BIODIVERSITAS ISSN: 1412-033X
Volume 24, Number 8, August 2023 E-ISSN: 2085-4722
Pages: 4324-4333 DOI: 10.13057/biodiv/d240814

Developing sustainable models of agroforest-landscape in Bogor, Indonesia

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Manuscript received: 30 January 2023. Revision accepted: 13 August 2023.

Abstract. *Nurrochmat NA, Purnomo H, Muhdin, Erbaugh JT. 2023. Developing sustainable models of agroforest-landscape in Bogor, Indonesia. Biodiversitas 24: 4324-4333.* Deforestation continues in Indonesia even though many regulations and precautions have been taken. It most likely happened due to the less economic contribution from the forestry sector, which caused the conversion from forest lands to more profitable land uses. The forest area covers 125 million hectares (66%) of 190 million hectares of country land but contributes only about 0.60% of the Gross Domestic Product (GDP). An agroforestry scheme is promoted to increase the economic value of the forest to increase both the community welfare and the environmental quality. This study indicates that the best agroforestry commodities for social scenarios are durian, ornamental plants, and laying hens, with the highest potential profit of IDR.143,857,559 (USD.9,652)/hectare/month and 9.19 tons/hectare carbon stock. While for the economic scenario is jackfruit, ornamental plants, and laying hens with a potential profit of IDR.146,908,379 (USD.9,789)/hectare/month and 18.66 tons/hectare carbon stock. In comparison, the ecology scenario promotes nutmeg and ornamental plants with a potential profit of IDR 36,814,280 (USD.2,470)/hectare/month, with the highest of 56.12 tons/hectare carbon stock. This study recommends the appropriate land use models for the government to address the conflict of interest between agriculture and forestry in contributing to Indonesia's FoLU (Forestry and other Land Uses) Net Sink in 2030.

Keywords: Agroforestry, deforestation, economic value, FoLU Net Sink, GDP

INTRODUCTION

Indonesia has allocated 125 million hectares (66%) of 190 million hectares of country land for forest zones. However, the forest sector contributed only 0.60% of the Gross Domestic Product (Nurrochmat et al. 2023). Despite most of the forests being public properties on state land and it's forbidden by government laws to use forest areas for agricultural and other non-forestry activities without a license or legal permit (Indonesia Law no. 41 the Year 1999 about Forestry), rural people surrounding the forests, often use them illegally. Forests are sources of food, medicinal plants, and many other natural resources. However, because the state protects the forest, local people have limited access to forest resources. In addition, the benefits generated from forests, dominated by wood production, were very small, making them poor and unable to meet their needs. People living in forests are one of the largest poor groups in Indonesia and worldwide (Davis et al. 2022; Ullah et al. 2022). Therefore, it is no reasonable choice if they want to choose more efficient and economical commodities to fulfill their unmet needs in life. This situation of forestland with unproductive economic value is one of the most important driving factors of deforestation because sooner or later, people will convert forests into more productive land use (Mulia et al. 2014; Nurrochmat et al. 2023).

Deforestation will decrease if the economic productivity of forests can be improved (Nurrochmat et al. 2022). Improving the economic productivity of forests is the key factor in protecting forests while also considering the social and ecological function of achieving Indonesia's FoLU Net Sink in 2030 (Nurrochmat et al. 2023). Therefore, it needs improvement in several aspects of forest management, such as governance (Maryudi et al. 2018; Erbaugh and Nurrochmat 2019), institution (Larasatie et al. 2022; Rochmayanto et al. 2022), economics and finance (Nurfatriani et al. 2015; Purwoko et al. 2022; Sheriffdeen 2022), management system and technology (Kaya et al. 2016; Yovi and Nurrochmat 2018; Mazya et al. 2023), science-based policy (Ekayani et al. 2016), and land use policy (Nurrochmat et al. 2020; Purwawangsa et al. 2022).

There are several ways to increase the economic productivity of the forests. One of them is community-based forest management (CBFM) following Law 11/ 2020 on Job Creation, as was replaced by the Provisional Law (Perppu) 2/2022, which includes smallholder private forests *(hutan rakyat)* and social forestry schemes. CBFM will increase the economic productivity of forests and the prosperity of the forest community. The private forests on Java Island are usually planted with various trees. They are not only fancy wood, such as teak *(Tectona grandis* L.f) or mahogany *(Swietenia mahagoni* (L.) Jacq.) but also nontimber forest products, such as pine (*Pinus merkusii* Jungh. & de Vriese) that produce pine gum and turpentine. Several fast-growing tree species such as *sengon (Paraserianthes falcataria* (L.) I.C.Nielsen*), jabon (Neolamarckia cadamba* (Roxb.) Bosser*), kayu afrika/manii (Maesopsis eminii* Engl.), fruit trees, as well as other commercial crops usually planted under the stands or alley cropping (Rimantho et al. 2023).

This research will provide several social, economic, and ecological scenarios that could be applied depending on land use priority. The research site is located in the Sukamantri Village, Tamansari Sub-district, Bogor District, on the foot of Salak Mountain, and borders the Halimun Salak National Park. In the village, an experimental garden is located at Institut Pertanian Bogor. Halimun Salak National Park has complex problems with the surrounding communities because of a previous improper policy of expanding the national park into several community forest lands. In decree 175/kpts8211/11/2003, released on June 10, 2023, the government expanded the Halimun Salak National Park area from 40,000 to 113,357 hectares. There were already people who occupied and farmed in these areas. Agriculture plantations that have already been planted cannot be replaced by forestry plants suddenly and arbitrarily. Agroforestry could be the solution to solve the tenurial conflict between the forestry and agricultural sectors (see Rahmani et al. 2021).

