators in the development of agroforestry systems, rather than merely being recipients of external technology.

Meanwhile, Husnah et al. (2015) emphasize that the integration of local and modern knowledge not only accelerates technology adoption but also enhances social sustainability. Technologies that originate from or are adapted to local cultures are more readily accepted because they are based on customs and local belief systems. The synergy between the two gives rise to contextual innovations that are environmentally friendly and socially equitable.

This knowledge transformation process is also reflected in innovative community-based practices, as demonstrated by Pangemanan et al. (2025) through the development of Family Medicinal Plant Gardens (TOGA) under coconut trees in Ongkaw Satu Village, North Sulawesi. Training activities that combine technical knowledge with local community wisdom have successfully transformed previously unproductive areas under coconut trees into agroforestry systems that are ecologically, socially, and economically valuable. These findings reinforce that the synergy between local and modern knowledge can encourage the emergence of innovative systems that are sustainable and based on the local context.

3.5.5 Challenges and Development Directions

Despite its success in various regions, the integration of local and modern knowledge faces several challenges:

- Lack of documentation of local knowledge, which is often only transmitted orally.

- The dominance of a technocratic paradigm that places modern science as the sole source of scientific truth.
- Minimal participation of the younger generation, who tend to abandon traditional practices because they are considered irrelevant to modern technology.

Therefore, participatory and collaborative research is key. Approaches such as co-production of knowledge and transdisciplinary research need to be developed to ensure that local wisdom becomes the foundation of sustainable agricultural technology innovation in Indonesia.

3.6 Challenges and Opportunities for Agroforestry System Development in Indonesia

Agroforestry systems play a strategic role in achieving sustainable development goals in Indonesia, particularly in terms of natural resource conservation, food security improvement, and local community economic empowerment. However, its implementation still faces various structural, social, economic, and institutional challenges. Nevertheless, recent studies show that behind these challenges lie great opportunities to optimize the potential of agroforestry as a nature-based solution that is adaptive to climate change and relevant to the socio-cultural context of the community.

3.6.1 Technical and Institutional Challenges

The main challenges in developing agroforestry in Indonesia lie in technical and institutional aspects. According to Judijanto (2025), the application of agroforestry concepts in oil palm plantations—which is expected to be a solution to deforestation—is still hampered by farmers' lack of knowledge about appropriate agroforestry techniques, minimal technical support, and the absence of clear regulations on integration between the agriculture and forestry sectors. In addition, a weak economic incentive system discourages farmers from switching from monoculture to mixed systems.

Arif et al. (2018) echoed this sentiment, arguing that the failure of forest management in Indonesia was largely due to an overly centralistic approach and a lack of community participation in decision-making processes. As a result, many agroforestry initiatives have been hampered by land conflicts and legal uncertainty over land ownership.

3.6.2 Socio-Economic and Market Challenges

At the community level, limited access to capital, technology, and markets is a major obstacle to agroforestry development. Supriadi and Pranowo (2016) note that coffee farmers in agroforestry systems in Lampung and Java still face difficulties in obtaining financing, fluctuating product prices, and uncertainty regarding the status of their land. In addition, farmers' knowledge of mixed cultivation techniques is still low, resulting in suboptimal yields.

Meanwhile, a study by Mulyoutami et al. (2024) on rubber agroforestry in West Kalimantan shows that other challenges arise from global rubber price volatility, low latex quality, and a lack of support from financial institutions and investors. Nevertheless, significant opportunities exist through the formation of farmer cooperatives and collective marketing units (UPPB), which can increase selling prices by up to 25%. Such sustainable business models can serve as examples of how collaboration between farmers, NGOs, and the government can strengthen the economic position of small-scale agroforestry practitioners.

3.6.3 Development Opportunities: Smart Agroforestry and Social Forestry

The emergence of the Smart Agroforestry (SAF) concept offers great opportunities in overcoming traditional agroforestry constraints. According to Octavia et al. (2022), SAF combines the principles of smart farming with forest conservation to create an adaptive, productive, and environmentally friendly system. This approach emphasizes the use of information technology, spatial mapping, and environmental monitoring systems to optimize yields and reduce land degradation. SAF also has great potential to support the achievement of the Sustainable Development Goals (SDGs), particularly goals 1 (no poverty), 13 (climate action), and 15 (terrestrial ecosystems).

