Plant Species Composition and Local Farmers' Perceptions of Agroforestry Practices: Initial Findings from Aceh and Java, Indonesia

Adisti Permatasari Putri Hartoyo[1,2*], *Leti* Sundawati[3], *Fitta* Setiajiati[3], and *Falah Rifqi* Amanullah[1]

[1]Department of Silviculture, Faculty of Forestry and Environment, Bogor Agricultural University (IPB University), IPB Dramaga Campus, Bogor Regency, 16680, Indonesia
[2]Environmental Research Center, Bogor Agricultural University (IPB University), IPB Dramaga Campus, Bogor Regency, 16680, Indonesia
[3]Department of Forest Management, Faculty of Forestry and Environment, Bogor Agricultural University (IPB University), IPB Dramaga Campus, Bogor Regency, 16680, Indonesia

Abstract. The local farmers have long implemented agroforestry systems, and many challenges are found in agroforestry practices. This study analyzed the plant species composition and local farmers' perceptions of agroforestry practices in Aceh and Java, Indonesia. We interviewed the local farmers and observed the species composition in the field. Most local farmers are in the 46-55-year-old age group (42%) with an elementary school education background (39%). Local farmers reported acquiring their agroforestry skills through self-experimentation. Most local farmers possess 2-5 years of experience. Only 29% of the farmers have participated in such groups or communities. Approximately 88% of local farmers have agrisilviculture as their preferred approach. They perceive their planted species' growth performance as in good condition (58%). The dominant tree species favored by local farmers are *Tectona grandis, Falcataria falcata, Swietenia macrophylla,* and *Durio zibethinus*. While in the realm of crops, the dominants are *Manihot esculenta*, *Ipomoea batatas*, *Musa paradisiaca*, and *Capsicum annum*. The main challenges faced by the local farmers are pest/disease attacks (43,9%), limited human resources availability (31,7%), and limited market (24,4%). The most needed in agroforestry practices are species selection (29,3%), cultivation techniques (24,4%), and irrigation systems (19,5%).

1 Introduction

In recent years, the concept of sustainable land use and natural resource management has gained significant attention as a crucial approach to addressing environmental degradation and biodiversity challenges in terms of sustainable landscape. Agroforestry is an innovative land management approach that involves intentionally integrating trees with crops, fishery, and/or livestock within a specific land area to optimize the ecological,

* Corresponding author: adistipermatasari@apps.ipb.ac.id

economic, and social benefits, as well as to create a harmonious, productive, and sustainable landscape [1-3]. Agroforestry is increasingly recognized for its ability to provide ecosystem services, environmental advantages, and economic resources within multifunctional operational landscapes. Agroforestry also holds particular significance for small-scale farmers, and its diverse product and service offerings underscore its multifunctional role within agroecosystems. The practice of agroforestry boasts a longstanding history across various global regions. In Indonesia, predominant agroforestry techniques utilized by farmers encompass home gardens, *tembawang, repong damar, huma, talun*, and so on that integrate with the local farmers' culture [4-6].

As the second-largest biodiversity, Indonesia faces deforestation and forest degradation issues [7]. The most significant environmental issue in Indonesia revolves around the degradation of its environment and the imminent threats faced by its ecological components. The diversity of plant life in both natural and human-altered ecosystems is decreasing over time and space, primarily due to human activities and various climatic factors [8]. A promising solution is the growing adoption of agroforestry, which presents a comprehensive approach to land use. This approach has the potential to directly enhance plant diversity while also addressing the loss and fragmentation of habitats. The importance of species diversity within agroforestry systems cannot be overstated, as it plays a pivotal role in driving both ecological and socio-economic benefits. Agroforestry systems offer a unique blend of ecological and agricultural components, enabling the cultivation of a wide array of plant species within a single, integrated landscape.

Local farmer involvement is one of the main actors in achieving sustainable landscape management. Local farmers have played an integral role in shaping and refining agroforestry practices over generations. Their indigenous knowledge, informed by years of observation and experimentation, has led to the development of unique management strategies that contribute to the resilience and sustainability of agroforestry systems. These practices often involve the deliberate selection and intercropping of plant species based on their complementary characteristics, such as nutrient cycling, shade tolerance, and growth patterns [15]. By studying the strategies employed by local farmers, we can uncover the underlying principles that govern species diversity in agroforestry systems and determine how these practices contribute to both ecological balance and livelihood improvement. This study delves into the initial findings of a study focused on plant species composition and agroforestry practices, specifically exploring practices among local farmers in Aceh and Java, Indonesia. This study analyzed plant species composition and local farmers' perceptions of agroforestry practices from Aceh and Java, Indonesia.