Agroforestry, especially the close farming system, is an excellent system. It could increase the farmer's income and decrease the potential risk of loss with multiproduct agroforestry (Nurrochmat et al. 2021; Rahmani et al. 2021). The tree's woods could be harvested at the end and sold after 10 or 20 years of cultivation; the horticulture crops could be harvested in one or two months, giving a monthly income. Then, the livestock, for example, laying hens, could give daily income. Multiproducts could also minimize the risk of loss due to a significant product price reduction. From an ecological perspective, agroforestry could reduce erosion due to the multi-strata of the canopy plantation. It could also strengthen the soil with tree roots to prevent landslides. From a social perspective, increased income could increase community welfare (Erbaugh et al. 2017; Rahmani et al. 2021). Moreover, agroforestry can provide organic farming; after that, chemical fertilizer could be minimized, even substituting with livestock manure fertilizer (Walters et al. 2016).

The agroforestry models that consider social, economic, and ecological aspects are expected to benefit long-term forest management (Purnomo and Mendoza 2011; Nurrochmat et al. 2021; Rahmani et al. 2022; Sayer et al. 2017). Increasing the economic productivity of land with agroforestry will improve community welfare (Erbaugh et al. 2017; Rahmani et al. 2021). Furthermore, it will also provide a scenario that could increase social acceptability with maximum economic benefits while considering the existence of forests for ecological functions (Rossita et al. 2021). These results are expected to be a recommendation and consideration in future land management decision conflicts that could help achieve Indonesia's FoLU (Forestry and other Land Uses) Net Sink in 2030 (see Di Gregorio et al. 2016; 2019; Nurrochmat et al. 2023).

MATERIALS AND METHODS

Time and place

The research was conducted in Sukamantri Village, Bogor District, West Java, Indonesia (Figure 1). This village comprises 15 community groups or *Rukun Warga* (RW) with a total area of 571.17 hectares. However, the potential land that can be used for agroforestry is only 235.07 hectares (LPPM IPB 2020). This village borders the Halimun Salak National Park, with many exciting tourist destinations, such as forest scapes, camping grounds, and agroforests. There is also an Institut Pertanian Bogor experimental garden covering an area of 26 hectares.

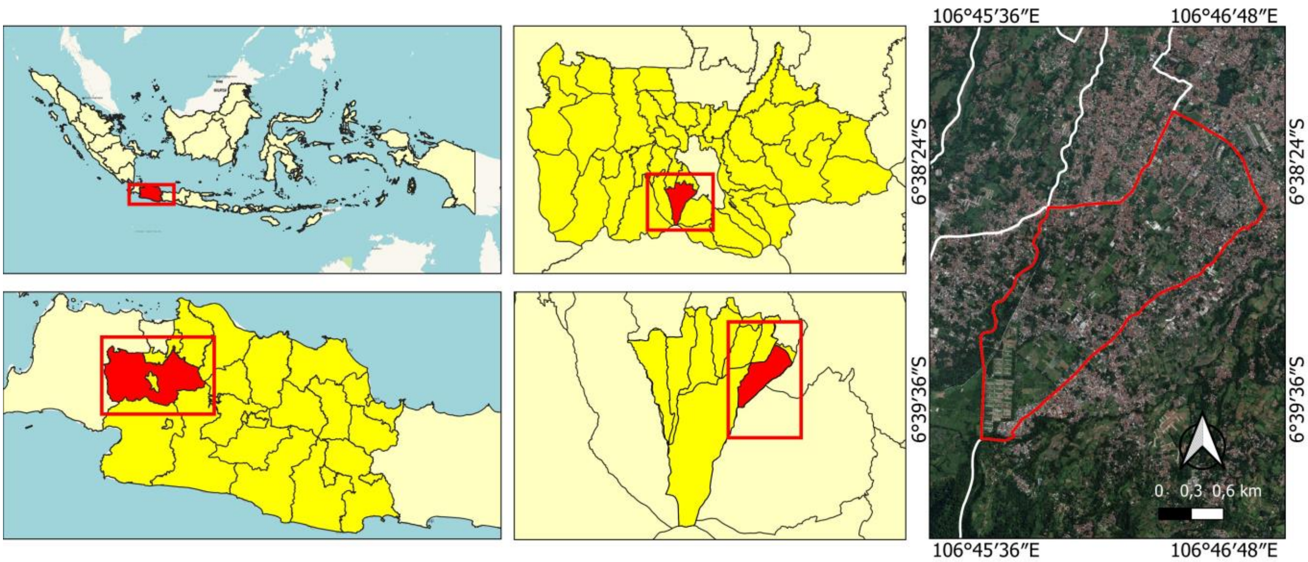

Figure 1. Location research site in Sukamantri Village, Bogor District, West Java, Indonesia

This research is divided into three stages: first, data collection; second, field survey; and third, data processing and analysis. The data was collected from November 2020 to January 2021 using a "Precision Village Mapping Method." Furthermore, from February 2021 to May 2021, key person interviews were conducted with farmers and stakeholders. The data analysis, development of agroforestry models, and investment analysis have been carried out from June 2021 to January 2022.

Research materials and tools

The materials used in this research are data and information collected from the LPPM IPB (precision village data) consisting of spatial and socio-economic data taken from the household census in Sukamantri Village. The data was taken in November 2020. Other materials are obtained from reports, scientific publications, and other pieces of literature. The tools used in this study are computer hardware and software, i.e., Stella 9.0.2, IBM, SPSS Statistics 25, Agishoft Metashape, and ArcGIS 10.4.

