NASS
NAN YANG ACADEMY OF SCIENCES

Research on World Agricultural Economy
https://journals.nasspublishing.com/index.php/rwae

ARTICLE

Bridging Farmers' Perceptions and Preferences for Economic Sustainability: Developing an Agroforestry Prototype in Private Forests in Bogor Regency, Indonesia

Bahruni [1*] ***, Naifa Sa'diyya*** [2] ***, Fitta Setiajiati*** [1,3] ***, Soni Trison*** [1]

[1] *Department of Forest Management, Faculty of Forestry and Environment, IPB University, Academic Ring Road Campus IPB Dramaga, Bogor 16680, Indonesia*

[2] *Division of Sustainability, Lokadata Institute, Jl. Letjen S. Parman Kav. 77, West Jakarta 11410, Indonesia*

[3] *Laboratory of Forest Policy and Economics, Division of Natural Resource Economics, Graduate School of Agriculture, Kyoto University, Yoshida North Campus, Kyoto 606-8502, Japan*

ABSTRACT

The ASEAN nations and the Indonesian government prioritize sustainable development through programs on water, energy, food, conservation, and climate change mitigation. Developing agroforestry in private forests holds strategic potential to enhance sustainable forestry and strengthen rural economies. Farmers' perceptions and preferences regarding agroforestry management are crucial for improving program outcomes. This study aims to develop an agroforestry prototype in private forests by integrating farmer perceptions and preferences with financial considerations. In Situdaun Village, Bogor Regency, West Java, Indonesia, we collected data through interviews utilizing a questionnaire. Subsequently, we conducted an analysis using descriptive statistics, Likert scale relative frequencies, and a financial feasibility assessment. The study findings indicate that farmers' perceptions and preferences are appropriate for agroforestry development. The economic viability of this agroforestry model is essential for farmers' well-being and ecological sustainability. Agroforestry aligns with the land maximization ap-

*CORRESPONDING AUTHOR:
Bahruni, Department of Forest Management, Faculty of Forestry and Environment, IPB University, Academic Ring Road Campus IPB Dramaga, Bogor 16680, Indonesia; Email: bahruni@apps.ipb.ac.id

ARTICLE INFO
Received: 25 July 2025 | Revised: 31 July 2025 | Accepted: 17 August 2025 | Published Online: 28 August 2025
DOI: https://doi.org/10.36956/rwae.v6i4.2534

CITATION
Bahruni, Sa'diyya, N., Setiajiati, F., et al., 2025. Bridging Farmers' Perceptions and Preferences for Economic Sustainability: Developing an Agroforestry Prototype in Private Forests in Bogor Regency, Indonesia. Research on World Agricultural Economy. 6(4): 17–37. DOI: https://doi.org/10.36956/rwae.v6i4.2534

proach, enhancing the restoration of degraded land and forests, supplying bioenergy, and reducing GHG emissions. We recommend efficient extension services to enhance farmers' institutional capacity, strengthened by government programs and policies to address livelihood requirements, incentive schemes, human capital development, stakeholder engagement for implementing the agroforestry prototype, and downstream processes, alongside developing community-based land and forest rehabilitation initiatives.

Keywords: Agroforestry Prototype; Financial Feasibility; Land Maximization; Perceptions; Preferences

1. Introduction

Private forests, defined as forests on private land under individual or communal property rights, play an increasingly strategic role in addressing environmental and socioeconomic challenges in Indonesia. Small-scale farmer-owned private forests, or *'hutan rakyat'* in Indonesia, have been expanding quickly [1]. Private forests are becoming more critical in the management and governance of national forests in Java, where state forest property is scarce and community demand for land is high [2, 3]. The situation in Bogor Regency is particularly noteworthy: the quantity of private forest increased significantly by 21,188.19 hectares from 2010 to 2020, reaching 33,084.91 hectares in 2020 [4].

The ASEAN Food, Agriculture and Forestry (FAF) Sector's Vision and Strategic Plan 2016-2030 emphasizes the importance of sustainable forest management within the ASEAN region. As the world's third-largest tropical forest area, ASEAN prioritizes addressing global environmental issues. The region's strategies incorporate socioeconomic and cultural factors at the landscape level, ensuring that the needs of present and future generations are met while advancing broader sustainable development goals. One of the key strategic thrusts of this policy framework is to increase resilience to climate change, natural disasters, and other shocks [5–8].

The government of Indonesia is currently implementing 17 national priority programs that encompass strategic objectives, including food, water, and energy self-sufficiency, alongside environmental conservation, with a target of achieving net-zero emissions. Within this policy framework, agroforestry holds significant potential to contribute to the achievement of these goals by enhancing food production, increasing household income, and strengthening adaptation to climate variability. In Kenya, during drought conditions, agroforestry farmers reported a 25% increase in food security compared with those involved in conventional farming systems [9]. Agroforestry is a land-use system commonly employed by numerous private forest proprietors in Java [10], facilitating the integration of timber, horticultural crops, and multipurpose tree species (MPTS) within a unified spatial and temporal framework [11] to increase smallholder production for augmented social, economic, and environmental advantages [12].

Compared with other regions, private forest cultivation in Java is characterized by greater intensification, diversification, and farmer autonomy [2]. The development of agroforestry in private forests in Bogor Regency, as devised by government programs, highlights its potential for advancing sustainable forestry development, particularly in enhancing rural private economies. It is part of the agroforestry private forest development scheme of the Bogor Forestry Service Branch (CDK Region I, Bogor Regency). However, despite their potential, agroforestry systems on private lands frequently suffer from implementation gaps, stemming primarily from top-down program designs that marginalize farmers' voices in key decisions such as species selection and cropping configuration [13–15].

On the basis of field observations in 2023, Situdaun Village in Tenjolaya Subdistrict exemplifies tenant farmers using informal agreements to administer segments of privately owned forests collectively. Landowners grant access without rental fees, and farmers are expected to participate actively in the upkeep of MPTS components and timber. From random combinations to alley cropping, spatial arrangements are often tailored to specific practices, species preferences, and farmers' knowledge. The government (CDK Region I) is the primary source of seeds, but differences between the species offered and those that are preferred often result in poor adoption, less care, and even neglect of the planted species, which lowers survival rates and reduces the effectiveness of agroforestry [16, 17]. The type of crops selected by farmers is essential for effective agroforestry land management. In addition, selecting cropping patterns is one of the strategies for regulating the success rate of land management. Deriving insight into farmers' perceptions of and preferences for agroforestry is essential for identifying systems with the highest potential for adoption, thus guiding the success of rural development projects [18].

The disjunction between governmental interventions and farmer autonomy illustrates a recurring deficiency in community forestry initiatives, wherein inadequate consideration of farmers' views and preferences undermines long-term sustainability [19, 20]. Farmers' knowledge systems, livelihood goals, and cultural valuations of specific species are seldom incorporated into agroforestry design, despite substantial evidence indicating that participatory approaches increase adoption rates, ecological resilience, and economic returns [21, 22]. Moreover, the efficacy of agroforestry depends not only on biophysical compatibility but also on socioeconomic viability, as farmers' perspectives influence land valuation, species prioritization, and the allocation of management resources [23]. Although the issue of private forest tenure has been extensively studied [24], insights into farmers' perceptions of and preferences for agroforestry systems at the farm level remain notably limited [25–27]. Addressing this gap requires recognizing the role of small-scale private forest owners in analyses and policy frameworks [28]. This research revealed a strong demand among respondents in decision-making related to forest management. Strengthening stakeholders' engagement across sectors and governance levels is essential to building inclusive coalitions that support long-term sustainability and transformative change [29]. Participatory approaches incorporating local knowledge enhance the legitimacy of forest governance interventions and improve compliance and effectiveness by aligning decisions with community-specific needs and priorities [30]. Therefore, comprehending farmers' cognitive and economic rationalities is essential for designing ecologically sustainable, financially feasible, and socially acceptable agroforestry prototypes. This involvement will increase the incentive to optimize their resources for the effective implementation of agroforestry.

This study aims to fill this significant gap by examining the attitudes and desires of private forest farmers in Situdaun Village, Bogor Regency. The objectives are: (1) to examine farmers' perceptions of agroforestry and its management in privately owned forestlands; (2) to identify tree and crop species that correspond with farmers' preferences and local ecological conditions; and (3) to create financially viable agroforestry model prototypes that align with farmers' decision-making processes. On the basis of these findings, this research highlights the role of farmers in the development of prototypes for agroforestry, which we propose can inform recommendations for the design of government programs in this area. Programs were designed to integrate farmers' perceptions and preferences, improve adoption and ensure sustainable agroforestry management. This approach promotes more practical, adaptable, and sustainable approaches to private forest governance in Indonesia.

2. Materials and Methods

2.1. Study Area

This study was conducted in one of the agroforestry-based private forests in Situdaun Village, Bogor Regency, West Java Province, Indonesia, designated as a target area for advancing community-based agroforestry by CDK Region 1, Bogor Regency. It is located at 106°42'32" East longitude, 6°37'21" South latitude with elevations ranging from 175–1500 meters above sea level (ASL) (**Figure 1**). The topography of Situdaun Village ranges from plains to steep hills on the southern slopes of Mount Halimun Salak. The district receives an average rainfall of 2,500 mm/year and an average temperature of 25–26°C. Covering an area of about 3.29 km^2 constitutes 14.53% of the total area of Tenjolaya District. Situdaun has an estimated population of 10,570 people [31]. The site was intentionally chosen for its role as a pilot area in advancing private forest agroforestry systems and the notable existence of active farmer collectives engaged in integrated forest-horticulture production. The socioecological environment of Situdaun, marked by informal land-sharing agreements and significant farmer involvement in timber and crop production, presents an exemplary model for examining local agroforestry dynamics rooted in practical application.

