Agroforestry development in Lake Toba catchment area: Farmer's perception and interest

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Abstract. The Lake Toba Catchment Area (LTCA) has degraded due to a lack of implementation of conservation principles. Agroforestry is one of the land-use techniques with a conservation approach. Agroforestry development in LTCA should be supported by stakeholders, especially farmers. Farmers' support will be formed if they have a good perception and interest in developing the agroforestry systems. The study aims to determine farmers' characteristics, perceptions, and interests in agroforestry development in LTCA. The study was conducted from July until August 2019 at Simalungun Regency, North Sumatra Province. Data were collected through semi-structured interviews using a questionnaire with 30 respondents. Measurement of farmers' perception and interest use a Likert scale. The data were then analyzed descriptively. The results showed that the farmers' age is dominated by the productive phase (30-50 years old); they are only completed elementary schools, with average landholding was <0.3 ha, and farming experience >10 years. Farmers' perceptions and interests in agroforestry development in LTCA are in good categories, each with a score of 4.18. These perceptions and interests of farmers are supporting factors that would positively impact the development of sustainable agroforestry in LTCA.

1. Introduction

Lake Toba is the largest volcanic lake globally, was formed due to the largest volcanic eruption ever to occur on earth approximately 75,000 years ago [1]. Lake Toba is located in the province of North Sumatra-Indonesia at 905 m above sea level (asl). The Lake Toba Catchment Area (LTCA) is about 110,000 ha of lake and 280,000 ha of land and classified as 43% hilly and 30% mountainous with peaks more than 2000 m asl, mostly covered by forest and farming area [1 - 3].

LTCA has degraded due to a lack of implementation of conservation principles in its land use. From 1985 to 1997, LTCA has lost about 16,000 ha of forest areas. The cause of this situation is the illegal conversion of the forest into farming land [3]. LTCA faces environmental crises like widespread deforestation, drought, a decline of the water level in the lake, a decrease in water quality, and loss of biological diversity [1]. More than half of LTCA is classified as critical land or land with high erosion risk, and this condition affects many farmers and natural resources.

Various types of agricultural crops, estate crops, and forest trees found in LTCA are potentially developed in agroforestry systems [4]. Definition of agroforestry is an art and science of cultivating trees in association with crops [5]. Agroforestry is land use techniques with a conservation approach and able to improve community livelihood sustainability. Agroforestry is linked to the double goal of providing a sufficient income to farmers and maintaining environmental services [2]. Agroforestry is
able to mitigate environmental problems through several mechanisms such as ecological and economic benefits through agricultural output. Hopefully, through agroforestry, land productivity around the LTCA will be improved, and the community's income will be increased.

Attempts to restore the ecosystem condition of the LTCA have been made a lot; however, these efforts have not produced sustainable results because of a lack of stakeholder coordination and support [3]. Agroforestry development in LTCA should be supported by stakeholders, especially farmers. Ecosystem services are related to agricultural activities. The concept of ecosystem services acknowledges that human and their environment are tightly linked. Stakeholder involvement in maintaining ecosystem services is particularly important in order to understand people's values and needs [6, 7]. Farmers' support in developing a sustainable agroforestry system will be formed if they have a good perception and interest. Farmers' perceptions of technologies in agriculture influence adoption behavior [8] to rehabilitate the critical land surrounding the LTCA and improve its productivity. Prioritas Nasional (PRINAS) implemented sustainable agroforestry systems that combine superior local plants with horticultural crops. This study aims to determine the characteristics of the farmers, farmer's perception, and interest in developing sustainable agroforestry systems.

2. Materials and Methods
The study of farmers' perception and interest in agroforestry development was conducted from July until August 2019. The data collected consists of primary and secondary data. The primary data were collected by semi-structured interviews using a questionnaire. Respondents in this study were farmers (30 respondents) in Pondok Buluh Village, Panribuan Sub-District, Simalungun District, North Sumatra Province, Indonesia. This village is located around the sustainable agroforestry demonstration plots that were established by PRINAS Project. The demonstration plot is placed in the Aek Nauli Forest Area with Special Purposes (KHDTK Aek Nauli). KHDTK is a forest area designated by the government for research and development, education and training, and religion and culture purposes [9]. The selection of respondents is using the purposive sampling method, i.e., farmers with agroforestry activities. The farmers in Pondok Buluh Village had practiced agroforestry activities by planting a combination of trees with crops.