Research procedures

The precision village data was taken using DPM (Drone Participatory Mapping). DPM is a mapping technique using an inclusive approach of humans and technology to collect precise village data by considering spatial dimensions, digital technology, community participation, and household census (LPPM IPB 2020; Mansfeld et al. 2020). This research employs three stages approach (Sjaf et al. 2022):

Making a working map

A working map is made by taking a high-resolution aerial photograph (5cm/pixel) using a drone in Sukamantri Village. The drone used in this activity is the Mavic 2 Pro, flying 100 to 150 m above the land. After that, aerial photographs were compiled using Agishoft Metashape and processed into working maps using ArcMap 10.4.

Retrieval of numeric data

After the working map has been successfully created, a census is carried out using a questionnaire application (android-based apps.) developed by LPPM IPB named the Merdesa.

Data processing

The results of the 3,464 households census are processed and integrated with spatial data from drone aerial photographs to develop precision village data (improve the existing village monograph). After receiving the precision village data, household interviews were conducted with 34 farmers to obtain data on the distribution of land ownership. The data will determine which land can be used for agroforestry, social forestry schemes, or other landscape models. In-depth interviews were conducted with five key persons in the sub-district and village representing government officials, community leaders, business actors, the management of the IPB experimental garden, and the chairperson and person in charge of the LPPM IPB who assisted the community in compiling Precision Village Data. These interviews were conducted by purposive sampling, using a snowball method with quota control. It means that who and how many key persons will be selected for the interview are determined while conducting in-depth interviews.

Data analysis

Developing a system dynamics model

This research uses a dynamic system approach because it provides an overview of a complex, uncertain, or dynamic system (Walters et al. 2016). It uses two approach methods for selecting the models: filtering and scoring. The filtering method starts with social analysis; after that, it continues with economic analysis and ecological analysis. The variables that will be investigated in the model are determined. The types of business activities, such as agricultural and forest commodities and landscapes, will be selected based on the surveys (household, in-depth interviews, and focus group discussion) concerning social preferences. Several components should be considered in system dynamics before developing a model such as the following:

State variable. State variables describe the accumulation of material in a system.

Driving variable. The driving variable affects other variables but is not affected by the system.

Constanta. Constants are numeric values that describe a system's characteristics that do not change or can be described as something that does not change under simulated conditions.

Auxiliary variable. An auxiliary variable is part of the value calculation, which is the rate of change of other variables and can be influenced and influenced by other variables in a system.

Transfer of material and information. Material transfer describes the physical transfer of material over a period. It lies between (i) two state variables, (ii) a source and a state variable, and (iii) a state variable and an exhaust/sink. The information transfer describes the use of information about state variables and systems intended to control changes from state variables in a system.

Sources and sinks. Sources and sinks describe the initial and final events of material transfer into and out of the system.

Social analysis

Social analysis is carried out by exploring the needs and desires of the community related to the development of business activities and land uses. The first step is to collect information on business activities and types of potential commodities developed in Sukamantri Village; then, filter the types of businesses or commodities rejected by the community or the community did not want to cultivate them (Rochmayanto et al. 2022). The next step is to filter the economic and ecological aspects (Rahmani et al. 2021). From the results of this screening, a list of the types of business activities and commodities accepted by the community will be obtained (socially acceptable). The top three models from social analysis with the highest score are the best social aspect models.

Economic analysis

Economic analysis elaborates on macroeconomic and financial data to obtain an optimal agroforestry system development model. Financial analysis determines the feasibility of business investment; investment can be interpreted as an economic resource spent to run a business expected to gain benefits or profits (see Nurrochmat et al. 2020). This study uses a dynamic model and is simulated over 25 years. An investment can be analyzed based on Net Present Value (NPV), Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR) (Magni and Marchioni 2020; Rahmani et al. 2021; Rossita et al. 2021). The top three models from economic analysis with the highest score are the best models for the economic aspect. The formula of financial criteria is explained as follows:

Net Present Value (NPV). NPV is the difference between the present value of the investment and future net cash receipts. If a business has NPV > 0, then the business is considered feasible to run. The business is considered financially unfit if the NPV value is ≤ 0. NPV can be obtained through the following equation:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t} \quad \text{..................................(4)}$$

Where;
NPV : Net Present Value
Bt : Benefits obtained in year-t
Ct : Costs incurred in year-t
i : Applicable interest rate
t : The lifetime of the business, or a business cycle

Internal Rate of Return (IRR). IRR is the maximum interest rate on a business that can pay for the resources used. If the IRR of a business is ≥ the interest rate, the business is feasible to run, and if the IRR is < interest rate, the business is not feasible to run. IRR can be obtained through the following equation:

$$IRR = i(+) + \frac{NPV(+)}{NPV(+) - NPV(-)}\left[i(-) - i(+)\right] \quad \text{................(5)}$$

Where:
IRR : Internal Rate of Return
NPV(+) : Positive NPV
NPV(-) : Negative NPV
i (+) : Interest rates that make the NPV positive
i (-) : Interest rates that make the NPV negative

Benefit Cost Ratio (BCR). BCR compares the total present value (PV) of benefits and the total present value (PV) of costs. A business activity or project is profitable if the value of BCR ≥ 1. It suffers a loss or is not feasible if the BCR is < 1. If BCR = 1, the business does not experience profit or loss. BCR can be obtained from the following equation:

$$BCR = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}} \quad \text{....................................(6)}$$

Where:
BCR : Benefit Cost Ratio
Bt : Benefits in year-t
Ct : Cost in year-t
t : The lifetime of the business, or a business cycle
i : Applicable interest rate

