



Increasing Farmers' Knowledge and Action in Agroforestry-Based Coffee Cultivation

Novita Rosiani Haloho¹, Elisabeth Sri Pujiastuti², Ferlist Rio Siahaan², Susana Tabah Trina Sumihar²

¹(Agribusiness Department Universitas HKBP Nommensen Medan)

²(Agroecotechnology Department Universitas HKBP Nommensen Medan)

Corresponding Author: Elisabeth Sri Pujiastuti

ABSTRACT: Agroforestry is a type of land management by expanding the types of crops and livestock that can be combined in one area of land which has a positive impact on both land conditions and the added value of agricultural products. The development of coffee agroforestry systems with various trees provides shade to the main crop. The system can also produce other products like those obtained from forest ecosystems, such as building materials, fruit, firewood and medicinal plants. This study used descriptive quantitative research methods with the secondary data analysis approach. The secondary data needed was general data of the research location, both the physical environment and the socio-economic community data related to farmers' income. The data were obtained based on reference studies from various sources. The dominant crops in the farmers' fields (90%) were bananas and cocoa. Bananas and cocoa are widely chosen by the community because these plants can be harvested in a short time. In addition, bananas and cocoa can be combined with other types of plants. Land cultivation activities were done individually and in groups which were carried out in accordance with the Technical Guidelines for Good Coffee Cultivation, starting from land preparation, planting shade, nursering, planting, fertilizing, pruning and shade plants management. The type of product that often sold was from coffee plant because the harvest period was short, which was every week, so the farmers were able to get faster and easier income.

KEYWORDS: Agroforestry, Coffee Cultivation, Farmers' Income

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I. INTRODUCTION

The majority of the people of Samosir District work as farmers, since there is a fast area of land that can be used for farming. Coffee is one of the potential plantation commodities in Samosir District. Cocoa and coffee are plantation crops that are widely planted by farmers because they are superior crops and the demand is high, so they give a larger farmers' income than other agroforestry crops [1]. The dominance of smallholder plantations leads to coffee farmers to be the main coffee producers. Coffee farmers still have difficulty in getting access to capital to increase productivity, especially in purchasing agricultural machinery which is expected to be able to support the post-harvest process [2].

Coffee is also one of Indonesia's export commodities which is quite important as a foreign exchange earner besides oil and gas. In addition to the increasingly open export opportunities, the domestic coffee market is still open widely. The coffee production from 2018 - 2020 has been fluctuated. In 2018 coffee production was 756.05 thousand tons, decreased to 752.51 thousand tons (as high as 0.47%) in 2019. In 2020 coffee production increased to 762.38 thousand tons (as high as 1.31%). The coffee production according to cultivation status in 2020 was 757.3 thousand tons or 99.33% [3]. Many of the farmers in Samosir apply an agroforestry system in their agricultural land. Arabica coffee plants can grow and bear fruit optimally at altitudes above 1,000 m above sea level, while robusta coffee at altitudes of 400–800 m above sea level [2].

Agroforestry is a type of land management by expanding various types of crops and livestock which can be combined and matched in one area of land which has a positive impact both on land conditions and on the added value of agricultural products. Agroforestry is a form of multi-canopies land use consisting of a mixture of trees, shrubs or annual crops which are often accompanied by livestock in one plot of land [4].

*Corresponding Author: Elisabeth Sri Pujiastuti

Agroforestry is developed to benefit humans or to improve people's welfare [5]. The development of coffee agroforestry systems with various trees provides shade for the main crop. The system can also produce other products such as those obtained from forest ecosystems, such as building materials, fruit trees, firewood and medicinal plants [6].

In coffee agroforestry systems, the water cycle is influenced by the presence of trees. Indirectly, the decrease in the level of erosion hazard is the impact arising from the replacement of horticultural commodities with coffee plants. The pattern of the flow of rainwater that falls to the ground can be changed through the presence of coffee shade plants. Falling rainwater is held up by the tree canopy and some of the rainwater condenses so it does not reach the soil surface. Stems and branches of plants drain rainwater that is retained in the plant canopy. The cover crop prevents erosion due to splashing of rainwater that falls from the leaves to the ground. Another role is shown by litter which is able to protect the soil from the splashing water. In addition, the survival of soil organisms and other small living things can be guaranteed by the presence of litter [6].