2 Method

2.1 Study Site

This study was carried out in 41 locations in Indonesia, namely Central Aceh, Bogor, Sukabumi, Banyumas, Pekalongan, Wonogiri, and Pati. Detail location is presented in Figure 1.

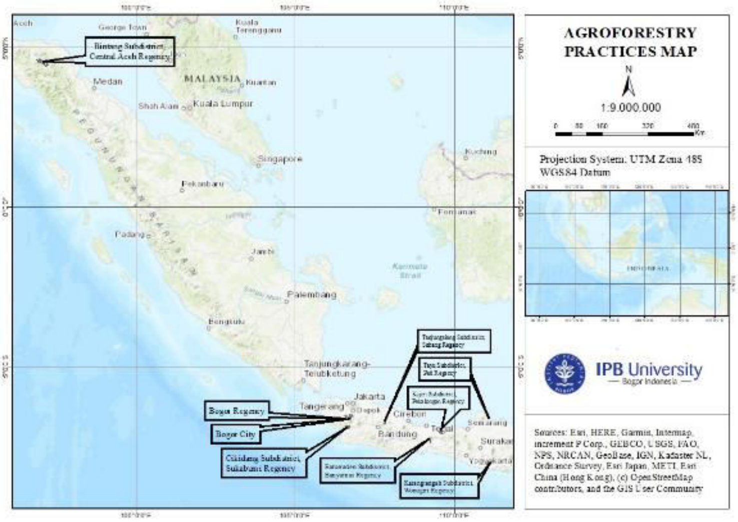

Fig. 1. Location of the study

2.2 Tools and Instruments

Tools used in this study were tally sheets, measuring tape, and camera. The instrument used was questionnaires to interview 41 farmers who had applied agroforestry practices.

2.3 Research Procedure

2.3.1 Interviewing the Local Farmers Related to the Management of Agroforestry Systems

We interviewed 41 local farmers using questionnaires about their identity, conditions of agroforestry sites, challenges faced by the local farmers, and their needs in managing agroforestry sites. The interview was conducted with the agroforestry farmers in each research location. The criteria of respondent is agroforestry farmer, the owner or the manager of the agroforestry system. After interviewing local farmers, we observed the composition of plant species in agroforestry systems.

2.3.2 Identifying Plant Species Composition

Identification of plant species composition was carried out by observing, identifying, and documenting the species in the field refer to Indra et al. [16]. We also adjusted the species composition by interviewing 41 local farmers.

3 Results

The results of interviews regarding farmer identity are shown in Figure 2, illustrating the distribution of age, educational background, duration/long time of agroforestry practices, and farmer involvement in the community. The conditions of the agroforestry sites are depicted in Figure 3 and Figure 4. The area of agroforestry land managed by each farmer can be seen in Figure 3. The agroforestry classification and farmers' perceptions of land conditions are shown in Figure 4. In detail, the species composition based on agroforestry classification is depicted in Table 1. The results of interviews regarding farmers' perceptions of the challenges they face and the need for implementing agroforestry practices are shown in Figure 5 and Figure 6.