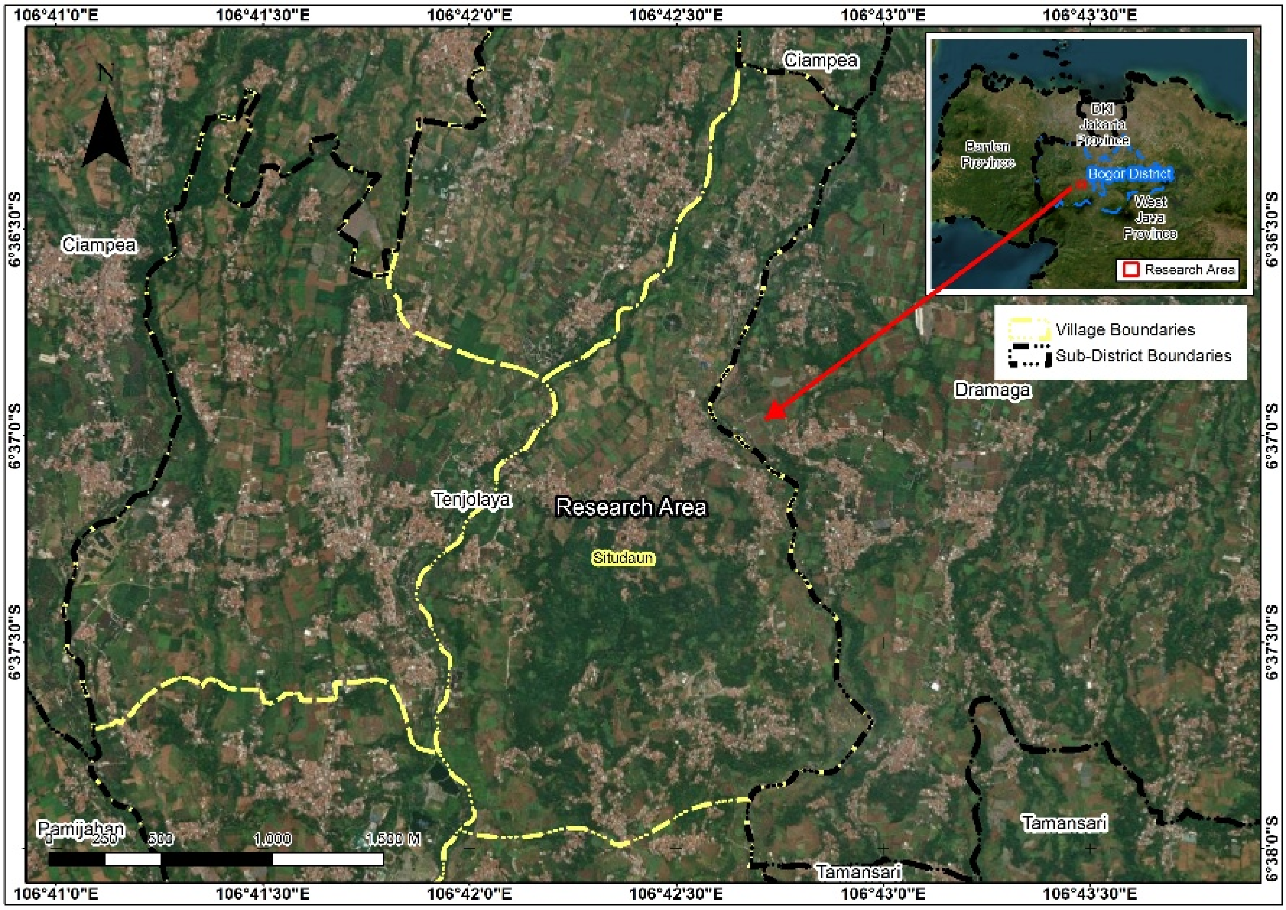

Figure 1. Study Area in Situdaun Village, West Java.

Sources: Esri Basemap and BIG - Badan Informasi Geospasial 2023.

2.2. Methodology

The research methodology is summarized in **Figure 2**, which presents a research framework.

2.3. Data Collection and Analysis

2.3.1. Data Collection

The research employed a mixed-methods framework, incorporating secondary sources while emphasizing primary data collection. To obtain primary data, we conducted structured interviews with private forest farmers. Direct interviews were conducted from June to September 2023. A total of 30 private forest farmers involved in agroforestry management within the study area were selected through a census method. The census is appropriate for small, well-defined populations where complete enumeration enhances statistical reliability and local significance [32]. The respondents comprised 23 Tunas Lestari farmer group members and seven tenant farmers, thus representing the full spectrum of farmer typologies in the study area. In each interview, the interviewer visited respondents at their home or private forest to gather data on agroforestry management practices. The questionnaire aimed to assess farmers' perceptions of agroforestry management within four main subsystems of private forest management. Each indicator was assessed using a five-point Likert scale widely recognized for measuring perceptions [33, 34]. The details of the Likert scale are presented in **Table 1**.

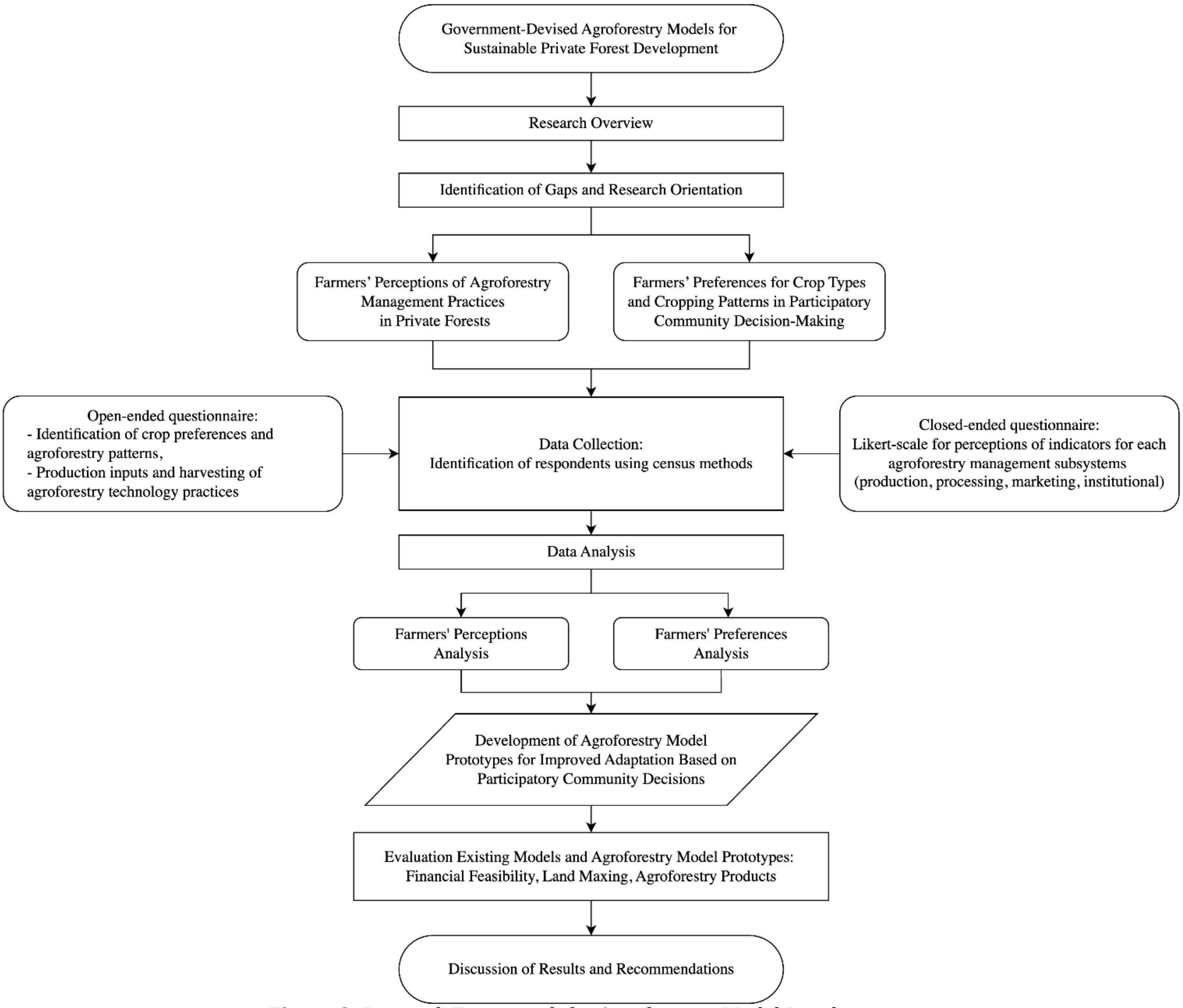

Figure 2. Research Framework for Agroforestry Model Development.

Table 1. Likert Scale of Agroforestry Management Assessment.

Respondent's Responses	Likert Scale	Description
Strongly Disagree	1	Strong disagreement with the condition of the assessed indicator, because the actual condition is deplorable/ very weak/ very low/ significantly underdeveloped compared to expectations.
Disagree	2	Disagreement with the condition of the assessed indicator is due to the actual condition being slightly poor/ slightly weak/ slightly low/ somewhat underdeveloped compared to expectations.
Neither	3	Moderate or enough position toward the condition of the assessed indicator, because the actual condition is acceptable and generally meets expectations, although it has not shown much progress/ improvement.
Agree	4	Agreement with the condition of the indicator being assessed, because the actual condition meets expectations or desired standards.
Strongly Agree	5	Strong agreement with the condition of the indicator being assessed, because the actual condition is excellent/ highly developed/ fully aligned with expectations/ desired outcomes.