One of the coffee agroforestry areas in North Sumatra is located in Samosir District, where forestry crops are combined with agricultural ones. According to [4], forestry plants did not contribute to farmers' income because farmers planted forestry plants in gardens for shade or hedges. Forestry plants (trees) being planted were mahogany, acacia, hibiscus, *medang*, *albazia*, agarwood, *sengon*, teak, *bayur* and champaca. In general, the service forms of tree species to the community included food, fuel (energy) and building materials. People also used the leaves of several tree species to feed their livestock. Tree species for animal feed included lamtoro, *sobsi* and calliandra [6]. Farmers cut down trees not for sale but to meet their own needs such as building houses, building livestock pens and other needs. The contribution obtained with the agroforestry system to household income was that the farmers got yields from forest without having to wait for the harvest period because they were able to obtain yields from agricultural crops either monthly or annually depending on the type of the crops [7]. Variables that affected the income of agroforestry farmers were age, garden total area, number of workers, ethnicity, religions, slopes of the garden and credit assistance [4].

Large-scale clearing of forest land caused a lot of damage and new problems, especially in forest areas. The damage to environmental conditions included soil erosion, flooding, drought, ecosystem extinction, and very fast global climate change [1].

The conversion of land from forests to coffee plantations or other agricultural systems will cause changes in the surrounding environmental conditions, especially hydrological functions, soil fertility, carbon storage, and biodiversity that lead to disruption of forest functions. Therefore, the values of wisdom in utilizing natural resources are very important. This is very important, empirically because one of the most worrying phenomena of the crisis is the unwise exploitation of natural resources [8]. Utilization of land and water resources must be carried out based on the principle of sustainability; every development and use of land related to the management of land resources needs to be planned properly and directed in watershed units (DAS) to prevent land degradation. Selection of inappropriate land use can lead to land degradation which will reduce its carrying capacity [5].

The application of agroforestry plant composition aimed to maintain forest ecological functions and increase farmers' income [9]. Factors that affected the income of coffee agroforestry farmers were the total area of arable land and the number of plant species [10], while the types of land developed for agroforestry was the shrub land, the open field and the dry agricultural land [5]. According to [11], one of the main problems in coffee agroforestry system was the low level of farmer knowledge about coffee-based agroforestry cultivation. Therefore, this study aimed to obtain information about the knowledge and actions of farmers in coffee cultivation.

II. METHODS

This study was held using descriptive quantitative research methods with the secondary data analysis (SDA) approach. The secondary data needed were general data on research locations, both the physical environment and socio-economic data related to farmers' incomes. The data were obtained based on reference studies from various sources, such as local government institutions and related research results [5], [4], [1] and [9]. Secondary data were obtained from various institutions that concerned with research, which will then be processed systematically and objectively.

III. RESULTS AND DISCUSSION

3.1 Socio-Economic Characteristics of Coffee Farmers

Farmers' socio-economic factors (age, education level, farming experience, land area, number of dependents and income level) had an effect on the level of adoption of agricultural technologies. It was also important to pay a special attention to the structure of the workforce in the agricultural sector, which was increasingly aging and scarce in implementing the strategy for adopting recommended technology for coffee

cultivation [11]. Land area was a production factor that affected the size of income because the size of land area affected the amount of production and income of respondents [10]. Income was the farmer's total income that has been reduced by production costs in agroforestry farming. Agroforestry income was the sum of income from gardens, fisheries, animal husbandry and agriculture [4]. Subsistence crops were plants that were not sold (did not generate monetary value and were consumed by farmers) so they were not included in the calculation, while commercial crops were plants that were sold by farmers (generated monetary value) [9].

The dominant crops in the farmers' fields (90%) were bananas and cocoa. Bananas and cocoa were widely chosen by farmers because these plants were able to be harvested in a short time; besides, bananas and cocoa was able to be combined with other types of plants [9]. The agroforestry lands owned by farmers were generally inherited land which will later be passed down from generation to generation. Initially, this abandoned land was overgrown with wild plants there such as pine, sugar palm and banana plants which were not planted. Then the gaps from these lands were planted with vegetables and other fruit crops for farmers' daily needs with simple management. However, with the development of the times and a little knowledge of the farmers, farmers began to plant species that were intensively harvested and managed so that the farming system were known as traditional agroforestry systems [12].