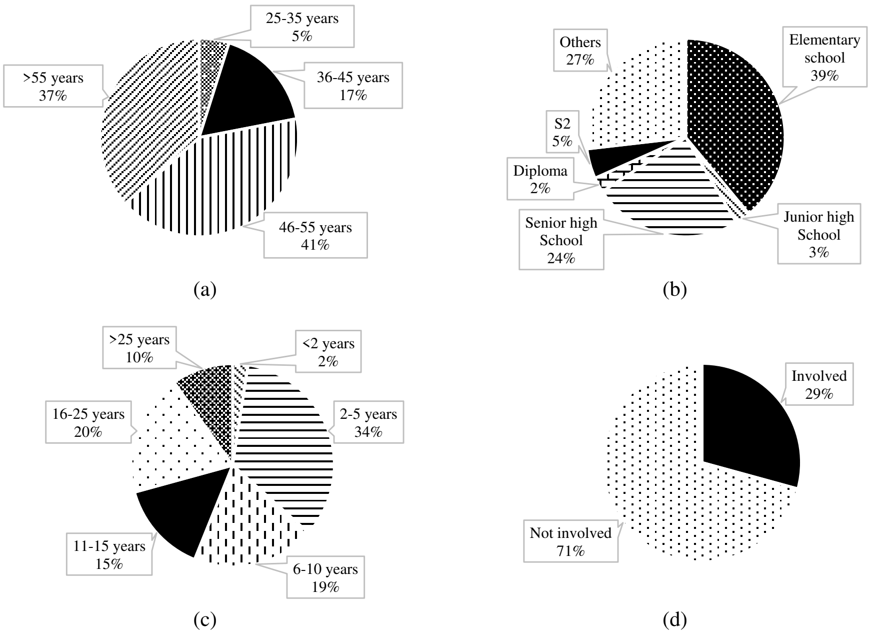

Fig. 2. Distribution of respondents' age (a), educational background (b), duration/long time of agroforestry practices (c), and their involvement in the farmer group of community (d)

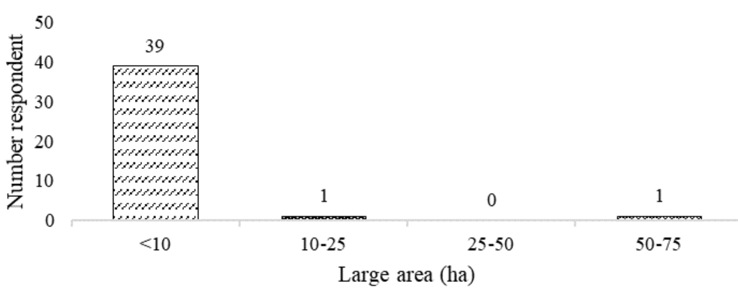

Fig. 3. The large cultivation area of the respondents

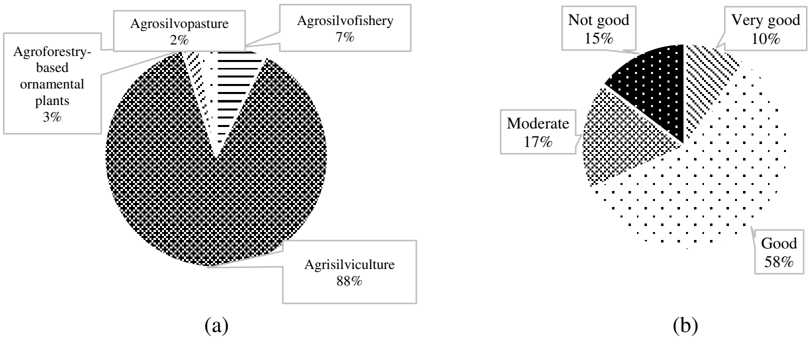

Fig. 4. Classification of agroforestry (a) and the perception of the respondents related to their plant species growth performance (b)

Table 1. Classification of agroforestry systems and its species composition

Plot	Classification	Species composition
1	Agrosilvofishery	Mango (*Mangifera indica*) + paddy (*Oryza sativa*), cucumber (*Cucumis sativus*), chili (*Capsicum annum*) + *nila* fish (*Oreochromis niloticus*)
2	Agrisilviculture	Umbrella tree (*Maesopsis eminii*), *sengon (Paraserianthes falcataria)*, *Mahoni* (*Swietenia macrophylla*) + *pohpohan (Pilea melastomoides),* chili (*Capsicum annum*)
3	Agrisilviculture	Teak (*Tectona grandis*) + chili (*Capsicum annum*), Maize (*Zea mays*), Cassava (*Manihot esculenta*)
4	Agrisilviculture	Nutmeg (*Myristica fragrans*) + chili (*Capsicum annum*), cassava (*Manihot esculenta*)
5	Agrisilviculture	*Sengon (Paraserianthes falcataria)*, *jabon (Neolamarckia cadamba)* + eggplant (*Solanum melongena*)
6	Agrosilvofishery	*Sengon (Paraserianthes falcataria), kemang (Mangifera kemanga), durian (Durio zibethinus)*, *kersen (Muntingia calabura)*, avocado (*Persea americana*), mango (*Mangifera indica*) + cassava (*Manihot esculenta*), maize (*Zea mays*), banana (*Musa paradisiaca*), peanut (*Arachis hypogaea*), catfish (*Clarias batrachus*)
7	Agrisilviculture	*Melinjo (Gnetum gnemon)*, star fruit (*Averrhoa carambola*), mangosteen (*Garcinia mangostana*), hairy fruit (*Nephelium lappaceum*), *lengkeng* (*Dimocarpus longan*) + cassava (*Manihot esculenta*), maize (*Zea mays*), banana (*Musa paradisiaca*), taro (*Colocasia esculenta*)
8	Agrosilvofishery	Teak (*Tectona grandis*) + lemongrass (*Cymbopogon citratus*), sweet potato (*Ipomoea batatas*), banana (*Musa paradisiaca*), chili (*Capsicum annum*), coconut (*Cocos nucifera*) + *nila* fish (*Oreochromis niloticus*), *bawal* fish (*Colossoma macropum*)
9	Agrisilviculture	Teak (*Tectona grandis*) + cassava (*Manihot esculenta*), peanut (*Arachis hypogaea*), chili (*Capsicum annum*)