We subsequently examined government papers, scientific literature, and institutional databases to gather secondary data. Interviews using Likert scale questionnaires to private forest farmers were deployed through closed-ended questionnaires to get perception data, particularly indicators within each of the subsystems of private forest management. Open-ended questionnaires to explore their preferences for agroforestry practices, rating score of desired species plants, and cropping pattern. Researchers conducted field observations to examine the overall conditions of their farming practices and identify various agricultural methods and their components, including tree crop components, and the species of trees and shrubs grown in fields[35].

2.3.2. Demographic Characteristics of Respondents

The demographic characteristics of the respondents are summarized in **Table 2**. These include key variables such as gender, age distribution, primary occupation, education, and income range.

Table 2. Demographic Characteristics of Respondents.

Category	Demographic Profile	Frequency	Percentage (%)
Gender	Male	30	100.00
Age	$\leq$ 40 years	3	10.00
	41–55 years	16	53.33
	56–70 years	10	33.33
	$\geq$ 71 years	1	3.33
Main Occupation	Private Forests Farmers	20	66.66
	Labor	8	26.67
	Entrepreneurship	2	6.67
Education Level	Not Pursued Formal Education	5	16.67
	Elementary School	21	70.00
	Junior High School	4	13.33
Annual Income	$<$ \$278	1	3.33
	\$278–\$700	4	13.33
	\$701–\$1,400	11	36.67
	\$1,401–\$2,500	5	16.67
	\$2,501–\$4,000	7	23.33
	$>$ \$4,000	2	6.67

Most respondents were engaged members of farmer group institutions, and this cohort exhibited more nuanced opinions, especially for the processing and institutional subsystems. It aligns with the findings of Sukwika[36], who identified that group affiliation enhances information accessibility, strengthens social capital, and facilitates the adoption of innovations.

Most forest farmer respondents (53.33%) were between 41 and 55 years old, which is typically associated with the workforce demographic. This group demonstrated the most positive opinions for production and marketing subsystems, presumably owing to their cognitive and physical abilities to adopt new methods[37]. This suggests that forthcoming interventions focus on this age demographic as pivotal change agents.

Most farmers had only primary to secondary education. Despite relatively low levels of formal education, this was frequently counterbalanced by practical knowledge and sustained engagement in land-based livelihoods. Rahut[38] revealed analogous findings, indicating that limited formal education seldom impedes practical proficiency in agroforestry management in subsistence systems. Different studies have shown that socio-economic characteristics substantially influence farmers' adoption behavior regarding new practices[39]. The predominant occupation among survey respondents was farming, especially those who worked in agroforestry systems. These people gave more complicated answers on Likert scales, which indicates they had stronger emotional and financial ties to their land-use systems. Farmers relying heavily on agroforestry are usually more open to changes that bring long-term ecological and economic stability [22].

2.3.3. Analysis of Farmers' Perceptions of Agroforestry Management

The quantitative data were coded and analyzed via statistical software. Quantitative descriptive analysis methods have been used to describe respondents' characteristics via survey responses and to support the literature. The technique applied was frequency distribution. The farmer characteristics analyzed included membership in agricultural farmer groups, age group, level of education, primary occupation, and annual income. This study analyzes farmers' perceptions of agroforestry management via the Likert scale score perception analysis equation and simple statistical analysis to identify the mode or the most frequently selected Likert scale number from the responses of all respondents, utilizing a five-point Likert scale. This analysis was used to analyze farmers' perceptions of agroforestry management, which includes four subsystems of private forest management (production, processing, marketing, and institutional subsystems) according to Hardjanto [40]. The Likert scale formula is as follows:

$$\text{TS} = \sum_{i=1}^{n} P_n \tag{1}$$

where:

TS = Total score

P_n = Likert scale number options

$$\text{PS (\%)} = \frac{TS}{Y x\, n} \times 100 \tag{2}$$

where:

PS = Percentage of respondents' perception score

Y = Maximum or highest score on the Likert scale

n = Number of respondents

The score interval determination categories (**Table 3** used in this research are as follows:

$$\text{Score interval (\%)} = \frac{PS_{max} - PS_{min}}{Number\ of\ Category} \tag{3}$$

where:

PS_{max} = Percentage of maximum perception score ($PS_{max} = 100$)

PS_{min} = Percentage of minimum perception score ($PS_{min} = 20$)

Table 3. Score Interpretation Categories.

Interval	Categories
20%–35.9%	Very Poor
36%–51.9%	Poor
52%–67.9%	Moderate
68%–83.9%	Good
84%–100%	Excellent

2.3.4. Analysis of Farmers' Preferences on Agroforestry Management

The farmers' preferences for crop and cropping patterns were analyzed via descriptive statistical analysis, i.e., identifying the mode or type of cropping. The crop types and patterns most frequently selected by all farmers were then used to develop recommended crop combinations for the agroforestry prototype.

2.3.5. Financial Feasibility Analysis of Agroforestry Model Prototype

The recommendations of the proposed agroforestry model prototype are determined by forest farmers' perceptions and preferences in selecting crop types, planting patterns, and cultivation techniques. This analysis was conducted to determine and compare the feasibility of land management for each agroforestry model on the basis of existing patterns and farmer preferences, which were designed as prototypes of agroforestry models. The agroforestry model prototype must meet the criteria of investment feasibility and be superior to existing models. The criteria used include the Net Present Value (NPV), Benefit Cost Ratio (BCR), and Internal Rate of Return (IRR), as presented in **Table 4**. The recommended agroforestry private forest business prototype is feasible if NPV > 0, BCR > 1, and IRR > i [41, 42]. The financial feasibility analysis of the agroforestry model in the private forest, Situdaun Village, is based on the following assumptions:

(1) the discount factor (DF) is 6% annually, following the Micro Credit Program capital (Kredit Usaha Rakyat/KUR) of Bank BRI on August 2023; (2) the capital source is entirely self-funded (USD/ha/year); (3) the financial feasibility is assessed by comparing the existing and prototype model with an area of 1 hectare and the business period is 20 years; (4) the expense incurred for obtaining or leasing land is not factored as the land is owned; (5) inflow and outflow prices portrayed are based on constant prices prevailing during the data collection; (6) the economy of the country remained stable during the analysis period; and (7) all monetary values were converted from IDR to USD using an exchange rate of USD 1 = IDR 15,241 based on www.ExchangeRate.org in 2023.

Table 4. Indicators of Financial Feasibility Analysis.

Indicators	Formula	Decision criteria
NPV	$NPV = \sum_{t=1}^{n} \frac{(Bt - Ct)}{(1+i)^t}$	$NPV > 0$
BCR	$BCR = \frac{\sum_{t=1}^{n} \frac{Bt}{(1+i)^t}}{\sum_{t=1}^{n} \frac{Ct}{(1+i)^t}}$	$BCR > 1$
IRR	$IRR = (i_2 - i_1)\left(\frac{NPV_1}{NPV_1 - NPV_2}\right) + i_1$	$IRR > i$

Note: Bt = Gross farmer revenue in year-t, Ct = Gross farming costs in year-t, n = Economic life of the business, t = Production period, i = Prevailing discount rate.

3. Results

3.1. Farmers' Perceptions on Agroforestry Private Forest Management

It is imperative to comprehend farmers' perceptions, attitudes, and preferences to develop and manage agroforestry through a holistic approach [39, 43]. The farmers' perceptions were analyzed within four principal subsystems: production, processing, marketing, and institutions [40]. **Figure 3** illustrates that the production subsystem had the highest perception score (75.1%), followed by marketing (72.5%), which falls in the good category. The processing (59.6%) and institutional (63.8%) components were in the "moderate" range, or in the fair category.

Figure 4 displays the results of the forest farmers' perception analysis via relative frequency for each Likert scale to identify all the responses of the respondents about agroforestry management in the study area.

Farmers' perceptions of private forest management are shaped by their practical experience and the knowledge they receive. This knowledge is often transmitted across generations and embedded in local cultural traditions. **Table 5** briefly presents the indicators used to analyze forest farmers' perceptions in the study area.

Figure 3. Likert Scale Frequency of Forest Farmers' Perceptions of Agroforestry Management System in the Study Area.

Figure 4. Likert Scale Category of Forest Farmers' Perceptions of Private Forest Management in The Study Area.

Table 5. Farmers' Perceptions of Agroforestry Private Forest Management in The Study Area.