3.2. Characteristics of Coffee Agroforestry

Productivity of agroforestry land use that can be optimized without causing land damage is limited to the topography of 0-15%. The use of agroforestry land in accordance with land capability class will guarantee the productivity and sustainability of land resources. On the other hand, if the use of agroforestry land is not in accordance with the land capability class, it must be evaluated because it will result in land degradation. The land capability classification system for agroforestry land use is based on land characteristics including the following factors: effective depth, slope, erosion and drainage found in the land unit of observation location. One type of land characteristic can affect more than one type of land quality such as soil texture can affect the availability of water, whether it is easy to cultivate and sensitivity to erosion [5].

Sloping land has a higher erosion rate. At the same time, farmers carries out more difficult land management when the agroforestry function can be expected because of the composition and arrangement of plant and tree species that exist in one piece of land [4], where the sustainability of land use supports the life and welfare of agroforestry farmers and their families [5].

According to [13], the types of agroforestry plants consist of:

1. Woody plants, such as acacia (*Acacia mangium*), sengon (*Falcataria molucana*), su-ren (*Toona sureni*), mahogany (*Swietenia macrophylla*), tisuk (*Hibiscus macrophyllus*), gmelina (*Gmelina arborea*), ganitri (*Elaeocarpus ganitrus*), puspa (*Schima noronhae*), jabon (*Anthocephalus kagamba*), teak (*Tectona grandis*) and afrika (*Maesopsis eminii*).
2. Plantation crops, such as coffee (*Coffea spp.*), cocoa (*Theobroma cacao*), clove (*Syzygium aromaticum*), coconut (*Coccoloba nucifer*), petai (*Parkia speciosa*), and nutmeg (*Myristica fragrans*).
3. Fruit plants, such as mango (*Mangifera indica*), mangosteen (*Garcinia mangostana*), durian (*Durio zibhetinus*), dukuh (*Lancium domesticum* var *ducu*), pisitan (*Lancium domesticum* var *typica*), kokosan (*Lancium domesticum* var *aquaeum*), and rambutan (*Nephelium lappaceum*).
4. Perennial undergrowth plants, such as cardamom (*Amomum cardamomum*), cayenne pepper (*Capsicum frutescent*), banana (*Musa spp.*), and grass.
5. Annual undergrowth plants such as ginger (*Zingiber officinale* Rose), turmeric (*Curcuma domesticae*), sweet potato (*Ipomoea batatas*), cassava (*Manihot utilissima*), and peanuts (*Arachis hypogaeae*).

Traditional agroforestry patterns can be classified into four types, namely agrisilvicultural patterns, Silvopastura patterns, agrosilvopastural and Silvofishery patterns [12]. The plants components of each pattern [12] are presented in Table 1.

The planting of this agroforestry pattern is usually carried out in a mixed or random way where forestry plants and fruit trees are planted on the edge of the land which will later be used as a fence for the land. The planting pattern for each of these agroforestry patterns is different and irregular because it depends on the different needs of each community. Variations in these types of plants can be beneficial for farmers/land managers. This is because these differences lead to different harvest times so that the plants can be harvested according to needs and can obtain sustainable income. This is because the types of plants found in agroforestry land vary widely. Some plants are harvested every day and every week such as coffee, betel, torch ginger, sweet potato, and chilies. Even vegetables can also be harvested for self-consumption. Some are harvested every month, such as candlenut, chocolate, and some are harvested every year, such as bananas, *nangka*, *durian*, *petai*, *jengkol*, and mango [12].

Table 1. Components of Agroforestry Plant Types

No	Pattern	Forestry Plants	Agricultural Plants	Livestocks
	Agrisilviculture	Pine, <i>Aren</i> , <i>Suren</i> , Mahogany, Candlenut, Clove, Jackfruit and <i>Durian</i>	Coffee, Onions, Chilies, Cacao, Ginger, Corn, Banana, Torch Ginger, Dutch Eggplant Betel, Turmeric, Cassava	-
	Silvopastoral	Pine, <i>Aren</i> , <i>Suren</i> , Teak	-	Cow, Buffalo, Free-range Chicken and Pig
	Agrosilvopastoral	Pine, <i>Aren</i> , <i>Suren</i> , Teak, Mahogany	Coffee, Cloves, Chilies, Corn, Peanuts, Turmeric, Onions	Cow, Buffalo, Free-range Chicken and Pig
	Silvofishery	Teak, Mahogany	-	Catfish and <i>Mujair</i>

However, with so many plants in one field it can affect the occurrence of plant diseases, where coffee plant diseases include diseases caused by fungi such as leaf rust, leaf spot, root fungus, shoot death, and diseases caused by nematodes. Pests and diseases that are classified as important are very detrimental because they can reduce the productivity of coffee yields once they reach high populations [14].