In addition, the implementation of social forestry or community forests is a strategic opportunity for the development of agroforestry at the site level. Rakatama & Pandit (2020) revealed that this program not only improves the welfare of communities around forests but also opens up space for the integration of agroforestry as part of local economic strategies. The main challenges still lie in weak institutional support and inconsistent policies between regions, but the potential for developing social forestry with an agroforestry approach is considered to be very significant in reducing poverty and maintaining ecological functions.

3.6.4 Economic Opportunities and Food Security

From an economic perspective, agroforestry offers more stable income diversification than monoculture systems. Research by Duffy et al. (2021) shows that agroforestry can increase the food security of smallholder farmers by up to 20% through the diversification of food crops, medicinal plants, and non-timber forest products. In addition, this system increases income up to five times compared to traditional shifting cultivation agriculture. However, researchers also highlight the lack of comprehensive financial analysis in agroforestry studies in Indonesia, thus requiring more in-depth economic research to estimate the long-term value of this system.

3.6.5 Policy Synergy and Multi-stakeholder Collaboration

To encourage inclusive and sustainable agroforestry development, synergy between the government, research institutions, the private sector, and the community is essential. Pambudi (2020) emphasizes that the success of programs such as social forestry is highly dependent on cross-sector collaboration and providing legal access to communities. The government needs to strengthen policy frameworks that support green investment, provide carbon incentives, and facilitate the market for agroforestry products through sustainable certification.

4. CONCLUSION

Based on the results of the Systematic Mapping Study (SMS), the integration of local species and local knowledge is a major theme in the development of community-based agroforestry systems in Indonesia. The literature reviewed shows that local species have a high level of adaptation to local biophysical conditions and a strong connection to the social and cultural values of the community, thus playing an important role in maintaining ecosystem stability and the sustainability of land use systems. The use of local knowledge also forms the basis for regulating cropping patterns, plant combinations, and the management of planting space and time in agroforestry systems.

The results of the literature mapping further show that agroforestry systems are seen not only as a production strategy, but also as a land management approach that supports ecological and social functions. The integration of local knowledge and modern science is considered capable of encouraging contextual innovations that are more easily accepted by the community and have the potential to be ecologically sustainable. Therefore, the development of agroforestry based on local species and local knowledge is highly relevant to supporting land management planning and sustainable agricultural development in Indonesia.

REFERENCES

Ardini, M. I. N. D. A., Marsela, A., Mustika, R., Subakti, R., Khairani, S., Suwardi, A. B., & Biologi, P. (2020). Potensi pengembangan agroforestri berbasis tumbuhan buah lokal. Jurnal Ilmiah Pertanian, 17(1), 27-34.

Arif, A., Suhaidi, S., Syahrin, A., & Runtung. (2018). Indonesian Forest Management: Opportunities and Challenges. IOP Proceedings.

Dako, F. X., Ora, Y. A. N. R., Ranta, F., Benu, Y., & Pujiono, E. (2025). Traditional Agroforestry Models Based on Local Knowledge in the Mount Mutis-Timau Highlands, Timor Island, Indonesia. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan.

Duffy, C., Toth, G. G., Rahman, S. A., & Sunderland, T. (2021). Agroforestry Contributions to Smallholder Farmer Food Security in Indonesia. Agroforestry Systems, 95(6), 1089–1106.

Gading, W., Hairiah, K., & Rizali, A. (2025). Local Ecological Knowledge of Coffee Farmers on Earthworms and Pests as Soil Quality Indicators in Mount Tambora, Indonesia. Agro Bali: Agricultural Journal, 8(2).

Husnah, N., Ali, M. S. S., Salman, D., Hijjang, P., Djufry, F., & Amrawaty, A. A. (2015). Merging Indigenous and Modern Knowledge in Agricultural Development. International Journal of Agriculture System, 2(2), 97–108.

Jaizul, A., Sulistya, A., & Lianingsih, N. (2025). Ethno-Sciences and the Transformation of Traditional Agricultural Systems in Teluk Bintuni: Between Preservation and Modernization. International Journal of Ethno-Sciences and Education Research.