No.	Indicators	Score (%)	Average (%)	Categories
Production Subsystem				
1	Reduced intensity of pests and diseases in crops due to agroforestry	64.7	75.1	Good
2	Increased profitability with the combination of forestry woods and fruit crops at appropriate spaces	74.0		
3	Enhanced management efficiency through the plant at regular intervals	73.3		
4	Increased benefits for environmental sustainability with the number of forestry wood plant combinations	82.7		
5	Suitability of land conditions for the selection of crop types	69.3		
6	Sufficient water storage capacity to sustain agroforestry systems	72.0		
7	Greater profits in agroforestry patterns compared to monoculture	84.7		
8	Suitability of plant spacing	81.3		
9	Selective seed selection to ensure quality	62.0		
10	Ease of planting and maintaining crops within agroforestry systems	86.7		
Processing Subsystem				
1	Farmers' ability to process agroforestry commodity products	44.7	59.6	Moderate
2	Facilities and supporting facilities for production processing	53.3		
3	Availability of labor for processing activities	70.7		
4	Interest of local communities in agroforestry processing activities	71.3		
5	Existing Partner support (e.g., cooperatives, NGOs, private sector)	52.7		
6	Raw material supply capacity for processing activities	64.7		
Marketing Subsystem				
1	Marketing ease	83.3	72.5	Good
2	Ease of access to market information	82.7		
3	The strength of the farmer's position determining the sales price	56.0		
4	Agroforestry products for commercial farming	63.3		
5	Agroforestry products for subsistence farming	77.3		

Table 5. *Cont.*

No.	Indicators	Score (%)	Average (%)	Categories
Institutional Subsystem				
1	The role of farmer groups in agroforestry management	60.0	63.8	Moderate
2	Extension's role in developing agroforestry management skills	56.7		
3	Farmers developing private forests based on their motivation	76.0		
4	The impact of community leaders' or fellow farmers' recommendations on agroforestry management	70.0		
5	The government assistance for agroforestry management	61.3		
6	Extension materials and farmer information effectiveness	58.7		

Note: The Likert scale scores can be interpreted as follows: 20%–35.9% indicates very poor, 36%–51.9% indicates poor, 52%–67.9% indicates moderate (fair), 68%–83.9% indicates good, and 84%–100% indicates very good.

3.2. Farmers' Preferences on Agroforestry Private Forest Management

The types of plants currently found in the study area are presented in **Table 6**, which includes forestry wood species, multipurpose tree species (MPTS), horticultural, and food crops.

The selected species' preferences for agroforestry prototypes with dominant and farmer-controlled criteria. Economic considerations include demand, price, ease of marketing, mastery of agroforestry technology, and environmental factors, including growth suitability. **Table 7** shows the selected species' preferences for agroforestry prototypes with dominant and farmer-controlled criteria.

Table 6. Types of Existing Plants in Agroforestry Private Forests in The Study Area.

Existing Plant Types			
Forestry Wood Plants	**MPTS**	**Horticulture**	**Crops**
Pinus merkusii (Pinus) *Swietenia macrophylla* (Mahogany) *Falcataria moluccana* (Sengon) *Maeosopsis eminii* (African Wood) *Terminalia mantaly* (Ketapang Kencana) *Sandoricum koetjape* (Kecapi) *Araucaria heterophylla* (Norfolk spruce) *Ficus benjamina* (Ficus) *Melaleuca cajuputi* (Eucalyptus) *Casuarina equisetifolia* (Casuarina) *Schima wallichii* (Puspa)	*Persea americana* (Avocado) *Artocarpus heterophyllus* (Jackfruit) *Psidium guajava* (Crystal guava) *Myristica fragrans* (Nutmeg) *Parkia speciosa* (Petai) *Archidendron pauciflorum* (Djenkol tree) *Nephelium lappaceum* (Rambutan) *Syzygium aromaticum* (Clove)	*Vigna unguiculata* ssp. *sesquipedalis* (Long Beans) *Capsicum frutescens* (Chili) *Mesonapalustris* (Black Cincau)	*Manihot esculenta* (Cassava) *Ipomoea batatas* (Potato)

Table 7. Farmers' Preferences For The Types of Potential Plants Cultivated By Farmers in The Study Area.

Forestry Wood Plants	MPTS	Crops
Falcataria moluccana (Sengon) *Swietenia macrophylla* (Mahogany) *Maeosopsis eminii* (African Wood)	*Persea americana* (Avocado)	*Vigna unguiculata* ssp. *sesquipedalis* (Long beans) *Manihot esculenta* (Cassava)

There was also a significant difference between the current land cover (**Table 6**) and the species preferred by people (**Figure 5**). This suggests that the ecological and economic potential is not fully used. Even though high-value horticultural and spice species are available locally, people do not use them because they do not know how to cultivate them or cannot access the market.

Cropping patterns in the Situdaun private forest are generally in the form of random mix patterns and block patterns (trees along borders). However, with respect to agroforestry patterns, most farmers (63.33%) choose alley-cropping (**Table 8**). Farmers preferred this method since it was easy to maintain and saved their time.

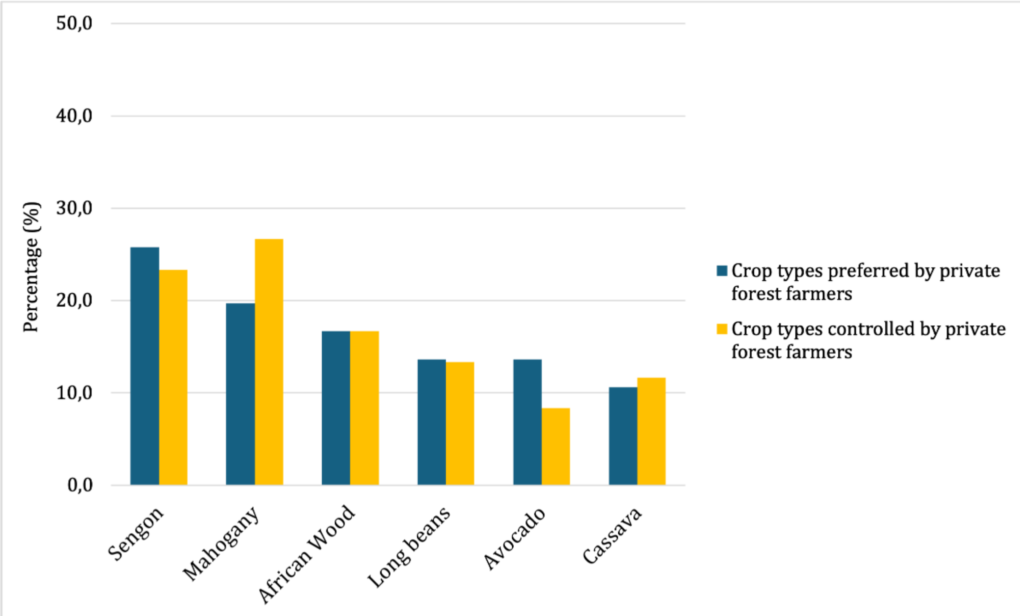

Figure 5. Selected Species Preferred and Controlled By Farmers.

Table 8. Preferences for Agroforestry Planting Patterns in Private Forest, Situdaun Village.

No.	Cropping Patterns	Respondents	
		Frequency	Percentage (%)
1	Alley Cropping	19	63.33
2	Trees Along Borders	2	6.67
3	Random Mixture	9	30.00
Amount		30	100

3.3. Financial Feasibility

Farmers generally use agroforestry technology in their forests to produce various crops for their daily needs. The types of crops and planting patterns they prefer form the basis for their decisions on which agroforestry prototypes to develop. High ratings in the production and marketing subsystem categories indicate that farmers have mastered the technology and information necessary for cultivating and marketing agroforestry products. Two contemporary agroforestry configurations—Existing Model I (Pine, Long Bean, Cassava in a Trees Along Borders system) and Existing Model II (Ketapang Kencana, Clove, Mahogany, Puspa, Rambutan, Avocado, Cassava Random Mixture system) are described. Two agroforestry prototypes were formulated according to farmers' articulated preferences and the ecological principles of Alley Cropping. The differences in the plant types in Prototype Agroforestry Model I include Mahogany, Sengon, Avocado, Long Bean, and Cassava; Prototype II includes Mahogany, African Wood, Avocado, Long Bean, and Cassava (**Figure 6**).

All the models meet the financial feasibility criteria, producing positive Net Present Value (NPV), a BCR greater than one, and an IRR greater than the Minimum Attractive Rate of Return (MARR), confirming their economic viability over 20 years, as shown in **Table 9**.