Table 1. Classification of agroforestry systems and its species composition (continued)

Plot	Classification	Species composition
10	Agrisilviculture	Teak (*Tectona grandis*), *sengon (Paraserianthes falcataria)* + cassava (*Manihot esculenta*), peanut (*Arachis hypogaea*), banana (*Musa paradisiaca*), sweet potato (*Ipomoea batatas*), chili (*Capsicum annum*)
11	Agrisilviculture	Teak (*Tectona grandis*) + cucumber (*Cucumis sativus*), peanut (*Arachis hypogaea*)
12	Agrisilviculture	Teak (*Tectona grandis*), *mahoni* (*Swietenia macrophylla*), *sungkai (Peronema canescens)* + sweet potato (*Ipomoea batatas*)
13	Agrisilviculture	*Gamal (Gliricidia sepium),* guava *(Psidium guajava)*
14	Agrisilviculture	*Duku (Lansium domesticum)*, *durian (Durio zibethinus)* + clove (*Syzygium aromaticum*), coffee (*Coffea* sp.)
15	Agrisilviculture	Teak (*Tectona grandis*) + peanut (*Arachis hypogaea*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), chili (*Capsicum annum*), Lemongrass (*Cymbopogon citratus*)
16	Agrisilviculture	Teak (*Tectona grandis*), *durian* (*Durio zibethinus*), *mindi* (*Melia azedarach*), breadfruit (*Artocarpus altilis*) + cassava (*Manihot esculenta*), taro (*Colocasia esculenta*), coconut (*Cocos nucifera*), maize (*Zea mays*), papaya (*Carica papaya*), eggplant (*Solanum melongena*)
17	Agrisilviculture	Cassava (*Manihot esculenta*), teak (*Tectona grandis*), hairy fruit (*Nephelium lappaceum*), *jengkol (Archidendron pauciflorum)*, chili (*Capsicum annum*), banana (*Musa paradisiaca*), sweet potato (*Ipomoea batatas*)
18	Agrisilviculture	Teak (*Tectona grandis*) + Cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), bengkoang (*Pachyrhizus erosus*)
19	Agrisilviculture	Teak (*Tectona grandis*), *sengon (Paraserianthes falcataria)*, jackfruit (*Artocarpus heterophyllus*) + cassava (*Manihot esculenta*), lemongrass (*Cymbopogon citratus*)
20	Agrisilviculture	Teak (*Tectona grandis*) + long bean (*Vigna unguiculata*), maize (*Zea mays*)
21	Agrisilviculture	Teak (*Tectona grandis*), *sengon (Paraserianthes falcataria)* + cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*)
22	Agrisilviculture	Damar (*Agathis dammara*), puspa (*Schima wallichii*), nagasari (*Mesua ferrea*) + Coffee (*Coffea* sp.), *nilam (Pogostemon cablin)*, pineapple (*Ananas comosus*), cassava (*Manihot esculenta*), Maize (*Zea mays*)
23	Agrisilviculture	Teak (*Tectona grandis*) + long bean (*Vigna unguiculata*), sweet potato (*Ipomoea batatas*), maize (*Zea mays*)
24	Agrisilviculture	Rubber (*Hevea brasiliensis*), durian (*Durio zibethinus*) + Coffee (*Coffea* sp.), cocoa (*Theobroma cacao*), pepper (*Piper nigrum*), vanilla (*Vanilla planifolia*)
25	Agrisilviculture	Breadfruit (*Artocarpus altilis*) + oil palm (*Elaeis guineensis*)
26	Agroforestry-based ornamental plants	Iron tree (*Eusideroxylon zwageri*), agarwood (*Aquilaria malaccensis*), teak (*Tectona grandis*), ebony (*Diospyros celebica*) + ornamental plants (Monstera, Philodendron,

		Dieffenbachia)

Table 1. Classification of agroforestry systems and its species composition (continued)

