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Profitability of coffee-based agroforestry system to support farmers' income in Toba Regency, North Sumatra Province, Indonesia

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Abstract. Indonesia is a country with the application of agroforestry systems on community land. People who live in Toba Regency, North Sumatra have long applied coffee-based agroforestry systems and have become a hereditary tradition. The purpose of this study is to determine the profitability of coffee-based agroforestry land and economic value for farmers so that it can be developed further. Coordinate points of land distribution, taken with GPS, conducted interviews, profitability analysis and income analysis to obtain farmer land data. Mapping the distribution of farmers' coffee-based agroforestry land was mapped with ArcGIS 10.8. Four respondent farmers implemented coffee-based agroforestry (*Coffea arabica*) with a planting distance of 2 m x 2.5 m combined with *Gmelina arborea* (white teak), *Eucalyptus* sp. (eucalyptus), *Cinnamomum verum* (cinnamon), *Pinus merkusii* (pine), *Psidium guajava* (guava), *Durio zibethinus* (durian), *Persea americana* (avocado), and others. Based on the profitability analysis, all four farmers' lands are feasible for further development. The economic value of land depends on the area of land managed by the farmer, where farmers with a land area of 2 Ha have the largest income during 10 years of land management, namely Mr. Biskean with an income of IDR 162,719,500. Utilization of Multi-Purpose Trees Species (MPTS) or plantation and industrial crops can increase the economic value and profitability of farmers' land.

1. Introduction

Biodiversity affects various aspects of Indonesian people's lives. Indonesia is not only rich in biodiversity, but also cultural diversity [1]. Existing plants are needed in fulfilling food needs and improving environmental quality. One alternative that can be applied is the development of sustainable agriculture, namely by developing agroforestry systems which are broadly defined as agricultural systems or land use systems that integrate spatially and temporally both trees and annual plants in an area [2].



With the integration of trees, agroforestry can preserve natural ecosystems through sustainable land management (including afforestation) and optimal resource utilization [3]. With the growing problem of global warming and in relation to climate change, agroforestry systems are thought to have a high potential for sequestering atmospheric carbon [2]. Agroforestry has a potential role in increasing farmers' income and sustainable landscape management [4-7]. Traditional agroforestry has long been practiced by rural communities to improve their livelihoods, such as selling timber or consuming fruits or edible plants that grow naturally [8]. Agroforestry systems have higher economic returns. In addition, agroforestry enhances rural economic development in the Guilan region of Iran [9].

Trees that grow and are highly favored because they have high economic value, but the harvesting time is long enough are very good and have the potential to be developed as agroforestry crops [10]. Profitability analysis and income analysis on a land needs to be done to determine whether or not a land is feasible to be developed in the future. The distribution of agroforestry can be found one of them in Ajibata Sub-district, Toba Regency, North Sumatra. For a long time, the community has implemented a coffee-based agroforestry system in this area and has become a hereditary tradition. The distribution of coffee-based agroforestry can be mapped using *ArcGIS*, where GIS can be used for data collection, data storage, data analysis, and geo-referenced data manipulation [11-13]. With the research related to the profitability of coffee-based agroforestry land in Ajibata Sub- district and its economic benefits for the community, it is hoped that it can be a source of information for the Toba Regency government in order to develop the potential of agroforestry land in Ajibata Sub-district to improve environmental quality and community welfare.

2. Research methods

2.1. Data collection

This research was conducted in Ajibata Sub-district, Toba Regency. A survey consisting of interviews and questionnaires was conducted with 4 members of a social forestry management group consisting of forest farmers assisted by KPH Region 4 Balige. Then from the interview data, profitability analysis and income analysis were calculated.

2.2. Data analysis

Several steps must be taken to determine the profitability value of community owned coffee-based agroforestry land in Toba Regency is by collecting data conducted through field surveys to farmers' land to inventory the constituent components of farmer owned agroforestry land, land coordinates are taken using GPS, it can be seen that the position of farmer owned coffee-based agroforestry land can be seen in the following.



Figure 1. Coffee-based agroforestry land in Toba Regency.