3.3. Knowledge and Actions of Farmers in Cultivating Coffee Plants in Agroforestry Systems

The ecosystem services provided by shade in coffee plantations were different from the ecosystem services provided by multistrata coffee. Multistrata coffee with more diverse shade trees (11 types of trees) was able to provide more diverse ecosystem services than shade coffee, which only had 3 types of trees, namely coffee as the main crop and *Gliricidia* sp. and *senon* as the shade plant. In multistrata coffee, there were 5 woody trees and 6 fruit trees that provided ecosystem services, while in shade coffee there were no fruit trees, only 2 types of woody trees [15].

Coffee shade trees were divided into 2 categories, namely permanent and temporary shade trees. Permanent shade tree species included *dadap* (*Erythrina subumbrans*), *lamtoro* (*Leucaena leucocephala*), *albasiah* (*Pasarianthes falcataria*), and *cypress* (*Casuarina* spp.). Specifically, the type of temporary shade plants was not determined, but the conditions for shade trees must be considered according to the physical conditions of the environment and the local agro-climate [6].

Shade trees in the coffee agroforestry system, apart from acting as shade for coffee plants, were also able to provide provisioning services for farmers such as fruit, animal feed, and firewood. Shaded coffee and multistrata coffee had almost the same vegetation structure in terms of vertical (plant height) and horizontal (basal area) stratification. This caused the level of canopy closure to also not be different and so was the case with the undergrowth plants. The existence of plants was closely related to the amount of light entering the lower layer [15].

[16] provided guidance on good coffee cultivation through Minister of Agriculture Regulation (Permentan) No. 49/Permentan/ OT.140/4/2014 concerning Technical Guidelines for Good Coffee Cultivation. The cultivation guidelines started from land preparation, shade planting, nursery, planting, fertilizing, pruning, and shade management. Farmers' knowledge and actions in coffee cultivation were based on these regulations, where good and correct nursery techniques were needed in order to increase the quantity and quality of coffee production.

The series of farmer activities carried out to manage traditional agroforestry included: soil management, procurement of various numbers of seeds, planting, plant maintenance, pests and diseases management, harvesting, and marketing of the product. The people of Paraduk Village carried out a traditional agricultural land management. The tools used were still manual in the form of hoes, sickles and harrows. Soil tilling activities were carried out individually or in groups; the first thing to do in soil tillage was clearing the land from grass and shrubs using a machete or sickle. The Village generally provided seeds for the farmers, but some of the farmers provide the seeds themselves. The seeds obtained by the owner of the land that would be planted in his garden were usually obtained by doing the seeding themselves, asking others to buy, finding in the surrounding environment and there were also seeds that came from their own or neighboring gardens which were carried by the wind or animals such as birds, squirrels and bats [12].

Schematic of traditional agroforestry land management process [12] was presented in Figure 1.