Ecology and carbon stock analysis

After obtaining the optimal economic model using financial analysis, an ecological aspect is carried out through carbon stock analysis. Ecological analysis was carried out by comparing the potential of biomass and carbon stock. Instead of following an increment model of forest stock in natural forests, this study measured the potential carbon stock of tree biomass in agroforests according to the previous studies (Siarudin and Indrajaya 2014). The tree biomass potential was calculated using the following allometric equation:

AGB = p x exp(-1.499+2.148ln(D)+ 2 3 0.207(ln(D)) - 0.028(ln(D)) ....(7)
Cs = 0.47 x AGB / 1000 ....(8)

Where:
AGB : Biomass of stands (kg/stand)
D : Diameter
p : Density (g/cm^3)
Cs : Carbon Stock (ton)

RESULTS AND DISCUSSION

This research started with data retrieval using the Data Desa Presisi method. It provides high-resolution spatial data that could show precise land cover information (Figure 2). The total area of each landcover was also gained, and it could be shown that the potential landcover used for agroforestry is 571.17 hectares.

There are various land covers in Sukamantri Village consisting of *palawija* garden, horticulture garden, mix plantation, paddy-rice field, meadow, vacant land, ornamental plants, fish pond, forest, settlement, and other land use (Table 1). It could be observed that some of the land covers are suitable for agroforestry while others are not. Agroforestry is not ideal for some areas due to some reasons. For example, a forest area is not a potential area because it is forbidden by the government law of Indonesia No 41/1999. Furthermore, the fish pond, settlement, and other land use areas are not potential due to the high costs to convert the buildings on the land into agroforestry.

Table 1. Land cover area in Sukamantri Village, Bogor, Indonesia

Land use	Area (ha)	Suitability
Palawija garden	46.13	Potential
Horticulture garden	15.27	Potential
Mix plantation garden	147.65	Potential
Paddy-rice field	2.80	Potential
Meadow	3.39	Potential
Vacant land	12.90	Potential
Ornamental plants	5.54	Potential
Fish pond	1.38	Not potential
Forest	65.23	Not potential
Settlement	104.06	Not potential
Other land use	166.82	Not potential
Total	571.17	

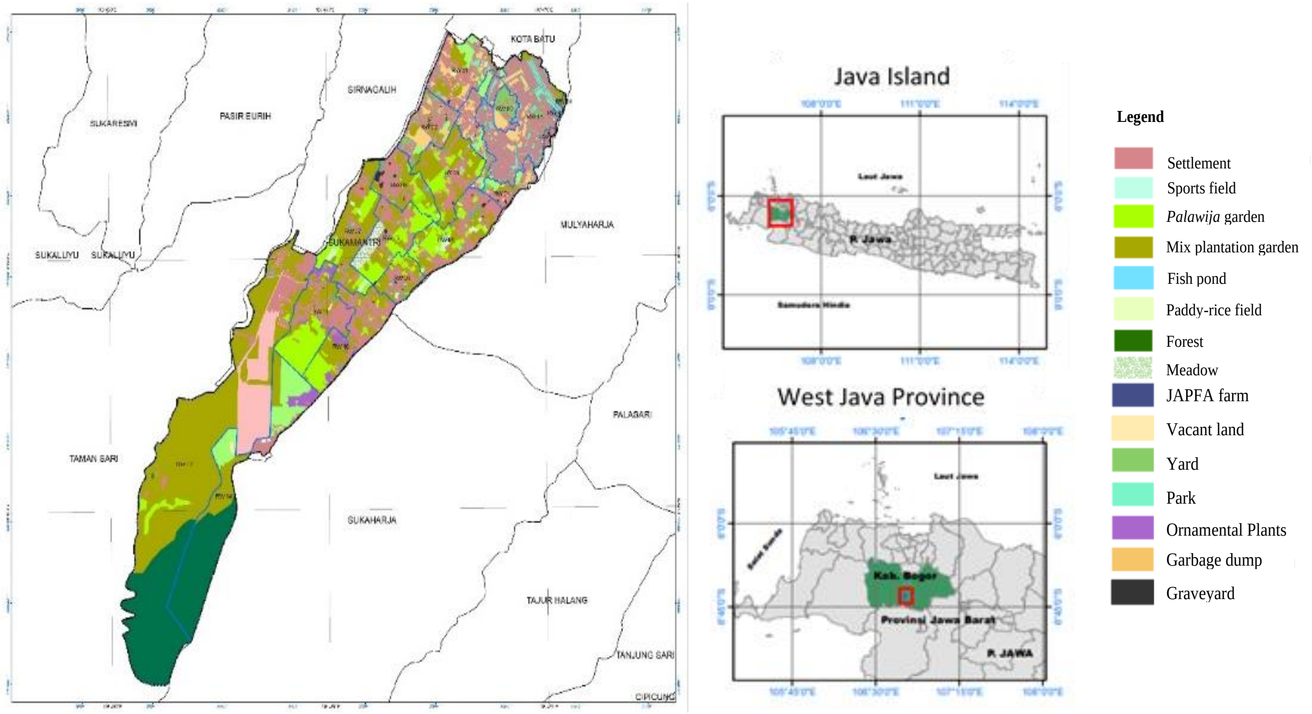

Figure 2. Landcover of Sukamantri Village, Bogor District, West Java, Indonesia. Source: LPPM IPB (2020)

Table 1 shows the current land covers in Sukamantri Village. It indicates that from 571.17 hectares of land, mostly covered with a mixed plantation garden of 147.65 hectares, the forest of 65.23 hectares, *palawija* garden (cassava, corn, etc.) of 46.13 hectares, and horticultural lands (mustard, etc.) of 15.27 hectares. If the forests belonging to the Halimun Salak National Park and other non-potential land covers are excluded, then the potential land for agroforestry is 235.07 hectares. Besides providing spatial data, the *Data Desa Presisi* also provided census data of 12,011 people in Sukamantri Village, obtained in 2020. Based on *Data Desa Presisi*, it has been known that the total number of people with the main job as a farmer was 145.

