Analytical hierarchy process (AHP) application in the selection of plant types on the community's agroforestry land

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Abstract. This research was conducted to develop a participatory in selecting the types of plants that are of interest to the community in agroforestry land. This study aimed to determine the plants types by the community in agroforestry land using the Analytical Hierarchy Process (AHP). This research was conducted from March to July 2019 in Sari Laba Jahe Village, Sibiru-biru Sub-district, Deli Serdang Regency, North Sumatra Province. Interviews and discussions with key respondents were conducted to obtain data and information related to the criteria and alternatives to be compiled in the AHP questionnaire. The data from the questionnaire was processed using the Expert Choice Software. The highest value obtained is the criteria for community knowledge about plants with a value of 0.237, followed by resistance to pests and diseases (0.223), characteristics and land quality (0.194) and community welfare (0.193). While the lowest weight value is found in the criteria for community needs with a value of 0.153. The most preferred types of plants to be planted on agroforestry land are rubber with a weight value of 0.233, followed by sengon (0.199), avocado (0.165), durian (0.164), teak (0.133) and mango (0.105). By conducting this research, they can help the decision-maker in terms of activities related to improving the community's economy, especially planting superior species.

1. Introduction
The Analytical Hierarchy Process (AHP) is one of the decision support systems that can be applied to determine the types of plants that people are most interested in planting based on certain criteria. Decision Support System (DSS) is an interactive information system that provides information, modelling and manipulating data. The DSS is used to assist decision making in semi-structured and unstructured situations where no one knows for sure how decisions should be made. Decision support systems are built to support the solution to a problem or to evaluate an opportunity. This AHP method can be used to solve a complex unstructured situation into several components in a hierarchical arrangement, by giving a subjective value about the relative importance of each variable, and determining which variable has the highest priority to affect the results in that situation [1]. The working principle of the AHP method is the identification of causal factors, hierarchical arrangement, prioritization, consistency and priority weights [2]. The causal factors can be expanded into criteria in
decision making [3]. The arrangement of the hierarchy is by determining the goals which are the goals of the overall system at the top-level [4].

Determination of the priority of each criterion and alternative in the AHP must be compared by pairwise comparison so that the value of the importance of the elements in the form of a qualitative opinion is obtained [5]. To quantify the qualitative opinion, a rating scale is used so that the opinion value will be obtained in the form of numbers (quantitative) known as the Saaty scale [6,7]. The AHP is a decision support model developed by Thomas L. Saaty. This decision support model will describe a complex multi-factor or multi-criteria problem into a hierarchy. It is an analysis and synthesis method that can assist the decision-making process. It is also a powerful and flexible decision-making tool, which can help in setting priorities and making decisions where qualitative and quantitative aspects are involved and both must be considered [2,6,7].

The AHP method is one of the multi-criteria decision makings that can assist in decision making. This method has been applied in many aspects. One of them can be applied to determine the type of salak agroforestry in South Tapanuli Regency, North Sumatra Province. The AHP method requires expert respondents to fill out questionnaires and interviews with several expert respondents. The expert respondent's assessment includes an assessment of the criteria and alternatives based on a predetermined rating scale [2,6,7]. Various studies using AHP have been carried out, such as: using the AHP method to plan forest management strategies [8], using AHP to determine allocations best land use, [9] and various applications of AHP in various fields and various regions [10,11,12,13,14,15,16,17].

In general, the people of Sari Laba Jahe Village apply an agroforestry system to their land. Sari Laba Jahe Village was chosen as the research location, because most of its area is an agricultural area. In addition, the people of this village mostly work as farmers and have good knowledge about farming. In addition, the territory has fertile soil. Various types of forestry plants and multi-purpose tree species (MPTS) have been planted in Sari Laba Jahe Village, but it is not yet known what types of plants are the priority for farmers to plant. Therefore, this research needs to be done. This study aimed to determine the priority level of forestry plant species and MPTS plants that are most in demand by the community to be planted and which can increase the level of community income in the area by using AHP.