The Primary data include internal characteristics of respondents, farming characteristics, farmers' perceptions and interests. Measurement and analysis of farmers' perception and interest are using a Likert scale. The Likert scale is a psychometric scale with multiple categories from which respondents choose to indicate their opinions, perceptions, attitudes, and feelings about a particular issue [10]. The variables to be measured are described through indicators in questions form that needs to be answered by respondents using a Likert scale. This study uses a Likert scale, with the highest score in each question being five and the lowest score being one (1).

| Perception Level                      | Score |
|---------------------------------------|-------|
| Very agree/very good/very important   | 5     |
| Agree/good/important                  | 4     |
| Less agree / less / less important    | 3     |
| Disagree/bad/not important            | 2     |
| Very disagree/very bad/very unimportant | 1    |

Scale interval = \( \frac{\text{maximum score} - \text{minimum score}}{\text{number of scales}} \)

The secondary data were collected through literature studies on statistical data from Statistics of Simalungun Regency, journals and related reports. The data were analyzed descriptively.
3. Results and Discussion

3.1. Internal characteristics

The internal characteristics of farmers are inherent in farmers themselves, consisting of age, education, farming experience, and landholding size. Some of these variables are related to perception.

3.1.1. Age. The age of farmers is dominated by the moderate with productive age, 30-50 years (55%) almost equal to farmers whose age are classified as old or more than 50 years (40%). Meanwhile, the percentage of young people whose age is less than 30 years was only 5% (Figure 1). This shows that farming at the study site is dominated by productive moderate ages and old farmers.

![Figure 1. Percentage of respondents based on age group.](image)

The farmer's age will align with his experience and knowledge following his biological growth and psychological development. Older farmers tend to be more cautious, so there is an impression that they are relatively unresponsive or slow. It does not mean that they do not want to accept changes, but maybe they have practical considerations.

3.1.2. Education. Education is the highest level or level of the farmer's last formal school. The education level of respondents is presented in Figure 2. Respondents, who finished primary school only, were reached 40%. In Pondok Buluh Village, there are only elementary schools, while junior school and senior high school are far from the village [13]. Most of the reasons children stop their studies are financial conditions, distance to the school, and transportation facility. The farmers who have an education level of junior school were as much as 30%. Meanwhile, very few farmers can continue their education to a higher level. Only about 20% of farmers can continue their education to high school and 10% can continue their studies at university.
Based on agroforestry research results in Lampung, education and landholding sizes are factors that significantly influence farmers' perceptions of landscape management of agroforestry [14]. Education, both formal and non-formal, is to increase knowledge and skills. Farmers who are well educated and have more technical knowledge will be able to communicate well. Therefore, farmer's education levels can influence their perceptions [15].

3.1.3. Farming experience. Farming experience is the length of agricultural activity carried out by the farmer expressed in units of years. Experience is a person's interaction with the environment to get knowledge, skills, and understanding of everything. Farmer experience is related to adopting technology or farming systems, while farming experience is useful in the early stages of the adoption of new farming technology [16].

Figure 3 shows that the farming experience of respondents is generally long (>10 years), which is about 80%. Farmers have been farming for a long time because it has been passed down from generation to generation, usually by their parents. Farmers with moderate farming experience (5-10 years) are only 15%. Farmers with new farming experience (<5 years) were just only 5%.
3.1.4. Landholding size. Landholding size is the land area managed by farmers for agricultural activities expressed in hectares. Figure 4 shows the percentage of the landholding size of the farmers. Most of the farmer's landholding size is <0.3 hectares (45%) and 35% landholding size of 0.3-0.5 hectares and the rest 20% landholding size is >0.5 ha.

The land is the main point in farming. It is one of the production factors, a place where agricultural products are produced, which significantly contributes to farming because the farming productivity is strongly influenced by the size and fertility of the land. Therefore, landholding size is one factor that has a positive and significant effect on farmer productivity [17].

![Figure 4. Percentage of respondents based on landholding size.](image)

3.2. Farming characteristics

Farming characteristics are the characteristics of an optimum farming environment for farmers, including (a) The conditions of current farming, and (b) The conditions of farming that are desired, the expectation of future farming conditions. The farming activities include selecting crop species and seeds, applying fertilizer, land preparation, pests and diseases prevention, crop yield, and crop market.