In this research, 34 farmers were interviewed, with in-depth interviews and purposive sampling. Some questions were conducted, i.e., Which commodities are most likely the communities like and not like, What are the reasons, and how much will they approximately get from these commodities? The respondents were chosen purposively around the village, representing farmers with small, medium, and large land ownership. The purposive sampling interviews were also conducted by a snowball sampling of some key persons from several stakeholders, which are: (i) The Village Head of Sukamantri; (ii) The Head of the experimental Garden of Institut Pertanian Bogor in Sukamanti Village; (iii) The farmer group leader in Sukamantri Village; (iv) The successful entrepreneur in Sukamantri Village; (v) The Dean of the Faculty of Agriculture, Institut Pertanian Bogor.

Additional information was obtained from the gathering attended by around 20 farmers and 10 people from different stakeholders (i.e., village government, Institut Pertanian Bogor, BNI Bank) conducted by Institut Pertanian Bogor and BNI Bank on June 6, 2021, in Sukamantri Village, Bogor, Indonesia. The data retrieval from interviews and other literature concluded the five best commodities from each agriculture sector: forestry, horticulture, and livestock production (Table 2).

The five best commodities are made into the model by Stella software with the causal loop diagram shown in Figure 3. Table 2 shows that the best commodity from the social analysis is durian for forestry purposes, ornamental plants for horticulture, and laying hens for the livestock sector. The Institut Pertanian Bogor experimental garden in Sukamantri Village also plants some Durian trees and provides a considerable economic value, with a selling price of up to IDR 300,000/piece. Institut Pertanian Bogor also collaborates with approximately 100 farmers near the experimental garden and the BNI Bank to develop the ornamental plant plantation and farming business, with some already exporting the products. In addition, PT. JAPFA operates a poultry business consisting of laying hens, broilers, and factories with an area of 25 hectares in Sukamantri Village, strengthening the chicken commodity farms from a social viewpoint. The livestock could be integrated with a forest system, namely silvopasture. Figure 3 shows a causal loop diagram of the agroforestry model in Sukamantri Village.

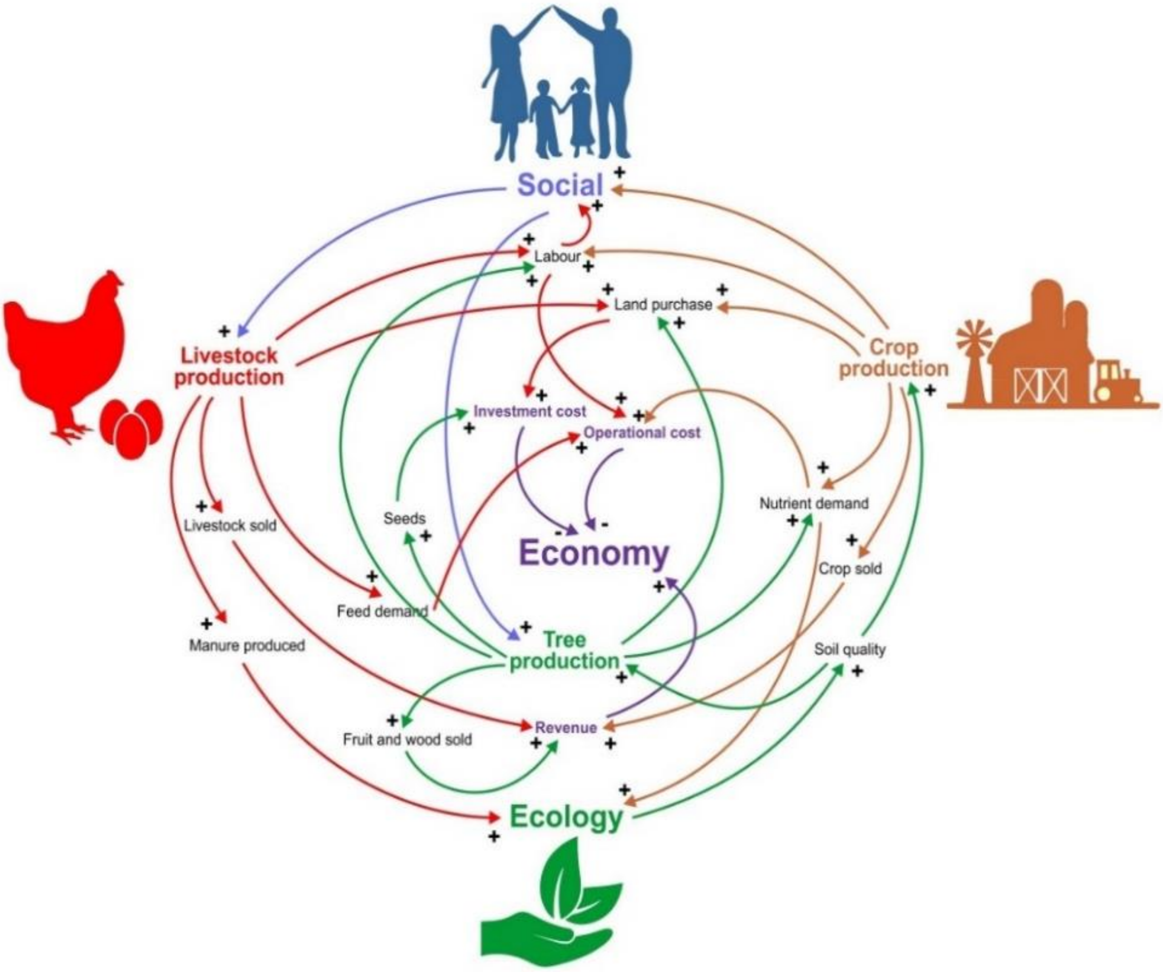

Figure 3. Causal loop diagram of agroforestry model in Sukamantri Village, Bogor District, West Java, Indonesia