Plot	Classification	Species composition
27	Agrisilviculture	Teak (*Tectona grandis*), orange (*Citrus sinensis*) + banana (*Musa paradisiaca*), chili (*Capsicum annum*)
28	Agrosilvopasture	*Sengon* (*Paraserianthes falcataria*), hairy fruit (*Nephelium lappaceum*) + banana (*Musa paradisiaca*), cassava (*Manihot esculenta*) + sheep (*Capra aegagrus hircus*)
29	Agrisilviculture	*Sengon (Paraserianthes falcataria)* + taro (*Colocasia esculenta*), chili (*Capsicum annum*), cassava (*Manihot esculenta*), banana (*Musa paradisiaca*), long bean (*Vigna unguiculata*)
30	Agrisilviculture	Teak (*Tectona grandis*) + cassava (*Manihot esculenta*)
31	Agrisilviculture	Teak (*Tectona grandis*), *sengon (Paraserianthes falcataria)* + sweet potato (*Ipomoea batatas*), jackfruit (*Artocarpus heterophyllus*)
32	Agrisilviculture	*Sengon (Paraserianthes falcataria)* + sweet potato (*Ipomoea batatas*), long bean (*Vigna unguiculata*), taro (*Colocasia esculenta*)
33	Agrisilviculture	*Sengon (Paraserianthes falcataria)* + pepper (*Piper nigrum*), ginger (*Zingiber officinale*), *porang* (*Amorphophallus muelleri*)
34	Agrisilviculture	*Mahoni (Swietenia macrophylla)*, *petai (Parkia speciosa)*, guava (*Psidium guajava*) + peanut (*Arachis hypogaea*), papaya (*Carica papaya*), banana (*Musa paradisiaca*)
35	Agrisilviculture	*Lamtoro (Leucaena leucocephala)*, avocado (*Persea americana*) + Gayo Coffe (*Coffea arabica)*, curcuma (*Curcuma longa*), chayote (*Sechium edule*), galangal (*Alpinia galanga*), lemongrass (*Cymbopogon citratus*)
36	Agrisilviculture	*Sengon (Paraserianthes falcataria)* + water spinach (*Ipomoea aquatica*), maize (*Zea mays*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*)
37	Agrisilviculture	Teak (*Tectona grandis*), *sengon (Paraserianthes falcataria)* + cassava (*Manihot esculenta*)
38	Agrisilviculture	*Sengon* (*Paraserianthes falcataria*), teak (*Tectona grandis*), bamboo (*Bambusa* sp.), *balsa* (*Ochroma pyramidale*) + banana (*Musa paradisiaca*), cardamom (*Lettaria cardamomum*), lemongrass (*Cymbopogon citratus*)
39	Agrisilviculture	Teak (*Tectona grandis*) + cassava (*Manihot esculenta*), maize (*Zea mays*)
40	Agrisilviculture	Teak (*Tectona grandis*), *mahoni* (*Swietenia macrophylla*), *mindi (Melia azedarach)* + aromatic ginger (*Kaempferia galanga*), cassava (*Manihot esculenta*), banana (*Musa paradisiaca*)
41	Agrisilviculture	Teak (*Tectona grandis*), *sengon (Paraserianthes falcataria)* + cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), peanut (*Arachis hypogaea*), cucumber (*Cucumis sativus*)

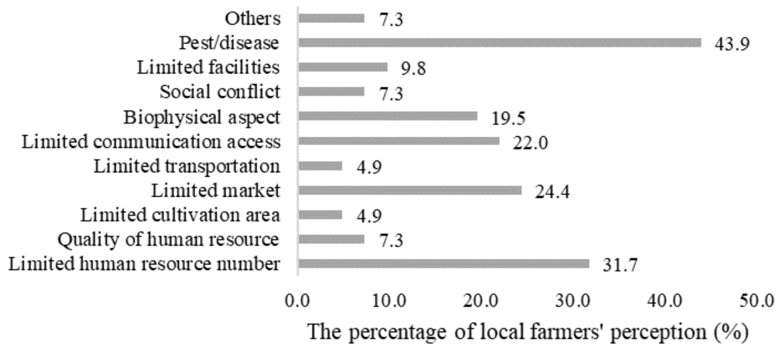

Fig. 5. Perception of the farmers related to the challenges in agroforestry practices