3.2.1. The existing farming conditions. The existing farming conditions are the current conditions in farming activities. Table 1 shows that the farming conditions are generally less, indicated by the average score for all aspects is 3.39.

| No  | Aspect                        | The average score | Category |
|-----|-------------------------------|-------------------|----------|
| 1   | Selection of crop species     | 3.55              | Good     |
| 2   | Selection of crop seeds       | 3.95              | Good     |
| 3   | Application of fertilizer     | 3.40              | Less     |
| 4   | Land preparation              | 2.90              | Less     |
| 5   | Prevention of pests and diseases | 3.35          | Less     |
| 6   | Crops yield                   | 3.35              | Less     |
| 7   | Crops Marketing               | 3.20              | Less     |
|     | The average score of all aspects | 3.39             | Less     |

Remarks: 1. 1.80 = very bad; 1.81-2.60 = bad; 2.61-3.40= less; 3.41-4.20 = good; 4.21-5.00= very good
Based on the results of interviews with farmers and observations in the field, we know that the types of plants in agroforestry at Pondok Buluh Village are as follows:

1. Forest (trees): *Toona sureni*, *Styrax benzoin*.
2. Multi-purpose and fruit trees: *Parkia speciosa*, *Durio zibethinus*, *Arenga pinnata*, *Archidendron jiringa*, and *Persea americana*.
3. Estate (crops): *Hevea brasiliensis*, *Coffea arabica*, *Theobroma cacao*, *Musa paradisiaca*.
4. Annual food crops and spices: *Zea mays*, *Capsicum annuum*, *Capsicum frutescens*, *Curcuma domestica*, and *Zingiber officinale*.

Farmers’ preference for plant type is in line with their wishes (Table 1.) Farmers also do not have difficulties in obtaining the seeds of the preferred plant species. The selection of crop species was crucial because the mistakes that might happen will have a long impact and be very damaging [4]. The selected species should be suitable with the specific site, grow and develop ideally together with other crops, and meet market expectations. The species site matching is an important aspect in choosing the type of plants [18]. It is known that for forest trees, farmers choose to plant *suren* tree (*T. sureni*) or, in the local language, called *ingul* tree. Meanwhile, farmers at Pondok Buluh Village are very interested in cultivating coffee (*Coffea arabica*) for estate crops.

Based on the interview results with farmers, the current condition of crops at Pondok Buluh Village for fertilizer, land preparation, and prevention of pests and diseases have a score of less than 3.40 with category less. Thus, farmers are still not satisfied with the current condition of crops where fertilizer application is still lacking. In addition, the plants such as bananas, chilies, and corn are still disturbed by pests such as caterpillars, pigs, and monkeys.

**3.2.2. The expectation of future farming conditions.** The expectation of future farming conditions is the ideal conditions that farmers expect to occur in their farming activities. Table 2 shows that the expected future farming conditions on the average score are generally 4.54 (very good). The farmers expect an improvement in all aspects. Improvement in the selection of plant type is related to an expectation of crops yield and crops marketing. Farmers prefer to select plant types based on growth suitability, market interest, and reasonable selling price. The farmers always considered the prices of crop yields in choosing plant types. The type of plant whose selling prices are relatively stable is safer to choose. The farmers are also interested in developing a new species of plant with high prices [19].

**Table 2. The average score of expectation farming conditions.**

| No | Aspect                              | The Average Score | Category     |
|----|-------------------------------------|------------------|--------------|
| 1  | Selection of crop species           | 4.35             | Very Good    |
| 2  | Selection of crop seeds             | 4.60             | Very Good    |
| 3  | Application of fertilizer           | 4.60             | Very Good    |
| 4  | Land preparation                    | 4.45             | Very Good    |
| 5  | Prevention of pests and diseases    | 4.60             | Very Good    |
| 6  | Crops yield                         | 4.70             | Very Good    |
| 7  | Crops Marketing                     | 4.45             | Very Good    |
|    | The average score of all aspects    | 4.54             | Very Good    |

Remarks: 1-1.80 = very bad; 1.81-2.60 = bad; 2.61-3.40 = less; 3.41-4.20 = good; 4.21-5.00 = very good

Agricultural land in LTCA is marginal in quality, with most of the soil is low fertility [2]. Thus, one of the crops' characteristics is intensive treatment more than forestry plants [18]. This is in line with farmers’ expectations that there should be improvements in crop management to increase soil fertility. Based on the results of interviews with farmers, it is known that they hope to add fertilizers so that the soil will be more fertile.
3.3. Development of sustainable agroforestry

KHDTK Aek Nauli is a mountainous area with an altitude between 1000-1750 m asl, with a slope ranging from 25 to 40%. KHDTK Aek Nauli is a part of the LCTA and a habitat for various protected plant and animal species. KHDTK Aek Nauli is located along the roadway to the tourist area of Lake Toba.