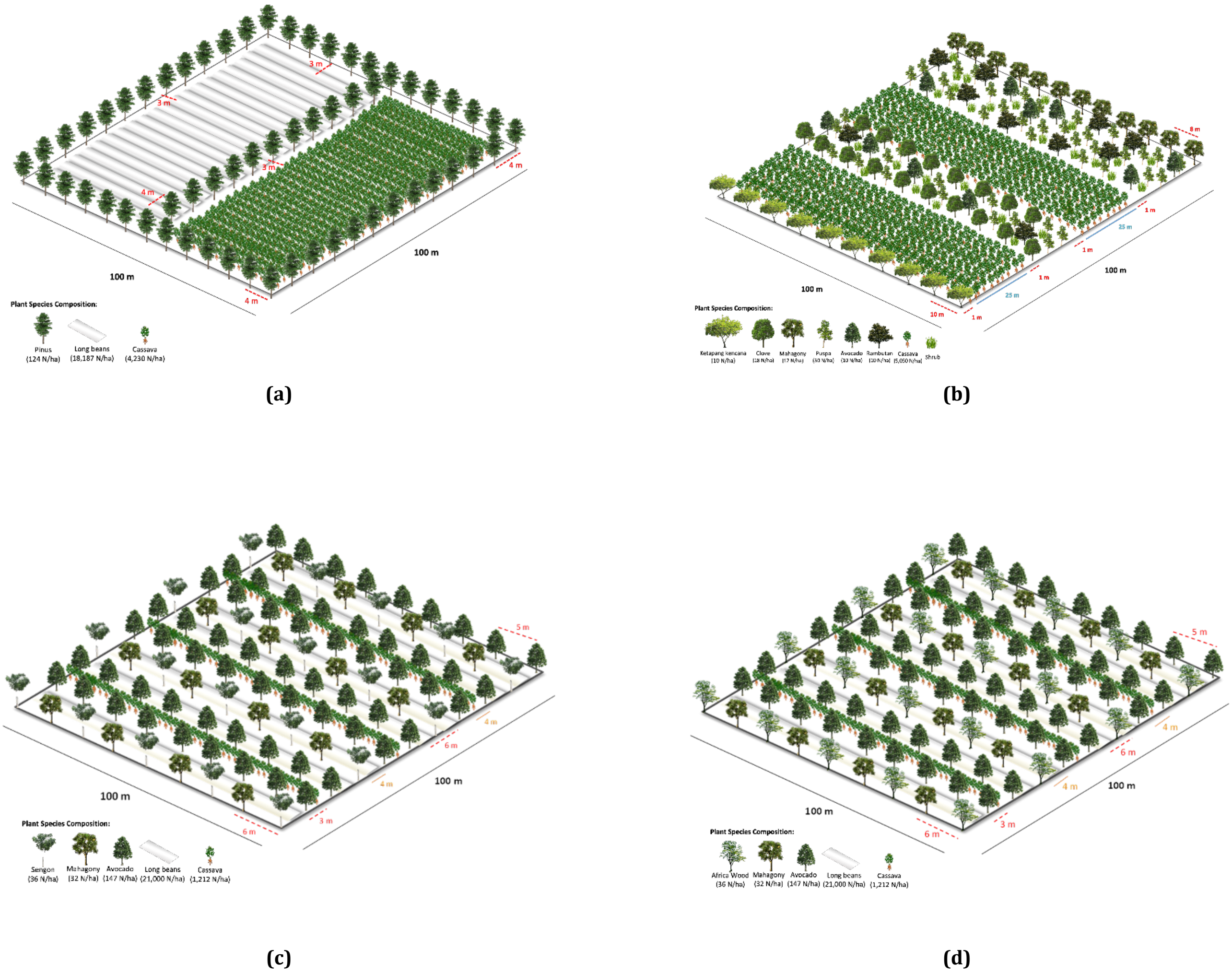

Figure 6. Agroforestry Model. (**a**) Existing Model I; (**b**) Existing Model II; (**c**) Prototype An Agroforestry Model I; (**d**) Prototype An Agroforestry Model II.

Table 9. Financial Analysis Results for The Agroforestry Model in The Situdaun Village Private Forest Over A 20-Year Period.

Financial Feasibility Criteria	Existing Model		Preference Model Prototype	
	I	II	I	II
NPV (USD/ha)	7,143,619	7,750,164	45,759,436	45,475,550
BCR	1.48	2.11	1.87	1.87
IRR (%)	59.30	28.14	39.31	38.99

4. Discussion

4.1. Farmers' Perceptions on Agroforestry Private Forest Management

Farmers, as key members of private forest farmer groups, play a critical role in decision-making and the implementation of activities related to private forest utilization [44]. Farmers' perceptions of private forest management are influenced by their experiences and information. Heterogeneity in farmers' knowledge, skill sets, and risk perceptions contributes to differentiated land management practices, as each farmer applies different strategies based on their understanding and experience [45]. The strong perception of the production subsystem indicates that farmers are aware of the real benefits of agroforestry, such as controlling pests, having more than one source of income, and making the best use of resources [46].

The low grade of the processing subsystem indicates that few farmers are engaging in value-added activities. Despite farmers having substantial access to raw materials (64.7%), they engage less in postharvest processing, indicating a lack of vertical integration within agroforestry value chains. Leakey [11] stressed that agroforestry systems work best when both upstream production and downstream processing and market readiness are good.

However, in the good category, marketing is still a challenge. The marketing subsystem comprises the marketing model, market structure, behavior, and price determination. Most farmers are price takers with a low bargaining position because they have uneven connections with middle traders, which are generally based on informal credit-debt agreements. It is a classic example of an oligopsonistic market structure, which always disadvantages smallholders [47]. Farmers need more bargaining power, and institutional innovation, such as farmer cooperatives or market information platforms, is needed immediately.

The perceptions of the institutional subsystem indicated weaknesses. Institutionally, farmers have access to inputs and some training; however, their lack of effort hinders their ability to make decisions and develop as a unified organization. The decreasing efficacy of government extension services exacerbates this issue.

4.2. Farmers' Preferences on Agroforestry Private Forest Management

Determining plant species composition and management practices is crucial for the success of an agroforestry system [37, 48]. Farmers exhibited a pronounced preference for species driven by economic incentives. Falcataria moluccana (Sengon), Swietenia macrophylla (Mahogany), and Maesopsis eminii (African Wood) are the most popular types of wood. Persea americana (Avocado) and Vigna unguiculata ssp. sesquipedalis (Long Bean) were the most popular MPTS and annual crop types, respectively. These preferences demonstrate a rational calculus, balancing economic returns and ecological stability within the agroforestry system [49]. Farmers participate in developing agroforestry prototype models by expressing their preferences for crop type, species, and cropping patterns. Farmers choose a restricted number of plant species for development compared with existing agroforestry systems. An analysis of perceptions regarding agroforestry management systems reveals that farmers tend to concentrate on increasing income, transitioning from subsistence agroforestry to semi-commercial agroforestry. In semi-commercial agroforestry, the increase of production scale focuses on various tree species, multipurpose tree species (MPTS), and crops expected to provide benefits [50, 51]. Farmers possess knowledge in species combinations within agroforestry that enhance economic and environmental sustainability, strengthened by proficiency in cultivating methods and market accessibility. **Figure 5** illustrates all considerations related to species preferences.

Farmer participation in the development of the agroforestry prototype model subsequently involves the selection of the agroforestry pattern. In the Situdaun private forest, cropping patterns predominantly consist of random mixed patterns and block patterns (trees along borders). However, in the development of agroforestry models, farmers selected alley-cropping patterns (**Table 8**). Farmers preferred this method since it was easy to maintain and saved them time. Alley cropping is in line with what the literature says about its role in protecting soil, increasing revenue, and making it more resilient [52]. To fully comprehend this pattern, farmers must be informed about appropriate species proportions, maintenance, control, pruning, and rotation in agroforestry management, emphasizing the necessity for enhanced extension services.

4.3. Financial Feasibility and Strategic Perspectives of the Agroforestry Frameworks

The assessment of the financial feasibility of agroforestry in Situdaun village revealed considerable disparities between the existing and prototype models in terms of economic viability and structural efficiency (**Figure 5**). Alley cropping patterns in the Prototype Model are not arbitrary but are based on empirical and normative frameworks. These models combine what farmers know, how to optimize space, and how to follow the rules. For example, Indonesia's Ministry of Environment and Forestry Regulation No. 8/2021 [53] recommended agroforestry systems that meet community needs and are suitable for land through structured arrangements such as alley cropping or block systems. This planting design has consistently exhibited superior performance in terms of resource utilization efficiency, erosion mitigation, and intercrop productivity [52, 54].

From an investment perspective, agroforestry development necessitates substantial initial capital for infrastructure, operational inputs, and labor [55]. This financial evaluation revealed that the economic performance of preference-based models is greater than that of traditional farmer-based systems. All the models meet the financial feasibility criteria. However, the magnitude of the difference between the models is striking. Agroforestry Prototype Models I and II produced a relatively high NPV, reaching USD 45 million per ha. Financially, the prototype model was six times better than the model currently practiced. This result indicates a systemic underutilization of land productivity potential in traditional models, despite long-standing adoption by farmers. An intriguing observation from this analysis is the relatively minor NPV disparity across preference models I and II, since the species composition difference is insignificant. The near equivalence of monetary value suggests that species-specific selection may be flexible and that profitability can be maintained if certain principles are adhered to: multistrata cropping, spatial–temporal complementarity, and market responsiveness [49, 56]. The BCR analysis further substantiates the economic advantage of the offered models and indicates that the preference model demonstrates remarkable allocative efficiency [42]. High BCR values are critical in rural economies, which are characterized by restricted investment resources and minimal risk tolerance [57]. The IRR validated the model's feasibility under different time value assumptions; however, NPV is widely considered a more reliable metric in long-term natural resource investments than IRR [58–60]. Furthermore, IRR might occasionally exaggerate the profitability of projects with initial cash inflows but restricted long-term gains, resulting in a short-term focus in planning when evaluated independently [61].

This striking economic gap cannot be ascribed to crop selection; it signifies a more profound issue within contemporary agroforestry dissemination: institutional path dependency and information asymmetry. Although farmers tend to follow traditional methods, the economic justification for varied, preference-oriented models is considerably more robust [22, 62]. The advantages of preference models encompass enhanced profitability and income stability, market alignment, and ecological diversity, which reduce income volatility, a considerable concern for smallholder livelihoods [63, 64]. Including longer-cycle timber species like mahogany in the preference models resulted in significant profitability by integrating quickly yielding intercrops, thereby substantiating the "income stacking" strategy promoted in the integrated agroforestry literature [65, 66]. One reason farmers do not adopt the prototype model is the consideration of annual subsistence needs. Investment in the agroforestry prototype is necessary until the sixth year. Furthermore, the existing model addresses subsistence needs earlier, as shown in **Figure 7**. The prototype implementation of the preference model enhanced the well-being of farmers, environmental conditions, and habitat quality, while contributing to increased carbon sequestration with higher stand density. However, its implementation requires external assistance to address challenges.

This discovery can influence farmer empowerment and policy adaptation, allowing local preferences and agroecological conditions to shape model adjustments while preserving economic outcomes. These findings also indicate that the prevailing belief that conventional agroforestry models are inherently more practical or economical is flawed. However, they demonstrate that integrating agroforestry design with farmer preferences and market orientation produces substantial economic advantages. Combining timber and horticulture crop varieties ensures short- and long-term revenue, increasing the resilience of agroforestry to weather and price fluctuations [11, 47]. These financial data suggest that agroforestry necessitates reconfiguration, focusing on spatial configurations that have been scientifically validated and species that producers prefer. Including ecological integrity, farmer objectives, and economic viability in the preference models enhances their quality as examples and necessitates a shift from the current policy of general agroforestry promotion to evidence-based, site-specific model prescriptions.