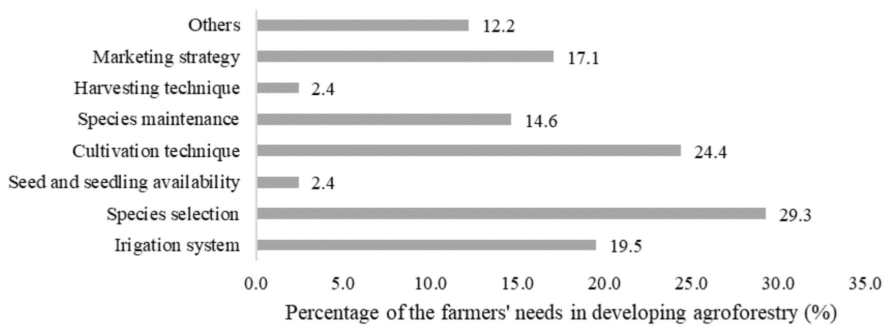

Fig. 6. The farmers’ needs for agroforestry management

4 Discussions

The implementation of agroforestry systems involves various dimensions, encompassing ecological, social, and economic considerations. As highlighted by Lahjie et al. [9], the social aspect of agroforestry practices can reduce conflicts between land managers, such as corporate entities, and the local communities' roles in forest management. On the economic aspect, the focus lies on evaluating the costs and benefits incurred by both land managers and the local communities neighboring the forest and agroforestry. Meanwhile, the ecological aspects encompass the evaluation of the forest's impact on crucial factors such as the hydrological cycle, soil fertility, and water sources. Harmonizing these multifaceted ecological, social, and economic aspects within the framework of forest and agroforestry holds the potential to reduce forest degradation and simultaneously enhance the quality of life and prosperity for the communities residing in the forest's vicinity.

Based on Figure 2a, most local farmers are in the 46-55-year-old age group (42%), closely followed by those aged more than 55 years old (37%). This indicates a significant representation of older individuals in the surveyed population. This concentration of respondents in the higher age brackets might imply that agroforestry practices are more commonly adopted by individuals with more life experience. Moving on to the educational background of the respondents as illustrated in Figure 2b, it is notable that a substantial portion of the participants have an elementary school education (39%). This finding suggests that agroforestry practices have appealed to a diverse range of educational backgrounds, with a significant number of participants having basic levels of formal education. This might indicate the practical and accessible nature of agroforestry, as it is adopted by individuals with varying educational attainment.

An interesting trend emerges in terms of how respondents acquired the knowledge to develop agroforestry practices. It is intriguing to observe that a significant number of local farmers reported acquiring their agroforestry skills through self-experimentation. This demonstrates a hands-on and experiential approach to learning, highlighting the practical nature of agroforestry development. This practical learning method may signify that agroforestry knowledge is often gained through trial and error, and this experiential learning could contribute to the innovation and adaptability of agroforestry techniques among practitioners. When considering the level of experience in agroforestry management, Figure 2c reveals that most local farmers possess 2-5 years of experience. This suggests that many individuals in the surveyed group are relatively new to agroforestry practices. This finding is essential in understanding the overall experience distribution, which might influence the level of innovation and advanced practices within the agroforestry community.

The data also highlights the role of farmers' groups or communities in improving the capabilities of respondents. However, it's worth noting that only 29% of the farmers have participated in such groups or communities, indicating that a considerable portion of respondents have not yet engaged with collective learning platforms. This suggests a potential avenue for further growth and development within the agroforestry community, as increased participation in these groups could enhance knowledge sharing and skill development.

In agroforestry systems, complex interactions occur among various components, spanning both ecological and economic aspects. There exist three primary categories of agroforestry systems, specifically: i) agrisilvicultural systems involve the intermingling of crops and trees, exemplified by practices like alley cropping or domestic gardens, ii) silvopastoral systems merge forestry with the grazing of domesticated animals, occurring in pastures, rangelands, or on-farm settings, and iii) agrosilvopastoral systems are the convergence of trees, animals, and crops that demonstrated by instances such as home gardens featuring animals and scattered trees in croplands designated for post-harvest grazing [2]. The scope of cultivation areas in Java holds consequential implications for land ownership rights within the domain of agroforestry. Based on Figure 3, a substantial majority of local farmers (95,1%) report cultivating areas less than 10 hectares. Among these local farmers, approximately 88% have embraced agrisilviculture as their preferred approach, followed by agrosilvofishery (7%) (Figure 4a). Notably, these local farmers perceive their planted species' growth performance in a good condition (58%) (Figure 4b).