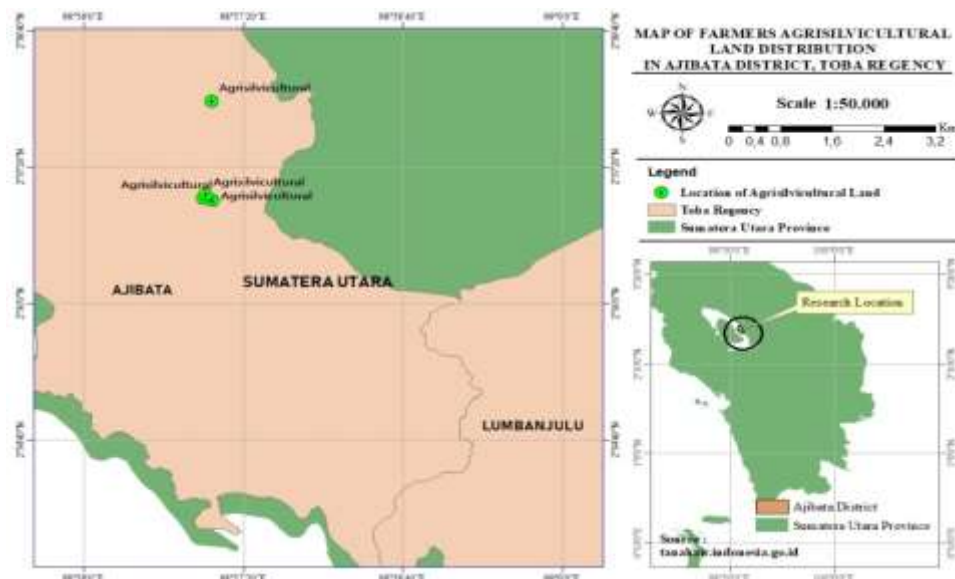


Figure 2. Map of coffee-based agroforestry land distribution in Toba Regency.

In the next step, interviews were conducted with farmer informants based on the interview mix. The data were then processed with Microsoft Excel based on the following profitability analysis and income analysis formulas:

2.2.1. Net present value (NPV). Is a discounted revenue, in its calculation using a discount factor because it normalizes the value of future profits to the present [4]. An activity is said to have benefits and is feasible if $NPV > 0$. The NPV formula is:

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

Note :
 NVP : Net Present Value
 Bt : Year t benefit/revenue
 Ct : Year t cost
 i : Interest/discount rate

2.2.2. Equal annual equivalent (EAE). Is used to compare the profit value of farming systems consisting of commodities that have different durations of planting periods, or compare the economic benefits of each commodity that has a different duration [14,15]. If $EAE > 0$, it means it will be profitable/feasible. The EAE formula is as follows:

$$EAE = NPV \frac{i(1 + i)^t}{(1 + i)^t - 1} \quad (2)$$

Note :
 NPV : Net Present Value
 i : Interest/discount rate
 t : Time in years 1,2,3,...,n calculation

2.2.3. Internal rate of return (IRR). Is an internal rate of return which is a measure of the ability of farm businesses to return loan interest [15]. IRR shows the interest rate that produces $NPV = 0$. An agroforestry activity is said to be profitable if the $IRR > \text{Discount Factor}$.

The formula is:

$$IRR = i_1 + \frac{NPV_1}{(NPV_1 - NPV_2)} (i_2 - i_1) \quad (3)$$

Note :
 NPV1 : Net Present Value 1
 NPV2 : Net Present Value 2
 i1 : Discount factors that result in positive NPV
 i2 : Discount factors that result in negative NPV

2.2.4. *Net benefit cost ratio (Net BCR)*. Describes the ratio of profits to costs incurred. If $BCR > 1$, then the farming business is said to be profitable [8]. The formula is:

$$Net\ BCR = \frac{\sum_{t=0}^{t=n} NPV (+)}{\sum_{t=0}^{t=n} NPV (-)} \quad (4)$$

Note :
 NPV (+) : Net Present Value that is positive
 NPV (-) : Net Present Value that is negative
 t : Year 1, 2, 3,...n calculation

2.2.5. *Payback period (PBP)*. Is the period needed to return the investment value from the benefits or business revenue [16].

$$Payback\ Period = n + \frac{a - b}{c - b} \times 1\ year \quad (5)$$

Note :
 n : The last year where the amount of cash flow still cannot cover the initial investment
 a : Total initial investment
 b : Cumulative amount of cash flow in year n
 c : Cumulative amount of cash flow in year n+1

2.2.6. *Profitability index (PI)*. To calculate the ratio between future net cash flows and the present value of investment [2]. If $PI > 1$, then the farming activity is said to be feasible.

$$Profitability\ Index = \frac{\sum_{t=0}^{t=n} PV\ Cash\ In}{Total\ Investment\ Value} \quad (6)$$

Economic analysis is applied to evaluate the performance of a system based on the benefits derived from the inputs used in the system. It helps to determine the economic benefits that can be obtained from the use of various crop combinations in agroforestry systems [2,17]. To calculate the economic value obtained by farmers, the following formula can be used:

$$T = \sum_{i=1}^n Y_i P_{Yi} - \sum_{i=1}^n X_i P_{Xi} \quad (7)$$

Note :
 T : Net income of agroforestry farmers
 Yi : Total output of the i-th commodity
 P_{yi} : Local price of i-th commodity output
 Xi : Number of i-th input
 P_{xi} : Local price of i-th input