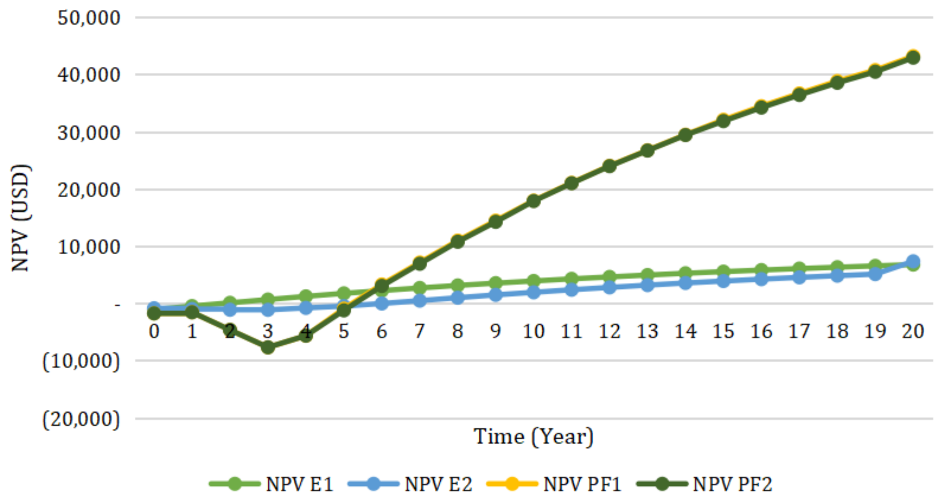

Figure 7. Net Present Value of The Agroforestry Model for Each Additional Length of Time.

The prototype model's financial feasibility is primarily driven by approximately 90% of the value of fruits and crops, with the remaining contribution derived from timber. The financial feasibility can be enhanced and fortified when strategically aligned to achieve multiple purposes. For the agroforestry systems of Situdaun Village, species such as Sengon, Mahogany, and African Wood exhibit considerable promise for bioenergy applications, including fuel for domestic or commercial purposes and conversion into value-added products such as wood pellets. Sengon and mahogany have considerable calorific value, making them viable bioenergy sources. The firewood potential in the private forests of Wonosobo Regency is estimated to be approximately 17 million liters of kerosene [53]. In addition, the prototype's carbon sequestration service exhibits a stand density of 215 stems/ha, enhancing its financial feasibility. The carbon sequestration potential of traditional agroforestry ranges from 51.02 Mg C/ha to 96.25 Mg C/ha [67], generating revenue between USD 812.3 and USD 25,878.5 per ha [68]. In Greece, the use of wood biomass from sessile oak, white poplar, and chestnut trees as a substitute for conventional fuels (electricity and diesel) provides environmental sustainability, with annual greenhouse gas emissions reduced by 6–26%, and high financial viability with a relatively short payback period [69]. The transition from conventional energy sources to renewable energy, specifically wood biomass, is affected by factors including proximity to resources such as private forests, agroforestry, and mixed orchards, along with the high costs related to energy infrastructure such as gas and electricity. While wood fuel biomass significantly reduces greenhouse gas (GHG) emissions compared to conventional heating sources, its adoption requires political initiatives, subsidies, compensation for GHG reductions, and public awareness, which are crucial for promoting biofuels [70].

Developing agroforestry in private forests based on perceptions and preferences is crucial in fostering community involvement in decision-making to restore degraded land and forests. The regenerative aspect of the land maxing approach strategy involves the restoration of natural capital through agro-ecosystem diversification and sustainable agroforestry practices. Furthermore, Land Maxing emphasizes community-driven or bottom-up strategies to establish all six essential capitals of sustainable development (natural, social, human, physical, financial, and political/corporate will) [71]. Agroforestry in the private forest of Situdaun village yields non-timber forest products (NTFPs), designated as Agroforestry Tree Products (AFTPs), to indicate their origin from privately owned land forests [72, 73].

The agroforestry prototype developed for the study area combines leguminous family trees, MPTS, and food crops in an alley cropping pattern, optimizing the use of growing space and enhancing soil fertility through nitrogen fixation, which increases the nutrient cycle and elevates soil organic matter content [74, 75]. This achievement is evident in Brazilian Atlantic Forest agroforestry, which has improved ecosystem services, preserved biodiversity, strengthened food security, reduced poverty, and increased soil resilience against degradation, addressing agricultural yield gaps in tropical and subtropical countries [76–78].

Implementing the **Land Maxing** concept in agroforestry within the private forests of Situdaun Village requires further promotion and development. Currently, farmer groups play a limited role, constrained by inadequate social and financial capital. To address these gaps, it is essential for the government and relevant stakeholders to offer targeted support aimed at improving farmers' knowledge and skills in the domestication and commercialization of endemic species, implement effective incentive schemes, and strengthen local institutional capacity to ensure long-term sustainability.

5. Conclusions

Farmers' perceptions regarding agroforestry represent their ability to adopt agroforestry practices and effectively market their products. However, challenges in processing and institutional frameworks frequently constrain their role, often relegating them to a position as suppliers to downstream industries. Establishing agroforestry prototypes involves farmers' decisions on tree composition, multipurpose tree species (MPTS), crops, and planting patterns. The combination of Mahogany, Sengon, African Hardwood, Avocado, Long beans, and Cassava within alley cropping patterns is a strategy that has been employed to optimize land use in accordance with the Land Maxing approach. The financial feasibility of agroforestry in community forests is significant and resilient, contributing substantially to the supply of fruit, food, wood, bioenergy, greenhouse gas emission reduction, and carbon sequestration. The findings of the study and subsequent recommendations are as follows: 1) The provision of more effective forestry extension services is necessary to enhance farmers' institutional capacity in management and value addition; 2) The government should implement programs that promote livelihood fulfilment, establish incentive schemes, and engage stakeholders to develop agroforestry prototypes and enhance downstream product processing; and 3) forest and land rehabilitation programs should be executed with community involvement, taking into account their preferences for crop types and agroforestry patterns that provide economic benefits and environmental sustainability.

Author Contributions

Conceptualization, B., N.S., F.S. and S.T.; methodology, N.S. and F.S.; software, N.S.; validation, B.; formal analysis, B. and N.S.; investigation, F.S. and N.S.; resources, S.T. and F.S.; data curation, N.S.; writing—original draft preparation, B., N.S. and F.S.; writing—review and editing, B.; visualization, N.S.; supervision, S.T.; project administration, S.T.; funding acquisition, F.S. All authors have read and agreed to the published version of the manuscript.

Funding

This research work was funded by the Ministry of Research Technology and Higher Education, Republic of Indonesia through the scheme of Matching Fund (*Kedaireka*) 2023. This publication received no external funding.

Institutional Review Board Statement

Ethical review and approval were waived for this study because this research involve human in a minimum way. The research permit for research work was given by the Dean of Faculty of Forestry and Environment, IPB University Number 3689/IT3.F4/TD.01/2023 on June 23rd, 2023.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. This research was supported by the Forestry Agency of West Java Province for field work permission through the collaboration letter between IPB University and the Forestry Agency of West Java Province number 17494/IT3.L1/HK.07.00/P/T/2023

and 1852/HK.02/CDKW-I. This agroforestry research is part of the study on Accelerating Participatory Critical Land Rehabilitation through the Implementation of Four-Dimensional Sustainable Agroforestry and Forest Health Monitoring in Bogor Regency, West Java. Fitta Setiajiati, a member of the research team, supported by Naifa Sa'diyya, collected data in the field. Researchers provided information and requested consent from respondents for data collection while maintaining the confidentiality of respondents' identities. The questionnaire form for data collection can be found in the data availability link.

Data Availability Statement

The data for this article can be found at https://ipb.link/bahruni-dataset.

Acknowledgments

The authors express gratitude to the Ministry of Research Technology and Higher Education, Republic of Indonesia, for the funding provided through the Matching Fund (Kedaireka) 2023 scheme; to the Forestry Agency of West Java Province for supporting this study; and to Dr. Adisti Permatasari Putri Hartoyo for the exceptional leadership of the Kedaireka team.

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

[1] Fujiwara, T., Awang, S.A., Widayanti, W.T., et al., 2018. Socioeconomic conditions affecting smallholder timber management in Gunungkidul District, Yogyakarta Special Region, Indonesia. Small-Scale Forestry. 17(1), 41–56. DOI: https://doi.org/10.1007/s11842-017-9374-1

[2] Darusman, D., Hardjanto, 2006. Economic review of community forests. Proceedings of Forest Products Research Seminar (FORDA). 4–13. Available from: https://adoc.pub/tinjauan-ekonomi-hutan-rakyat-oleh-dudung-darusman-dan-hardj.html (cited 17 July 2023). (in Indonesian)

[3] Maryudi, A., Devkota, R.R., Schusser, C., et al., 2012. Back to basics: considerations in evaluating the outcomes of community forestry. Forest Policy and Economics. 14(1), 1–5. DOI: https://doi.org/10.1016/j.forpol.2011.07.017

[4] Dishut, Dinas Kehutanan, 2022. Area of community forest by regency in west java. Available from: https://opendata.jabarprov.go.id/id/dataset/luas-hutan-rakyat-berdasarkan-kabupatenkota-di-jawa-barat (cited 17 July 2023). (in Indonesian)

[5] ASEAN Ministers of Agriculture and Forestry, 2015. 2016–2025 Vision and strategic plan for asean cooperation in food, agriculture and forestry. Available from: https://faolex.fao.org/docs/pdf/asean197569.pdf (cited 26 June 2025).