In the realm of agroforestry systems, a common occurrence involves the cultivation of a diverse array of commodities. These commodities typically encompass forestry products alongside various crops, livestock feed, and firewood [10]. Local farming demonstrates distinct inclinations toward species selection, particularly driven by economic considerations. The predominant tree species favored by local farmers encompass teak (*Tectona grandis*) at approximately 56,1%, *sengon* (*Paraserianthes falcataria*) at around 36,6%, along with *mahoni* (*Swietenia macrophylla*) at around 9,8% and durian (*Durio zibethinus*) at around 9,8%. In the realm of crops, cassava (*Manihot esculenta*) takes the lead at about 48,8%, followed by sweet potato (*Ipomoea batatas*) at approximately 31,7%, banana (*Musa paradisiaca*) at 26,8%, and chili (*Capsicum annum*) also at 26,8%.

Agroforestry represents a compelling approach to land management, adept at both preserving and augmenting biodiversity diversity while also serving as carbon stocks [11-13]. The significance of agroforestry extends to its pivotal role in safeguarding biodiversity due to the presence of numerous species, whether native or introduced, within a seminatural ecosystem [14]. These show how agroforestry is not merely a land management technique, but a comprehensive strategy contributing to a sustainable and harmonious coexistence between agricultural activities and the environment. By acknowledging and harnessing its ecological benefits, agroforestry stands as a key player in the broader realm of conservation and sustainability efforts. Detailed classification of the agroforestry system and its species composition is presented in Table 1.

The adoption and advancement of sustainable agroforestry practices are pivotal in the pursuit of resilient and environmentally friendly agricultural systems. The findings of this study underscore the multifaceted challenges that farmers encounter in their quest to develop and maintain agroforestry systems. Predominantly, pest and disease attacks emerge as a major concern, constituting 43,9% of the reported challenges. This highlights the vulnerability of agroforestry systems to biotic stressors and the critical need for effective pest management strategies. Limited human resource availability, accounting for 31,7% of the reported challenges, poses a significant obstacle to the efficient implementation and management of these complex systems. This underscores the importance of capacity-building efforts and knowledge dissemination among farming communities engaged in agroforestry. Moreover, the study reveals that a restricted market for agroforestry products poses a considerable challenge, representing 24,4% of the reported concerns (Figure 5). This limitation emphasizes the necessity for targeted market access strategies and value chain development to ensure that farmers can benefit from their agroforestry endeavors economically.

Species selection emerges as a critical consideration, with 29,3% of respondents emphasizing its importance. This reflects the significance of identifying suitable tree and crop species that harmonize ecologically and functionally within the agroforestry system, contributing to enhanced productivity and ecological balance. Cultivation techniques, noted by 24,4% of the local farmers, also warrant substantial attention. Developing innovative and site-specific cultivation practices can optimize resource use efficiency, minimize environmental impact, and bolster overall system resilience. Furthermore, the study highlights the imperative of efficient irrigation systems, identified by 19,5% of local farmers (Figure 6). Water scarcity is a pervasive challenge in many agricultural regions, and devising water management strategies tailored to agroforestry systems can ensure sustainable water usage and mitigate potential conflicts over water resources.

The findings of this study provide critical insights into the challenges faced by farmers engaged in agroforestry practices, as well as their perspectives on strategies for overcoming these challenges. The integration of their recommendations into agroforestry policies and extension programs can facilitate the adoption and successful implementation of sustainable agroforestry systems. Moreover, future research endeavors could delve deeper into context-specific challenges and solutions, considering socio-economic factors, local ecological dynamics, and technological innovations that can further enhance the resilience and productivity of agroforestry practices.

5 Conclusion

Most local farmers are in the 46-55-year-old age group (42%), closely followed by those aged more than 55 years old (37%). The most dominant educational background of the local farmers is an elementary school education (39%). This finding suggests that agroforestry practices have appealed to a diverse range of educational backgrounds. Local farmers reported acquiring their agroforestry skills through self-experimentation. When considering the experience level in agroforestry management, most local farmers possess 2-5 years of experience. This suggests that many individuals in the surveyed group are relatively new to agroforestry practices. Additionally, only 29% of the farmers have participated in such groups or communities. This suggests a potential avenue for further growth and development within the agroforestry community, as increased participation in these groups could enhance knowledge sharing and skill development.