In the PRINAS project, the development of sustainable agroforestry demonstration plots at KHDTK Aek Nauli was carried out by combining a local superior tree species, i.e., sureni (T. sureni) and some adaptive tree species around LTCA such as taxus (T. sumatrana), macadamia (M. integrifolia), and andaliman (Z. acanthopodium) with the intercrops like mulberry (M. cathayana) and ateng coffee (Coffea arabica). Ateng coffee is a local name for varieties of arabica coffee widely developed in Simalungun District, North Sumatra Province. The advantages of this type of coffee are that the plants are relatively short and bear much fruit [20].

The total area of the sustainable agroforestry demonstration plot that has been established is about 4 hectares. The plots have the following planting pattern: 3 hectares planted with trees: T. sumatrana, M. integrifolia, and Z. acanthopodium with a spacing of 10 x 6 m and combined with coffee plants with a spacing of 2 x 1.5 m. At the same time, 1 hectare was planted with tree T. sureni with a spacing of 10 x 5 m and combined with M. cathayana with a spacing of 2 m x 1 m. The sustainable agroforestry pattern is expected to provide continuous income throughout the year. The main plants were planted with wide spacing, so there is adequate space for planting agricultural/estate crops/mulberry crops [21].

The forest area is a natural resource that has economic and ecological functions. Economic function related to forest products in the form of timber and non-timber forest products. Ecological functions related to environmental services such as ecotourism. The development of a sustainable agroforestry demonstration plot in KHDTK Aek Nauli has economic and ecological functions.

Development of sustainable agroforestry in KHDTK Aek Nauli aims to rehabilitate the degraded forests, produce wood (T. sureni wood) and non-wood forest products (macadamia fruit, andaliman fruit, coffee), and create environmental services through natural silk ecotourism. T. sureni wood is suitable for boats and is also used as raw materials for handicrafts and typical Batak carvings. M. integrifolia produces edible seeds and ateng coffee provides potential cash income for farmers. This agroforestry pattern can also support Lake Toba tourism's development through silkworm cultivation attraction and the diversification of natural silk products. The natural silk as an ecotourism attraction presented starting from the introduction of mulberries, silkworm cultivation, feeding the silkworm with mulberry leaf, cocoon harvesting, and processing of diversification of natural silk products.

Agroforestry patterns have been proven to be able to contribute to farmers' income. The amount of the agroforestry contribution is generally influenced by many factors. Those were land area, the selling price of agroforestry commodities, and the plant types. Agroforestry commodities can contribute to farmers' income, especially fruits and woods. Factors that affect the sustainability of the agroforestry system include the provision of agroforestry technology, counseling, government support, and the seriousness of farmer groups. [22].

The sustainable agroforestry demonstration plot in KHDTK Aek Nauli has become a show window in the development of sustainable agroforestry. The combination of timber trees, estate crops, and silkworm cultivation can increase land productivity and high environmental value [23]. Thus, this sustainable agroforestry demonstration plot can showcase lessons learned in rehabilitating the forest and land areas in LTCA. Furthermore, the ecological and economic benefits of agroforestry systems can improve environmental conditions, increase food security, and improve the economy [24-25]. Therefore, integrated agriculture development in an agroforestry system (livestock, livestock feed, agriculture, estate crops, and forestry) is prioritized to create a sustainable forest and a prosperous community [4].
3.4. Farmer's perception
Perception is the way you think about something. Perception is how people see and interpret events, objects and humans. The perception process consists of three stages: selection, organization, and interpretation [26]. Most attitudes and behavior were influenced by their perceptions [27].

Agroforestry serves multiple functions, such as economic and environmental services [4]. The development of agroforestry focused on the community living near the forest in order to provide optimal benefits for them. Positive views from the farmers related to the way of thinking may positively impact agroforestry development [28]. Therefore, it is crucial to identify farmers’ perceptions of developing a sustainable agroforestry system at LTCA.

| No | Aspect                        | The average score | Category  |
|----|-------------------------------|-------------------|-----------|
| 1  | Environmental condition       | 4.30              | Very good |
| 2  | Farmer motivation             | 4.10              | Good      |
| 3  | Selection of crop seeds       | 4.00              | Good      |
| 4  | Application in the field      | 4.20              | Good      |
| 5  | Increased revenue             | 4.20              | Good      |
| 6  | Marketing                     | 4.30              | Very good |
| 7  | Participation                 | 4.20              | Good      |
| 8  | Institutional                 | 4.10              | Good      |
| 9  | Increased welfare             | 4.20              | Good      |
|    | The average score of all aspects | 4.18          | Good      |

Remarks: 1-1.80 = very bad; 1.81-2.60 = bad; 2.61-3.40= less; 3.41-4.20 = good; 4.21-5.00= very good

In general, the farmers’ perceptions (Table 3) are good. Farmers perceive that agroforestry development in LTCA is good because this sustainable agroforestry development will motivate farmers’ enthusiasm, facilitate the selection of plant seeds, be easy to apply in the field, and increase farmer's income and participation, and strengthen farmer group institutions.