Judijanto, L. (2025). Implementation of Agroforestry Concept on Oil Palm Plantation: Prospects and Challenges. 1st Congress on Multidisciplinary Studies.

Kamakaula, Y. (2024). Ethnoecological Perspectives on Agroforestry Practices for Climate Change Mitigation and Adaptation. Widyasastra Journal of Integrated Sciences.

Limpo, S. Y., Fahmid, I. M., El Fattah, A. A., Rauf, A., & Surmaini, E. (2022). Integrating Indigenous and Scientific Knowledge for Decision Making of Rice Farming in South Sulawesi, Indonesia. Sustainability, 14(5), 2952.

Mulyoutami, E., Mawesti, D., Triana, E., Purwanto, E., & Widayati, A. (2024). Towards a Sustainable Business Model for Rubber Agroforestry in Indonesia. World Agroforestry Centre.

Nugroho, H. Y. S. H., Sallata, M. K., Allo, M. K., Wahyuningrum, N., & Supangat, A. B. (2023). Incorporating Traditional Knowledge into Science-Based Sociotechnical Measures in Upper Watershed Management. Sustainability, 15(4), 3502.

Octavia, D., Suharti, S., Murniati, & Nugroho, H. Y. S. H. (2022). Mainstreaming Smart Agroforestry for Social Forestry Implementation to Support Sustainable Development Goals in Indonesia: A Review. Sustainability, 14(15), 9313.

Pambudi, A. S. (2020). The Development of Social Forestry in Indonesia. Journal of Indonesian Sustainable Development Policy, 1(1), 15–28.

Pangemanan, E. F., Saroinsong, F. B. (2025). Agroforestri Pekarangan: Biodiversitas, Ketahanan Pangan, Jasa Ekosistem. Yayasan Bina Lentera Insan. Manado. 147p.

Pangemanan, E. F., Kalangi, J. I., Saroinsong, F. B. (2025). Agroforestri Berbasis Kelapa. Yayasan Bina Lentera Insan. Manado. 123p.

Pangemanan, E. F., Kalangi, J. I., Saroinsong, F. B., & Nurmawan, W. (2025). Pelatihan Optimalisasi Area Kelapa dengan Pengembangan Kebun TOGA Mandiri di Desa Ongkaw Satu, Kecamatan Sinonsayang, Kabupaten Minahasa Selatan. Jurnal Lentera: Penelitian dan Pengabdian Masyarakat, 6(2), 64-68.

Rakatama, A., & Pandit, R. (2020). Reviewing Social Forestry Schemes in Indonesia: Opportunities and Challenges. Forest Policy and Economics, 114, 102052.

Rendra, P. P. R., Sulaksana, N., & Alam, B. Y. (2016). Optimalisasi pemanfaatan sistem agroforestri sebagai bentuk adaptasi dan mitigasi tanah longsor. Bulletin of Scientific Contribution, 14(2), 117-126.

Saroinsong, F. B. (2020). Supporting plant diversity and conservation through landscape planning: A case study in an agro-tourism landscape in Tampusu, North Sulawesi, Indonesia. Biodiversitas Journal of Biological Diversity, 21(4).

Saroinsong, F. B., Ismail, Y., Gravitiani, E., & Sumantra, K. 2021. Utilization of home gardens as a community empowerment-based edible landscape to combat stunting. IOP Conference Series: Earth and Environmental Science, 940(1), 012093.

Sukmawati, W., Maarif, M. S., & Arkeman, Y. (2014). Inovasi sistem agroforestry dalam meningkatkan produktivitas karet alam. Jurnal Teknik Industri, 4(1).

Supriadi, H., & Pranowo, D. (2016). Prospek Pengembangan Agroforestri Berbasis Kopi di Indonesia. Perspektif, 14(2), 135-150.

Titdoy, S., Thomas, A., Saroinsong, F. B., & Kainde, R. P. (2014, October). Sistem agroforestri di Desa Tolok Satu Kecamatan Tompaso Kabupaten Minahasa. In COCOS (Vol. 5, No. 2).