Approximately 88% of local farmers have agrisilviculture as their preferred approach, followed by agrosilvofishery (7%). They perceive their planted species' growth performance in good condition (58%). The predominant tree species favored by local farmers encompass teak (Tectona grandis) at approximately 56,1%, sengon (Falcataria falcata) at around 36,6%, along with mahoni (Swietenia macrophylla) at around 9,8% and durian (Durio zibethinus) at around 9,8%. In the realm of crops, cassava (Manihot esculenta) takes the lead at about 48,8%, followed by sweet potato (Ipomoea batatas) at approximately 31,7%, banana (Musa paradisiaca) at 26,8%, and chili (Capsicum annum) also at 26,8%. The main challenges faced by the local farmers are pest/disease attacks (43,9%), limited human resources availability (31,7%), and limited market (24,4%). Therefore, the most needed in agroforestry practices are species selection (29,3%), cultivation techniques (24,4%), and irrigation systems (19,5%).

References

1. M. Zhang, J. Liu, Does agroforestry correlate with the sustainability of agricultural landscapes? evidence from China's nationally important agricultural heritage systems, Sustainability. **14**, 7239 (2022)
2. FAO. Agroforestry. (2015) Available online: https://www.fao.org/forestry/agroforestry/80338/en (accessed on 21 August 2023)
3. D. Octavia, S. Suharti, I.W.S. Dharmawan, H.Y.S.H. Nugroho, B. Supriyanto, D. Rohadi, G.N. Njurumana, I. Yeny, A.Hani, N. Mindawati, Suratman, Y. Adalina, D. Prameswari, E.E.W. Hadi, S. Ekawati, Mainstreaming Smart Agroforestry for Social Forestry Implementation to Support Sustainable Development Goals in Indonesia: A Review, Sustainability. **14**, 9313 (2022)
4. D. Rohadi, T. Herawati, N. Firdaus, R. Maryani, P. Permadi, National strategy for agroforestry research in Indonesia 2013–2030 (Centre for Research and Development on Forest Productivity Improvement, Forestry Research and Development Agency, Bogor, 2013)
5. A.P.P Hartoyo, I.Z Siregar, Supriyanto, L.B. Prasetyo, I. Theilade, Biodiversity, carbon stocks and community monitoring in traditional agroforestry practices: preliminary results from two investigated villages in Berau, East Kalimantan, Procedia Environmental Sciences. **33**, 376 – 385 (2016)
6. A.P.P Hartoyo, Supriyanto, I.Z. Siregar, I. Theilade, L.B. Prasetyo, Agroforest diversity and ethnobotanical aspects in two villages of Berau, East Kalimantan, Indonesia, Biodiversitas **19**, 387-398 (2018)
7. Indrayaja et al., Tropical forest landscape restoration in Indonesia: a review, Land. **11**, 328 (2022)
8. M.G. Muluneh, Impact of climate change on biodiversity and food security: a global perspective—a review article, Muluneh Agric & Food Secur. **10**, 36 (2021)
9. R.M. Lahjie, B.D.A.S. Simarangkir, Z. Hasid, Analisis investasi lahan hutan dengan sistem agroforestri lanskap, Jurnal Hutan Tropis. **1**, 39-45 (2013)
10. A.B. Lahjie, Teknik Agroforestry, (UPN Veteran, Jakarta, 2001)

11. J. Shibu, B. Sougata, Agroforestry for biomass production and carbon sequestration: an overview, Agroforest Syst. **86**, 105-111 (2012)
12. P.K.R. Nair, D.N. Vimala, B.M. Kumar, M.S. Julia, Carbon Sequestration in Agroforestry Systems, Advances in Agronomy. 108 (2010)
13. A.P.P. Hartoyo, L.B. Prasetyo, I.Z. Siregar, Supriyanto, I. Theilade, U.J. Siregar, Carbon stock assessment using forest canopy density mapper in agroforestry land in Berau, East Kalimantan, Indonesia, Biodiversitas **20**, 1661-1676 (2019)
14. A. Atangana, D. Khas, S. Chang, A. Degrande, Tropical Agroforestry, (Springer, America Latin, 2014)
15. A.P.P. Hartoyo, L. Hutagalung, F. Kulsum, A. Sunkar, E.N. Herliyana, S. Hidayati, Species composition, structure, and management in gayo coffee-based agroforestry system: the case of Mude Nosar Village, Central Aceh Regency, Journal of Nat. Res. EnvMan. **13**, 37–48 (2022)
16. Indra G, Mukhtar E, Syamsuardi, Chairul, Mansyurdin. 2024. Plant species composition and diversity in traditional agroforestry landscapes on Siberut Island, West Sumatra, Indonesia, Biodiversitas **25**, 1412-033X (2024)