[6] ASEAN Ministers on Agriculture and Forestry, 2024. The forty-sixth meeting of the asean ministers on agriculture and forestry (the 46th AMAF). Available from: https://asean.org/wp-content/uploads/2024/10/JPS-46th-AMAF-final.pdf (cited 26 June 2025).

[7] ASEAN Secretariat, 2025. ASEAN Economic Community (AEC) strategic plan 2026–2030 of the ASEAN community vision 2045. ASEAN Secretariat. Available from: https://asean.org/wp-content/uploads/2025/06/AEC-Strategic-Plan-2026-2030.pdf (cited 26 June 2025).

[8] Catacutan, D., Finlayson, R., Gassner, A., et al., 2018. ASEAN guidelines for agroforestry development. ASEAN Secretariat. Available from: https://asean-crn.org/wp-content/uploads/2019/09/2018-ASEANGuideline-agroforestry.pdf (cited 26 June 2025).

[9] Quandt, A., Neufeldt, H., Gorman, K., 2023. Climate change adaptation through agroforestry: opportunities and gaps. Current Opinion in Environmental Sustainability. 60, 1–7. DOI: https://doi.org/10.1016/j.cosust.2022.101244

[10] Sanudin, Fauziyah, E., 2015. Characteristic of private forest based on its management orientation: case study in Sukamaju Village, Ciamis District and Kiarajangkung Village, Tasikmalaya District, West Java. Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia. 1(4). Available from: https://smujo.id/psnmbi/article/view/1151 (cited 17 July 2023). (in Indonesian)

[11] Leakey, R.R.B., 2017. Definition of agroforestry revisited. Multifunctional Agriculture. 5–6. DOI: https://doi.org/10.1016/b978-0-12-805356-0.00001-5

[12] Musvoto, C., Kgaphola, J., Kahinda, J.M., 2022. Assessment of homegarden agroforestry for sustainable land management intervention in a degraded

landscape in South Africa. Land Degradation & Development. 33(4), 611–627. DOI: https://doi.org/10.1002/ldr.4173

[13] Evans, K., Jong, W.D., Cronkleton, P., et al., 2010. Participatory methods for planning the future in forest communities. society & natural resources. 23(7), 604–619. DOI: https://doi.org/10.1080/08941920802713572

[14] Ruhimat, I.S., 2020. Analysis of farmers decision making in selecting understorey species in mixed garden. Jurnal Agroforestri Indonesia. 3(2), 111–122.

[15] Widiarti, A., 2013. Forest recovery with community participation. Jurnal Penelitian Hutan Dan Konservasi Alam. 10(2), 215–228. (in Indonesian)

[16] Kuswantoro, D.P., Junaedi, E., Handayani, W., et al., 2014. Agroforestry landscape assessment in a priority watershed (Cikawung watershed). Balai Penelitian Teknologi Agroforestri: Ciamis, Indonesia. (in Indonesian)

[17] Rahman, S.A., Jacobsen, J.B., Healey, J.R., et al., 2017. Finding alternatives to swidden agriculture: does agroforestry improve livelihood options and reduce pressure on existing forest?. Agroforestry Systems, 91(1), 185–199. DOI: https://doi.org/10.1007/s10457-016-9912-4

[18] Gosling, E., Reith, E., Knoke, T., et al., 2020. Exploring farmer perceptions of agroforestry via multi-objective optimisation: a test application in Eastern Panama. Agroforestry Systems. 94(5), 2003–2020. DOI: https://doi.org/10.1007/s10457-020-00519-0

[19] Darusman, D., Hardjanto, Suharjito, D., et al., 2013. Membangkitkan kehutanan indonesia: kristalisasi konsep dan strategi implementasi. In: Frandy, Y.H., Nastiti, D., Januarini, N. (Eds.). PembangunanKehutanan Indonesia Baru. Refleksi Dan Inovasi Pemikiran. IPB Press: Bogor, Indonesia. (in Indonesian)

[20] FAO, 2020. The state of the world's forests 2020. FAO and UNEP: Rome, Italy. DOI: https://doi.org/10.4060/ca8642en

[21] Meijer, S.S., Catacutan, D., Ajayi, O.C., et al., 2015. The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in Sub-Saharan Africa. International Journal of Agricultural Sustainability. 13(1), 40–54. DOI: https://doi.org/10.1080/14735903.2014.912493

[22] Mercer, D.E., 2004. Adoption of agroforestry innovations in the tropics: A Review. Agroforestry Systems. 61, 311–328. DOI: https://doi.org/10.1023/B:AGFO.0000029007.85754.70

[23] Hudiyani, I., Purnaningsih, N., Asngari, P.S., et al., 2017. Farmers' perceptions of agroforestry pattern private forests in Wonogiri Regency, Central Java. Jurnal Penyuluhan. 13(1), 64. DOI: https://doi.org/10.25015/penyuluhan.v13i1.14709 (in Indonesian)

[24] Kuyah, S., Whitney, C.W., Jonsson, M., et al., 2019. Agroforestry delivers a win-win solution for ecosystem services in Sub-Saharan Africa. A meta-analysis. Agronomy for Sustainable Development. 39(5), 47. DOI: https://doi.org/10.1007/s13593-019-0589-8

[25] Kinyili, B.M., Ndunda, E., Kitur, E., 2020. Influence of agroforestry on rural income and livelihood of smallholder farmers in the Semi-Arid Region of Sub-Saharan Africa. Journal of Tropical Forestry and Environment. 10(1). DOI: https://doi.org/10.31357/jtfe.v10i1.4691

[26] Ouko, C.A., Mulwa, R., Kibugi, et al., 2018. Community perceptions of ecosystem services and the management of Mt. Marsabit Forest in Northern Kenya. Environments. 5(11), 121. DOI: https://doi.org/10.3390/environments5110121

[27] Victoria, M.M., 2020. Contribution of forestry provisioning ecosystem services to the household income of small holder farmers adjacent Chyulu Hills Forest, Makueni County, Kenya. International Journal of Environmental Sciences & Natural Resources. 23(4). DOI: https://doi.org/10.19080/ijesnr.2020.23.556117

[28] Tiebel, M., Mölder, A., Bieling, C., et al., 2024. Understanding small-scale private forest owners is a basis for transformative change towards integrative conservation. People and Nature. 6(1), 337–353. DOI: https://doi.org/10.1002/pan3.10579

[29] Atmadja, S., Martius, C., Leonard, S., et al., 2021. Transformational change to reduce deforestation and climate change impacts. FAO: Rome, Italy. DOI: https://doi.org/10.4060/cb7314en

[30] Dawson, N.M., Coolsaet, B., Sterling, E.J., et al., 2021. The Role of indigenous peoples and local communities in effective and equitable conservation. Ecology and Society. 26(3), 19. DOI: https://doi.org/10.5751/ES-12625-260319

[31] Badan Pusat Statistik, 2020. Tenjolaya District in Figures 2023. Available from: https://bogorkab.bps.go.id/id/publication/2023/09/26/5d912548984fcaa7247750e8/kecamatan-tenjolaya-dalam-angka-2023.html (cited 17 July 2023). (in Indonesian)

[32] Makwana, D., Engineer, P., Dabhi, A., et al., 2023. Sampling methods in research: a review. international journal of trend in scientific research and development. 7(3), 762–768. Available from: https://www.researchgate.net/publication/371985656