Farmers also value the perception that agroforestry development in LTCA is outstanding because it is supported by environmental conditions such as species of plants, topography, soil fertility and suitable climate for agroforestry activities. Therefore, factors that should be considered for achieving success in agroforestry are environmental factors, supporting factors, and socio-cultural factors [4].

Sustainable agroforestry development potentially increases the marketing of harvested products. The marketing of agroforestry products is considered an important aspect [18]. The selection of plant species, trees and estate or mulberry crops in sustainable agroforestry demonstration plots has widely considered marketing. Trees and estate crops planted in the demonstration plots like *T. sureni* and *C. arabica* are known to have economic and market value. The farmers make agroforestry patterns with *T. sureni* to increase revenue and prevent erosion and landslide [29]. Farmers around LTCA currently cultivated *C. arabica* because of its great demand and economic value. These estate crops have long supported the economy of communities around LTCA [30]. Farmers in LTCA have the perception that agroforestry by combining *T. sureni* trees and *C. arabica* will be very profitable because it has high economic value, where the yield from *C. arabica* can increase household income, and *T. sureni* wood can be an investment for the future.

3.5. Farmers’ interest in the development of sustainable agroforestry systems
Interest is a desire, a high inclination of the heart towards something. Interest is a feeling of liking or bounding with a thing or activity without anyone asking for it [31]. For example, the interest of farmers is the desire to be involved in agricultural activity. Several factors influence farmers’ interest: land area, experience, income, assistance, and education [32].

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Farmers' interest in agricultural activities is also influenced by their perceptions [33]. Therefore, farmers' interest in agroforestry development is good because this activity is interesting for them, very suitable for the development of LTCA, provide to the farmers' livelihoods, and is also suited for filling their spare time.

Table 4. The Average score of farmers' interests in agroforestry development in LTCA.

| No | Aspect                                          | The average score | Category     |
|----|------------------------------------------------|------------------|--------------|
| 1  | Agroforestry is interesting for farmers         | 4.50             | Very good    |
| 2  | Agroforestry is suitable for LTCA development  | 4.30             | Very good    |
| 3  | Agroforestry is suitable for the main livelihood | 4.10             | Good         |
| 4  | Agroforestry is suitable for side livelihood   | 3.90             | good         |
| 5  | Agroforestry is suitable for filling leisure time | 4.10             | good         |
|    | The average score of all aspects               | 4.18             | good         |

Remarks: 1.0-1.80 = very bad; 1.81-2.60 = bad; 2.61-3.40 = less; 3.41-4.20 = good; 4.21-5.00 = very good

Table 4 shows that farmers have a strong interest in the development of sustainable agroforestry at LTCA. This can be seen from the aspects of interest, suitability, and livelihoods. According to the livelihood aspect, farmers are interested in agroforestry development as the main livelihood, a side income, or to fill their spare time. One of the reasons farmers' interests in agroforestry development are related to the agroforestry design is the broader spacing for the trees by using a spacing of 10 m x 5 m. This spacing is in line with farmers' expectations because coffee plants can produce continuously throughout the year. In addition, agroforestry as a mixed-farming model has an increasingly significant role for farmers with limited landholding size. Therefore, applying a better pattern will provide the possibility to increase harvest and farmers' revenue [30]. Therefore, the selection of tree and crop species, cropping patterns, and spacing influence farmers' interest in developing agroforestry.

4. Conclusions
Most of the farmers at the research site are of productive age, have low education, have long farming experience, and have landholding size <0.3 ha. All farmers are not satisfied with the current farming condition; in the future, they expect an improvement in all farming aspects. The development of agroforestry systems in Lake Toba Catchment Area aims to rehabilitate the degraded forests, produce timber and non-timber forest products, and develop environmental services through natural silk ecotourism. The establishment of sustainable agroforestry demonstration plots at KHDTK Aek Nauli was carried out by combining a local superior tree species with the intercrops like mulberry (Morus cathayana) and coffee (Coffee arabica). Farmers' perceptions of agroforestry development through the establishment of sustainable agroforestry demonstration plots are considered good, with a score of 4.18. It is because they have a positive view both from an economic and ecological perspective. Farmers also have a good interest in sustainable agroforestry development, both as their main and secondary livelihood.

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