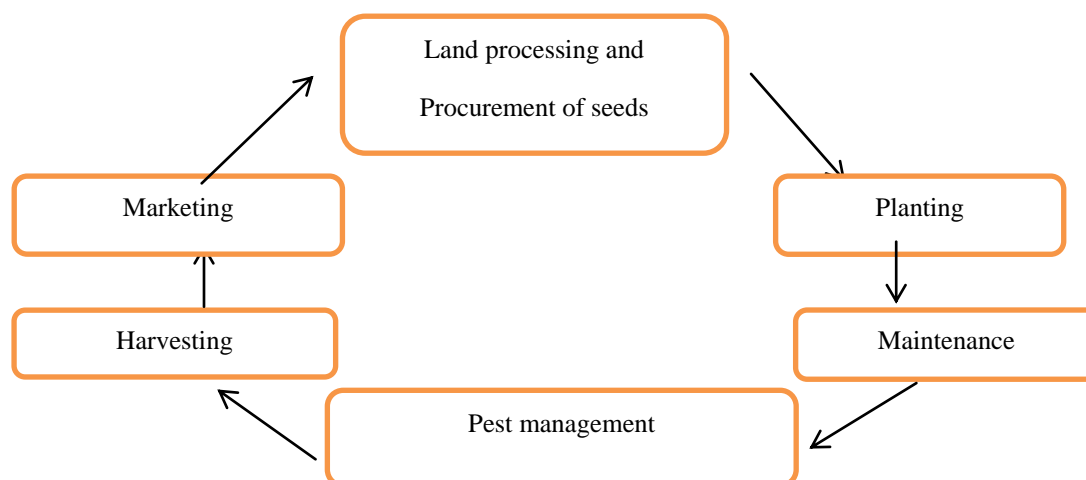


Figure 1. Schematic of Traditional Agroforestry Land Management Process

Most farmers still used random seeds when inserting coffee plants. This was because random seeds were easy to find in their garden [11]. The average number of types of plants planted by farmers [12] was shown in Table 2.

Table 2. Average Number of Plant Types Planted by Farmers

No	Average Types of Plants		
	Forestry	Fruits	Agriculture
	9	12	21
	10	9	11
	7	7	15
	6	5	10

Most of the forestry plants were pine, aren and suren, while fruit trees included avocado, jackfruit and durian. Coffee, ginger, corn, peanuts and bananas were agricultural crops that were mostly grown by farmers. In agroforestry, the plant spacing was generally irregular, the number of trees of each type varies, and within one species there were different age variations, so that there were harvesting time variations between each agroforestry plant which also caused differences in time in obtaining income from agroforestry products [1].

The observations in the field showed that in the agroforestry pattern in Paraduk Village there were no regular spacing done by farmers which meant that there was less attention to provide growing space for plant development. According to the farmers, the closer the spacing, the more plants were able to be planted so that they would generate greater income as well. This caused an unequal distribution of sunlight and nutrients to intolerant and tolerant plant species. Agroforestry garden maintenance activities included weeding and fertilizing activities. The damage that occurs to plants growing on agroforestry land was generally caused by pests and diseases. However, there were also several cases of damage experienced by farmers where their crops were attacked or disturbed by buffalo, wild boar and mongoose; they damage the farmers' gardens by eating the leaves and fruit in the gardens. The insecticide that was often used was Decis. The reason behind this choice was because it contained low residue, did not harm humans when used, and had low price. The various tree types in this agroforestry pattern caused different harvesting times depending on the productivity of these types of plants. Harvesting annual plant species, namely wood, was aimed to meet household needs, such as building a house or other needs, paying debts, having big parties, and other needs. Farmers usually sold felled wood in the form of boards and beams of various sizes, while branches and twigs were also be sold as firewood [12]. The same statement was stated by [4]. Income from timber was able to be used not only for daily needs but also for meeting temporary needs such as for tuition fee for the children, for celebrations, building houses, and other urgent needs. Forest resources, especially in agroforestry management, had a very high resource value [1].

The results of the interviews showed that the type of plant that was often to be the source of farmers' income was coffee. This is because the harvest period was fast, namely every week, so it was faster to sell and get income. Price differences that occurred between farmers, agents, and the market were caused by several factors, mostly are the difference in profits and transportation costs for different distances [12].

IV. CONCLUSION

By adopting the traditional agroforestry systems, farmers started to grow intensively harvested and managed species that gain more added value from previous farming activities. Agrisilvicultural patterns in farming used various types of plants with different harvest times so that they were able to be harvested according to needs and obtained sustainable income. Cultivation activities were carried out individually and in groups which were done in accordance with the Technical Guidelines for Good Coffee Cultivation, starting from land preparation, shade plants planting, seeding, planting, fertilizing, pruning and shade plants processing. The series of farmer activities carried out to manage traditional agroforestry included: land management, procuring a variety of seeds, planting, plant maintenance, pests and diseases management, harvesting, and marketing the yields. The product that was often to be sold was those of coffee plant, because of its short harvest period, which was every week, so the farmers were able to get faster and easier income from it.

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