[33] Harpe, S.E., 2015. How to analyze likert and other

rating scale data. Currents in Pharmacy Teaching and Learning. 7(6), 836–850. DOI: https://doi.org/10.1016/j.cptl.2015.08.001
[34] Grovers, R.M., Fowler Jr, F.J., Couper, M.P., et al., 2009. Survey methodology (2nd ed.). A John Wiley & Sons: Hoboken, NJ, USA.
[35] Chisika, S., Park, J., Park, H., et al., 2022. Farmers' perception of ecosystem services from agroforestry practices in kenya: the case of kakamega county. Journal of Sustainability Research. 4(4). DOI: https://doi.org/10.20900/jsr20220016
[36] Sukwika, T., Yusuf, D., Suwandhi, I., 2020. The institutional of local community and stratification of land ownership in surrounding community forests in Bogor. Journal of Tropical Forest Management. 26(1), 59–71. DOI: https://doi.org/10.7226/jtfm.26.1.59
[37] Suryani, E., Dariah, D.A., 2012. Increasing land productivity through agroforestry systems. Jurnal Sumberdaya Lahan. 6(2), 101–109. (in Indonesian)
[38] Rahut, D.B., Behera, B., Ali, A., 2015. Household access to water and choice of treatment methods: empirical evidence from Bhutan. Water Resources and Rural Development. 5, 1–16. DOI: https://doi.org/10.1016/j.wrr.2014.09.003
[39] Phondani, P.C., Maikhuri, R.K., Rawat, L.S., et al., 2020. Assessing farmers' perception on criteria and indicators for sustainable management of indigenous agroforestry systems in Uttarakhand, India. Environmental and Sustainability Indicators. 5, 100018. DOI: https://doi.org/10.1016/j.indic.2019.100018
[40] Hardjanto, 2017. Community forest management. In: Waldi, R.D. (Ed.). IPB Press: Bogor, Indonesia. (in Indonesian)
[41] Kadariah, 1999. Introduction to project evaluation. In: Karlina, L., Gray, C. (Eds.). Publishing Institute of the Faculty of Economics, University of Indonesia: Jakarta, Indonesia. Available from: https://lib.ui.ac.id/detail.jsp?id=120991 (in Indonesian)
[42] The World Bank, 2005. The effectiveness of world bank support for community-based and -driven development - an oed evaluation (English). In Kumar, N., Vajja, A., Pozzoni, B., et al. (Eds.). The World Bank: Washington, D.C., USA. DOI: https://doi.org/10.1596/978-0-8213-6390-4
[43] Reddy, M.V.R., Ravi, S.D., Kulkarni, P.S., et al., 2011. Numerical model for the analysis of the thermal-hydraulic behaviors in the calandria based reactor. Computational fluid Dynamics 2010. Springer: Berlin/Heidelberg, Germany. pp. 669–676. DOI: https://doi.org/10.1007/978-3-642-17884-9_85
[44] Maryudi A., Nawir A.A., Dwiko B., et al., 2015. Complex regulatory frameworks governing private smallholder tree plantation in Gunungkidul District, Indonesia. Forest Policy and Economics. 59, 1–6. DOI: https://doi.org/10.1016/j.forpol.2015.05.010
[45] Premono, B., Lestari, S., 2023. Multipurpose trees species-based agroforestry at Ogan Komering Ulu Selatan, South Sumatera. In Proceedings of the 3rd Sriwijaya International Conference on Environmental Issues, Palembang, Indonesia, 5 October 2022. DOI: https://doi.org/10.4108/eai.5-10-2022.2328349
[46] Mbow, C., Smith, P., Skole, D., et al., 2014. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Current Opinion in Environmental Sustainability. 6(1), 8–14. DOI: https://doi.org/10.1016/j.cosust.2013.09.002
[47] Mbow, C., Van, N.M., Luedeling, E., et al., 2014. Agroforestry Solutions to Address Food Security and Climate Change Challenges in Africa. Current Opinion in Environmental Sustainability. 6, 61–67. DOI: https://doi.org/10.1016/j.cosust.2013.10.014
[48] Puspasari, E., Wulandari, C., Darmawan, A., et al., 2017. Social economic aspects agroforestry system in the forest community work area (Hkm) District West Lampung, Lampung Province. Jurnal Sylva Lestari. 5(3), 95–103. DOI: https://doi.org/10.23960/jsl3595-103 (in Indonesian)
[49] Jose, S., 2009. Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry Systems. 76(1), 1–10. DOI: https://doi.org/10.1007/s10457-009-9229-7
[50] Sardjono. M.A., Djogo, T., Susilo, H., et al., 2003. Classification of agroforestry component and pattern combination. World Agroforestry Centre: Bogor, Indonesia.
[51] Ananta, R., Sulistyo, J., 2011. Characteristics of calorific value of sengon tree component in Wonosobo sawmill industry centers [Bachelor's Thesis]. Universitas Gadjah Mada: Yogyakarta, Indonesia. Available from: https://etd.repository.ugm.ac.id/penelitian/detail/166285
[52] Kang, B.T., Attakrah, A.N., Reynolds, L., 1999. Alley Farming. Macmillan Education Ltd: London, UK. Available from: https://books.google.co.id/books?id=7t0c9bk1GjYC&printsec=frontcover#v=onepage&q&f=false
[53] Regulation of the Minister of Environment and Forestry, Republic of Indonesia, 2021. Forest Management and Forest Management Plan Preparation, as well as Forest Utilization in Protected Forests and Production Forests. Available from: https://peraturan.bpk.go.id/Details/235254/permen-lhk-no-8-tahun-2021 (cited 17 July 2023).

[54] Nair, P.K.R., 2011. Agroforestry systems and environmental quality: introduction. Journal of Environmental Quality. 40(3), 784–790. DOI: https://doi.org/10.2134/jeq2011.0076

[55] Kamar Dagang dan Industri Indonesia (KADIN), 2022. Business Case Study of Agroforestry. KADIN/Indonesian Ecolabeling Institute: Jakarta, Indonesia.

[56] Nair, R.P.K., Nair, V.D., Mohan, K.B., et al., 2010. Carbon Sequestration in Agroforestry Systems. Advances in Agronomy. 108, 237–307. DOI: https://doi.org/10.1016/S0065-2113(10)08005-3

[57] Szott, A., Motamed, M., 2024. Agriculture sector cost benefit analysis guidance. Available from: https://assets.mcc.gov/content/uploads/pub-2024001293901-ag-scba.pdf (cited 17 July 2023).

[58] Cooperate Finance Institute, 2023. Discount rate. Available from: https://corporatefinanceinstitute.com/resources/valuation/discount-rate/ (cited 27 August 2023).

[59] Gittinger, J.P., 1982. Economic analysis of agricultural projects, 2nd ed. McEuen, J. E. (Ed.). The Johns Hopkins University Press: Baltimore, MD, USA.

[60] Magni, Carlo, A., Marchioni, A., 2020. Average rates of return, working capital, and NPV-consistency in project appraisal: A sensitivity analysis approach. Available from: https://mpra.ub.uni-muenchen.de/99922/ (cited 17 July 2023).

[61] Zhuang, J., Liang, Z., Lin, T., et al., 2007. Theory and practice in the choice of social discount rate for cost-benefit analysis: a survey. Asian Development Bank: Mandaluyong City, Philippines. Available from: https://www.adb.org/sites/default/files/publication/28360/wp094.pdf

[62] Pattanayak, S.K., Mercer, D.E., Sills, E., et al., 2003. Taking stock of agroforestry adoption studies. Agroforestry Systems. 57(3), 173–186. DOI: https://doi.org/10.1023/A:1024809108210

[63] Buttoud, G., 2013. Advancing agroforestry on the policy agenda: a guide for decision-makers. Place, F., Gauthier, M. (Eds.). Food & Agriculture Organization of the United Nations (FAO): Rome, Italy. Available from: https://www.fao.org/4/i3182e/i3182e00.pdf

[64] Montagnini, F., 2024. Integrating landscapes: agroforestry for biodiversity conservation and food sovereignty. Springer Cham: Cham, Switzerland. DOI: https://doi.org/10.1007/978-3-031-54270-1

[65] Coe, R., Sinclair, F., Barrios, E., 2014. Scaling up agroforestry requires research 'in' rather than 'for' development. Current Opinion in Environmental Sustainability. 6, 73–77. DOI: https://doi.org/10.1016/j.cosust.2013.10.013

[66] Schroth, G., Da Fonseca, G.A.B., Harvey, C.A., et al., 2004. Agroforestry and Biodiversity Conservation in Tropical Landscapes. Island Press: Washington, D.C., USA. pp. 1–535.

[67] Hartoyo, A.P.P., Khairunnisa, S., Pamoengkas, P., et al., 2022. Estimating carbon stocks of three traditional agroforestry systems and their relationships with tree diversity and stand density. Biodiversitas Journal of Biological Diversity. 23(12). DOI: https://doi.org/10.13057/biodiv/d231207

[68] Siagian, K., Karuniasa, M., Mizuno, K., 2024. The estimation of economic valuation on carbon sequestration of agroforestry land system. Journal of Natural Resources and Environmental Management. 14(2), 231–231. DOI: https://doi.org/10.29244/jpsl.14.2.231

[69] Kolovos, K.G., Kyriakopoulos, G., Chalikias, M.S., 2011. Co-evaluation of basic woodfuel types used as alternative heating sources to existing energy network. Journal of Environmental Protection and Ecology. 12(2), 733–742.

[70] Kyriakopoulos, G., Kolovos, K.G., Chalikias, M.S., 2010. Environmental sustainability and financial feasibility evaluation of woodfuel biomass used for a potential replacement of conventional space heating sources. Part II: A Combined Greek and the nearby Balkan Countries Case Study. Operational Research. 10(1), 57–69. DOI: https://doi.org/10.1007/S12351-009-0033-Y

[71] Leakey, R.R.B., Harding, P.E., 2025. Land maxing': regenerative, remunerative, productive and transformative agriculture to harness the six capitals of sustainable development. Sustainability. 17, 5876. DOI: https://doi.org/10.3390/su17135876

[72] Simons, A.J., Leakey, R.R.B., 2004. Tree domestication in tropical agroforestry. Agroforestry Systems. 61, 167–181.

[73] Foundjem, T.D., Tchoundjeu, Z., Speelman, S., et al., 2012. Policy and legal frameworks governing trees: incentives or disincentives for smallholder tree planting decisions in Cameroon? Small-scale Forestry. 12, 489–505. DOI: https://doi.org/10.1007/s11842-012-9225-z

[74] Lal, R., 2020. Regenerative agriculture for food and climate. Journal of Soil and Water Conservation. 75(5), 123A–124A.

[75] Schreefel, L., Schulte, R.P.O., de Boer, I.J.M., 2020. Regenerative agriculture the soil is the base. Global Food Security. 26, 100404. Available from: https://www.cdfa.ca.gov/State_Board/docs/2023may_attachment__regenerative_ag_the_soil_is_the_base.pdf

[76] Leakey, R.R.B., 2010. Agroforestry: a delivery mechanism for multifunctional agriculture. in: Kellimore, L.R. (Ed.). Handbook on Agroforestry: Management Practices and Environmental Impact.

Nova Science Publishers: New York, NY, USA. pp. 461–471.

[77] Leakey, R.R.B., 2012. Living with the trees of life—towards the transformation of tropical agriculture. CABI: Wallingford, UK. pp. 1–200.

[78] Leakey, R.R.B., 2013. Addressing the causes of land degradation, food/nutritional insecurity and poverty: a new approach to agricultural intensification in the tropics and sub-tropics. in: Hoffman, U. (Ed.). Wake up Before it is too Late: Make Agriculture Truly Sustainable Now nor Food Security in A Changi-g Climate, UNCTAD Trade and Environment Review 2013, Chapter 3. UN Publications: Geneva, Switzerland. pp. 192–198.