3. Results and discussion

Based on direct surveys to the land of 4 respondent farmers who implement coffee-based agroforestry, coffee (*Coffea arabica*) is used as the main crop because in the area coffee planting and cultivation has become a hereditary habit. Coffee is the main source of income for farmers in this area. The coffee planted has a spacing of 2 m x 2.5 m. Forestry and MPTS plants on farmers' land include *Gmelina arborea* (white teak), *Pinus merkusii* (pine), *Eucalyptus* sp. (eucalyptus), *Aleurites moluccanus* (candlenut), *Persea americana* (avocado), *Artocarpus heterophyllus* (jackfruit), *Cinnamomum verum* (cinnamon), *Parkia speciosa* (petai), *Durio zibethinus* (durian), *Psidium guajava* (guava), *Mangifera indica* (mango). For annual crops and agricultural crops, *Solanum betaceum* (eggplant), *Musa acuminata* (banana), *Alpinia galanga* (galangal), *Manihot utilissima* (cassava), *Ananas comosus* (pineapple), *Saccharum officinarum* (sugarcane), *Curcuma domestica* (turmeric), *Zea mays* (corn), and *Dioscorea bulbifera* (air potato) dominate.

Table 1. Crops that make up the coffee-based agroforestry Toba Regency.

No	Farmer name	Building Blocks		
		Annual crops	Forestry crops and MPTS	Agricultural crops
1	Bisken Manurung	a. <i>Coffea arabica</i> L (coffee)	a. <i>Gmelina arborea</i> (white teak)	a. <i>Solanum betaceum</i> (dutch eggplant)
		b. <i>Zanthoxylum acanthopodium</i> (andaliman)	b. <i>Pinus merkusii</i> (pine)	b. <i>Musa acuminata</i> (banana)
			c. <i>Eucalyptus</i> sp (eucalyptus)	c. <i>Alpinia galanga</i> (galangal)
2	Pranso Sinurat	a. <i>Coffea arabica</i> L (coffee)	a. <i>Cinnamomum verum</i> (cinnamon)	a. <i>Musa acuminata</i> (banana)
			b. <i>Aleurites moluccanus</i> (candlenut)	b. <i>Manihot utilissima</i> (cassava)
			c. <i>Parkia speciosa</i> (petai)	c. <i>Ananas comosus</i> (pineapple)
			d. <i>Durio zibethinus</i> (durian)	
			e. <i>Artocarpus heterophyllus</i> (jackfruit)	
			f. <i>Persea americana</i> (avocado)	
			g. <i>Psidium guajava</i> (guava)	
3	Rizar Sinurat	a. <i>Coffea arabica</i> L (coffee)	a. <i>Aleurites moluccanus</i> (candlenut)	a. <i>Musa acuminata</i> (banana)
			b. <i>Mangifera indica</i> (mango)	b. <i>Saccharum officinarum</i> (sugar cane)
			c. <i>Psidium guajava</i> (guava)	c. <i>Curcuma domestica</i> (turmeric)
				d. <i>Zea mays</i> (corn)
				e. <i>Ananas comosus</i> (pineapple)
				f. <i>Alpinia galanga</i> (galangal)
4	Mrs. Gultom	a. <i>Coffea arabica</i> L (coffee)	a. <i>Aleurites moluccanus</i> (candlenut)	a. <i>Zea mays</i> (corn)
			b. <i>Persea americana</i> (avocado)	b. <i>Ananas comosus</i> (pineapple)
			c. <i>Psidium guajava</i> (guava)	c. <i>Dioscorea bulbifera</i> (air potato)

Based on the profitability analysis of coffee-based agroforestry land owned by farmers, the results are presented in Table 2.

Table 2. Farmer land profitability analysis data in Toba District, Sumatera Utara.

No.	Farmer name	NPV (Rp/ha)	EAE	IRR (%)	Net BCR	PBP (year)	PI
1	Bisken	IDR100,032,620	IDR14,314,900	170	48.7	2.9	57.0
2	Pranso	IDR 38,482,826	IDR 5,506,982	118	23.7	3.2	32.1
3	Rizar	IDR 66,464,817	IDR 9,511,269	150	39.2	3.1	50.1
4	Gultom	IDR 42,681,487	IDR 6,107,820	117	27.1	3.2	32.8