This agroforestry model exemplifies the close farming system. Closed-loop agriculture is a farming practice in which all nutrients and organic materials are recycled back into the soil they were grown. It is part of an agricultural practice that helps farmers reduce or eliminate external inputs while preserving soil nutrients and carbon levels. The litter from trees and horticulture could be fed to livestock production, and the cattle dung could be used to fertilize the plants. The litter's gasses could also fuel power plants or stoves (Walters et al. 2016). Several studies show that litter could also be a mixed component for chickens fed. However, the percentage is insignificant (Banaszak et al. 2022; Dewi et al. 2022; Sonnabend et al. 2022). The models are built using information gathered from interviews and literature studies. This research generates a socially acceptable, economically feasible, and ecologically sustainable model. Moreover, social analysis is generated by obtaining social preference. The economic analysis employs indicators of NPV (Net Present Value), BCR (Benefit Cost Ratio), and IRR (Internal Rate of Return); it also demonstrates the ecological analysis to forecast carbon stock. The Stella Dynamic System could be used for agricultural production systems comprising multidimensional components and drivers interacting in complex ways to influence production sustainability (Walters et al. 2016). Following data processing with several assumptions and a literature review, the dynamic system with Stella produces the models for financial feasibility and carbon stock shown in Figure 4 and Table 2.

Following the forest threshold, the agroforestry could be set in several patterns-for instance, small islands, large islands, and line-planting agroforests (Figure 5). The agroforestry could be maximized using the Line Planting Agroforest System (Figure 5). The small and large island systems are ineffective for the product's maintenance and harvest. The canopy of the trees could also cover the ornamental plants, so some of these plants that are not tolerant would have reduced productivity. On the other hand, the line planting agroforest could increase the sunshine for the trees and crops and ease the maintenance and harvest. Therefore, the land-planting agroforest system is the most recommended for the model. For comparison, Rahmani et al. (2021) reported that the NPV, BCR, and IRR of oil palm monoculture are IDR 62,644,836 (USD 4,476.84), 1.39, and 20.77%, respectively, while the oil palm agroforestry planted in the experimental plot potentially generates much better values of financial indicators with NPV, BCR, and IRR being IDR

209,221,212 (USD 14,951.76), 1.79, and 24.42%.

Farm crops and horticulture (fruits and ornamental plants) provide many economic benefits, while forest trees (durian, jackfruit, and nutmeg trees) will give more ecological benefits because of some environmental services. One of the most critical ecological services is carbon stock. Carbon emissions absorbed and stocked inside the wood of the trees could reduce the greenhouse gasses in the atmosphere and the global warming effect. Many countries already recognize the importance of carbon stock. By 2016, the carbon stock market was made in the Paris Agreement Article 6 (Paris Agreement, 2016) to meet the Nationally Determined Contribution (NDC) target. In 2022, the carbon price from the European Union was around USD 80 or IDR 1,192,408 per metric ton of carbon per year (using the exchange rate of Bank Indonesia on September 20, 2022), with IDR 14,905.10 for USD 1. Suppose these environmental services from carbon stock could be counted as a benefit. In that case, the economic value of forestry trees could be increased, especially for the nutmeg tree, which could give the highest carbon stock but the least NPV. Table 3 shows the intercropping combination due to proposed social, economic, and ecological scenarios.

Table 2. Results of Stella models of the financial and carbon stock analysis

Commodity	NPV (IDR (USD)) /ha	Number (unit /ha)	BCR	IRR (%)	Potential profit (IDR (USD)/ ha/month)	Carbon stock (ton /ha)
Forestry						
Durian (10×10 m^2)	2,852,165,997 (191,355)	100	3.04	13.48	9,507,220 (638)	51.05
Avocado (6×5 m^2)	2,422,920,785 (162,556)	333	2.60	18.49	8,076,403 (542)	52.47
Mango (10×10 m^2)	2,678,668,784 (179,715)	100	3.13	19.67	8,928,896 (599)	48,21
Jackfruit (6×6 m^2)	4,648,300,596 (311,860)	277	3.43	24.05	15,494,335 (1,040)	78.32
Nutmeg (10x9 m^2)	565,655,786 (37,950)	111	1.47	11.64	1,885,519 (127)	84.18
Horticulture						
Ornamental plants (50×50 cm^2)	11,482,922,799 (770,402)	1500	3.36	>100.00	38,276,409 (2,568)	-
Mustard (15×15×30 cm^2)	1,252,520,584 (84,033)	2000 kg	1.66	23.48	4,175,069 (280)	-
Paddy (20×20 cm^2)	504,774,519 (33,866)	8000 kg	1.37	14.16	1,682,582 (113)	-
Corn (30×30 cm^2)	1,089,914,301 (73,124)	15000 kg	1.64	21.38	3,633,048 (244)	-
Cassava (100×40 cm^2)	331,695,962 (22,254)	80000 kg	1.16	12.07	1,105,653 (74)	-
Livestock						
Laying hens 2,000 heads (20×10m^2)	68,530,383,033 (4,597,781)	20,000	2.66	>100.00	228,434,610 (15,326)	-
Broiler 10,000 heads (250×10 m^2)	35,691,178,092 (2,394,561)	20,000	6.63	>100.00	118,970,594 (7,982)	-
Goat (9,000 m^2 grass)	1,124,546,080 (75,447)	225	1.49	20.76	3,748,487 (251)	-
Catfish nursery 82 broodstock (1000 m^2)	10,527,937,439 (706,331)	410 broodstock 2,400,000 seeds	1.26	>100.00	35,093,125 (2,354)	-
Rabbit 6 heads (2×1 m^2)	55,720,656,145 (3,738,362)	15,000	1.75	>100.00	185,735,520 (12,461)	-