Coffee-based agroforestry land owned by 4 respondent farmers is feasible to develop. This is because the resulting NPV, EAE, IRR, PBP, Return to Labor, and PI values meet the feasible criteria. The largest NPV and EAE values are from Mr. Bisken Manurung's land at Rp. 100,032,620 and Rp. 14,314,900. and based on the PBP value, the fastest land in returning investment is Mr. Bisken Manurung's land, which is 2 years and 9 months. The value of the Net BCR is obtained at 27.1 to 48.7, which means that farmers will get benefits of 27.1 to 48.7 times each expenditure. In this coffee-based agroforestry, this profitability calculation needs to be done to measure the opportunity of a land in managing investment. Where, with a positive NPV on 4 farmers' land, the farm is feasible to run. Then, whether the effort to be spent is proportional to the results obtained. This is done so that farms can apply effective budget management in running their business. The highest income of 4 farmers came from coffee sales. Therefore, coffee-based agroforestry is appropriate for farmers to develop.

The four farmer respondents, Mr. Bisken, Mr. Pranso, Mr. Rizar, and Mrs. Gultom, said that all the crops on their land, such as fruits and vegetables, are used by the community for consumption. In contrast to coffee and other forestry crops, all of which are sold to have an economic impact. During 10 years of land management, the benefits obtained by farmers from coffee-based agroforestry land are as follows.

Table 3. Farmers' income during 10 years of coffee-based agroforestry land management in Toba District, Sumatera Utara.

No.	Farmer name	Area (Ha)	Expenditure (Input) (YiPi)	Income (Output) (YiPi)	Revenue Over 10 Years
1	Bisken M	2	IDR 2,696,500	IDR 165,416,000	IDR 162,719,500
2	Pranso S	1	IDR 2,071,000	IDR 65,460,800	IDR 63,389,800
3	Rizar S	2	IDR 2,301,000	IDR 111,329,600	IDR 109,028,600
4	Mrs. Gultom	1	IDR 2,550,000	IDR 74,132,800	IDR 71,582,800

When viewed from farmers' income in Table 4, while managing coffee-based agroforestry land, farmers benefit. Coffee is the species with the highest economic value. There are differences in the total income of 4 farmers in Ajibata Sub-district. This is influenced by the area of land that farmers cultivate. Mr. Bisken and Mr. Rizar have a higher income than Mr. Pranso and Mrs. Gultom because the land area cultivated is different. The area of land cultivated will affect the level of income of farmers. This is in accordance with research [18] which states that if the land area increases, the farmer's income will also increase and vice versa if the land area used is small or narrow, the income earned by farmers will also decrease because what is planted is small. So, the relationship between land area and farmers' income is positively correlated.

Besides providing high economic value, coffee-based agroforestry is also very beneficial for the environment, with many ecological benefits provided. This is in accordance with statements and research stating that coffee-based agroforestry has a role in soil and water conservation, biodiversity, nutrient addition, microclimate modification, addition of carbon reserves, suppressing pest attacks and coffee diseases, and increasing farmers' income [4]. In addition, coffee-based agroforestry also plays a role in climate change adaptation and mitigation. Climate change adaptation in coffee-based

agroforestry is realized in the form of land, water and biodiversity conservation and microclimate control, while mitigation is in the form of additional carbon stocks so that CO₂ emissions are reduced.

Farmers in Toba Regency in managing their coffee-based agroforestry land get hereditary knowledge from their ancestors, such as holding ceremonies and praying with the hope that the land will provide a bountiful harvest as well as a culture of mutual cooperation in the Toba community. Indigenous knowledge used by farmers can contribute to increased profitability and food security. This is supported by statements that reinforce that local knowledge supports biodiversity, so that later it can be influential for the recovery of areas where biodiversity is being lost [19].

The economic value and profitability of land can certainly be improved. Efforts can be made to implement a more intensive agroforestry system farming by using high economic value plants in composing agroforestry, such as *Multi-Purpose Trees Species* (MPTS) or plantation and industrial crops as a substitute for long-producing trees. In the shade of the canopy can be planted with medicinal plants whose growth does not interfere with plants on coffee-based agroforestry land owned by farmers. Medicinal plants are suitable for development because they are widely available in nature and do not require large costs in their care [20].

4. Conclusion

Coffee-based agroforestry is a system applied to farmers' land in Ajibata Sub-district. Coffee (*Coffea arabica*) is planted with a spacing of 2 m x 2.5 m. The dominant factors for choosing the types of plants that make up this coffee-based agroforestry pattern include economic factors, especially the high selling price of products, fast growth, and fast production. By managing coffee-based agroforestry land, farmers in Ajibata Sub-district gain economic value and live more prosperously. Farmers' land also has good prospects for future development based on land profitability analysis. The utilization of *Multi-Purpose Trees Species* (MPTS) or plantation and industrial plants can increase the economic value and profitability of coffee-based agroforestry land owned by farmers in Ajibata Sub-district.

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