Note: Using the exchange rate of Bank Indonesia (September 20, 2022), IDR 14,905.10 for USD 1

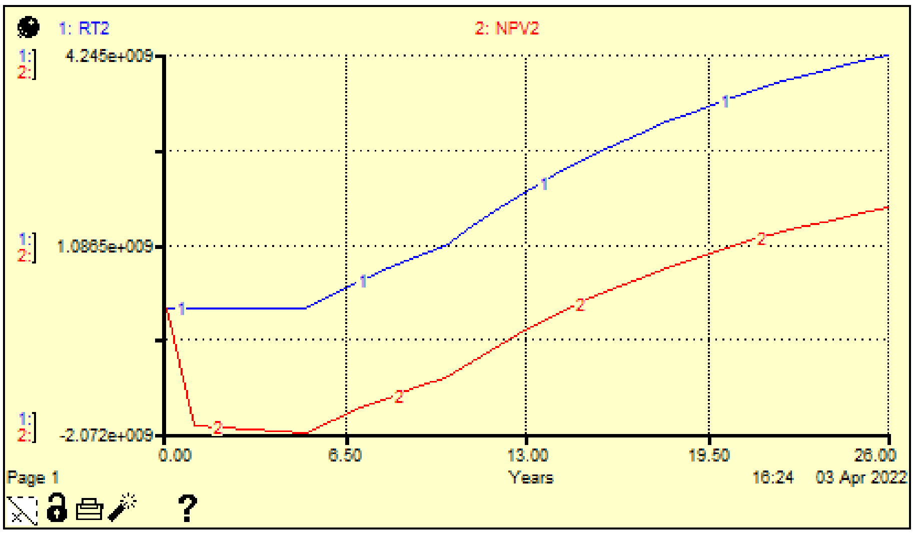

Figure 4. Results of data processing using the system dynamics model Stella

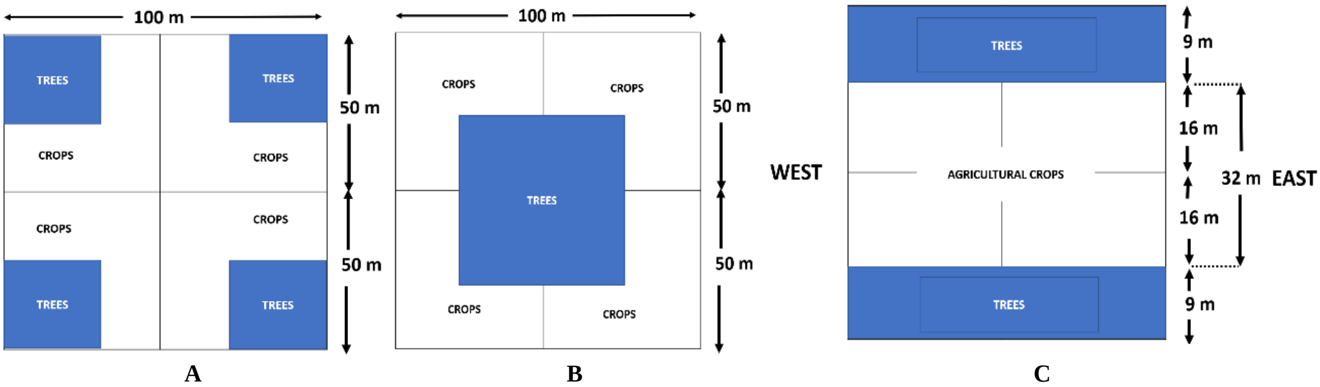

Figure 4. Illustration of recommended agroforestry patterns: A. Small island system; B. Large island system; C. Line planting agroforest (Nurrochmat 2022)

Table 3. Agroforestry intercropping combinations, plant, and farm spacing

Scenario	Combination	Number of commodities per hectare				
		Durian (10 × 10 m²)	**Jackfruit (6 × 6 m²)**	**Nutmeg (10 × 9 m²)**	**Ornamental plants (0.5 × 0.5 m²)**	**Laying hens 2,000 heads (20 × 10 m²)**
Social	Durian	18	0	0	450	8,000
Economy	Jackfruit	0	66	0	450	8,000
Ecology	Nutmeg	0	0	74	1,200	0

Table 4. Comparison of the financial feasibility with a potential profit of each agroforestry scenario

The best Scenarios	Combination	Financial feasibility criteria				
		NPV* (IDR (USD)) /hectare	**BCR****	**Total cost (IDR (USD)) /hectare**	**Potential profit (IDR (USD) /hectare/month)**	**C-stock (tons / hectare)**
Social	Durian, ornamental plants, laying hens, and carbon trading	43,157,267,586 (2,895,470)	4.42	12,618,118,876 (846,564)	143,857,559 (9,652)	9.19
Economy	Jackfruit, ornamental plants, laying hens, and carbon trading	43,922,057,192 (2,946,780)	4.46	12,693,910,308 (851,649)	146,406,657 (9,823)	18.66
Ecology	Nutmeg, ornamental plants, and carbon trading	11,044,284,083 (740,973)	4.37	3,272,846,112 (219,579)	36,814,280 (2,470)	56.12

Note: Using the exchange rate of Bank Indonesia (September 20, 2022) with IDR 14,905.10 for USD 1; NPV* = Net Present Value; BCR** = Benefit Cost Ratio

Table 3 shows the agroforestry with the best social, economic, and ecological value. For the social scenario, the agroforestry composition consists of durian, ornamental plants, and laying hens, while for the economic scenario, the composition consists of jackfruit, ornamental plants, and laying hens. Although providing organic fertilizer as a by-product of the livestock, silvopasture harms the environment due to the methane gasses produced by the production process. Methane is one of the most dangerous greenhouse gases. Therefore, the best option for the agroforestry model based on ecology should eliminate the livestock commodities, which consist only of nutmeg trees and ornamental plants. The ecological scenario could be done if the interest rate for this business could be kept at a low level, around 8%, or the rate for smallholder businesses or *Kredit Usaha Rakyat* (KUR), and the carbon market could be established in Indonesia at the same price as in European countries. Table 4 shows the comparison of the financial feasibility of several agroforestry scenarios.

Table 4 shows the financial and ecological analysis for the best agroforestry scenario for 25 years for a 1 hectare from social, economic, and ecology. In this calculation, the carbon trading value is also calculated. The highest profit is gained from the economic scenario with an NPV of IDR 43,922,057,192 (USD 2,946,780), followed by the social scenario with an NPV of IDR 43,157,267,586 (USD 2,895,470), and the ecological scenario with an NPV of IDR 11,044,284,083 (USD 740,973). The BCR values follow the same order. Thus, following the economic scenario, the total agroforestry lands will gain a profit of IDR 146,406,657 (USD 9,823), followed by the social scenario of IDR 143,857,559 (USD 9,652), and the ecological scenario of IDR 36,814,280 (USD 2,470). The carbon stock shows different order where the ecology scenario has the highest value with 56.12 tons/hectare, the economic scenario with 18.66 tons/hectare, and the social scenario with 9.19 tons/hectare. This result aligns with agroforestry's carbon stock from Siarudin and Indrajaya (2014) and Rahayu et al. (2022), with 42.30 tons/hectare and an interval of 14.80-106.20 tons/hectare. Most farmers only intensively plant *palawija* and horticulture crops. They generated a much higher income compared to mustard IDR 4,175,069 (USD 280)/hectare/month, paddy of IDR 1,682,582 (USD 113)/hectare/month, corn IDR 3,633,048 (USD 244)/hectare/month and cassava IDR 1,105,653 (USD 74)/hectare/month (Table 4). If all 235.07 hectares of the potential land could be managed well by agroforestry, the Sukamantri Village will benefit from social, economic, and ecological aspects. The farmers' income will increase, and they will become more prosperous. The village's economy will improve, so the development of the village will increase. Moreover, the ecological quality will also be improved with many carbon stocks that could be sold on the carbon market.

After interviewing key stakeholders, it is known that this scenario is preferred. However, some conditions must be met, i.e., farmers are expected to have access to a larger land area, at least 1 ha. Furthermore, farmers are given significant business capital because the fruit-yield period is quite long. It has been addressed by collaboration between BNI Bank, the Ministry of Cooperatives, and Sukamantri Village Farmers. This collaboration promises farmers to be given up to IDR 2 billion in loans. Finally, farmers expect that agricultural extension workers can assist in the agroforestry planting activity, and the harvested yields will be easily sold to the off-takers.

In conclusion, agroforestry is important to improve the land cover of less productive lands in the community welfare and economic value that support achieving Indonesia's FoLU (Forestry and other Land Uses) Net Sink target in 2030. This research confirmed that the best agroforestry commodities for social scenarios in the research site are durian, ornamental plants, and laying hens, with a potential profit of IDR 143,857,559 (USD 9,652)/hectare/month and 9.19 tons/hectare of carbon stock. The economic scenario is jackfruit, ornamental plants, and laying hens, with a potential profit of IDR 146,406,657 (USD 9,823)/hectare/month and a carbon stock of 18.66 tons/hectare. Lastly, the ecology scenario is nutmeg and ornamental plants (excluding laying hens) with a potential profit of IDR 36,814,280 (USD 2,470)/hectare/month with the highest carbon stock of 56.12 tons/hectare.

The government should consider agroforestry to address the conflict of interest between agriculture and forestry. Moreover, these agroforestry models are expected to be done in other villages to increase the forest land cover. Indeed, some stakeholders, i.e., the government, village communities, and companies, have to collaborate to make this program successful. These agroforestry schemes are potentially profitable, as hypothesized by the financial analysis, and good for improving environmental quality. At the same time, it also increases community welfare and succeeds Indonesia's FoLU Net Sink 2030.

ACKNOWLEDGEMENTS

We gratefully acknowledge Mr. Sujimin, the owner and founder of Jimmy HanTu Corp., and the Sukamantri Village head for their invaluable contributions to this paper. We also thank all IPB Sukamantri University's Experimental Garden staff and the Sukamantri Village community leaders who assisted this study with data and information.

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