2. Materials and Methods

2.1. General condition of the research site
Sari Laba Jahe Village with an area of 8.88 km² is located in Sibiru-biru Sub-district, Deli Serdang Regency. Geographically, it is located between 3°28'-3°47' North Latitude and between 9°861'-9°870' East Longitude. The boundaries of the area are to the north it is bordered by Deli Tua Sub-district, to the south by Sinembah Tanjung Muda (STM) Hilir Sub-district, to the east by Patumbak Sub-district, and the west by Namo Rambe Sub-district [18]. Most of the people of Sari Laba Jahe Village work as farmers. Sari Laba Jahe Village is located at an altitude of 28 meters above sea level.

2.2. Data Collection
The step of this research is: determining expert respondents, making hierarchical structures, making AHP questionnaires, filling out questionnaires by expert respondents, processing data with expert choice and determining the weights of criteria and alternatives. The expert respondents selected in this study consisted of ten people who were selected purposively. In this study, the AHP questionnaire was arranged based on a hierarchy structure. The hierarchical structure of the problems compiled must reflect the relationship between the goal, criteria, and alternatives. In addition, interviews were also conducted with key informants/stakeholders. Key informants provided in-depth qualitative information about the physical and socio-economic conditions of the study area. Key informants/stakeholders are people who are familiar with the research site.
2.3. Data analysis
Analysis of the data in this study using AHP. AHP using a systems approach for decision making. The recommended procedure for solving a problem using the AHP method based on the AHP principles is as follows:

2.3.1. Organize problems into a hierarchy
In this step, the objectives to be achieved are mutually agreed upon with the expert respondents. Next, determine the criteria and alternatives to achieve the goal.

2.3.2. Comparing hierarchical elements on paired bases
Based on the hierarchical level, then fill out the questionnaire with a weight vector on the AHP scale from 1 to 9, known as the Saaty scale (Table 1).

| Level of Interest | Definition                     |
|-------------------|--------------------------------|
| 1                 | equal importance               |
| 3                 | moderate importance            |
| 5                 | essential or strong importance |
| 7                 | very strong importance         |
| 9                 | extreme importance             |
| 2, 4, 6, 8        | If in doubt between two adjacent values |
| 1 / (1-9)         | The inverse of importance values on a scale of 1-9 |

2.3.3. Merge all priority vectors
The last step is to combine the priority vectors (weights) of each level obtained in the second step, to produce the overall weight. All data was obtained from the results of filling out questionnaires by expert respondents, then processed using an expert choice application/software.

3. Results and Discussions

3.1. Respondent characteristic
Based on the results of the study, the characteristics of the expert respondents were all natives of Sari Laba Jahe Village and came from the Karo Tribe. Gender of expert respondents 70% were male and 30 were female (Figure 1). The age range of respondents is 22 to 58 years (Figure 2). The level of education of expert respondents is senior high school and junior high school (Figure 3). The occupations of the expert respondents are mostly farmers (70%) and the rest are civil servants (village officials).
Figure 1. Gender of expert respondents.

Figure 2. Education level of expert respondents.
3.2. Hierarchy structure of forestry plant species selection and MPTS

Based on the results of discussions with expert respondents, a hierarchical structure chart was obtained in the selection of forestry plant species and MPTS as presented in Figure 4.

![Hierarchical structure chart in the selection of forestry plant species and MPTS.](image)

**Figure 4.** Hierarchical structure chart in the selection of forestry plant species and MPTS.

Based on Figure 4, it can be seen that there are five criteria in the selection of forestry plant species and MPTS in Sari Laba Jahe Village, namely: land characteristics and quality, pest and disease resistance, community needs, community knowledge of plants, community welfare. Based on Figure 4, it can be seen that there are six choices of plant species in the selection of forestry plant species and MPTS in Sari Laba Jahe Village, namely: avocado, durian, mango, teak, sengon, and rubber. The selection of these six types of plants is based on the types of plants that have been planted by the people of Sari Laba Jahe Village for a long time ago.
3.3. Priority level of criteria and alternatives in the selection of forestry plant species and MPTS

Based on the results of data processing using expert choice, the ranking criteria can be seen in Table 2. The rankings for alternative plant species are presented in Table 3.

Table 2. Ranking of respondents selection results based on criteria.

| No | Criteria                              | Value weight | Rank |
|----|---------------------------------------|--------------|------|
| 1  | Land characteristics and quality      | 0.194        | 3    |
| 2  | Disease pest resistant                | 0.223        | 2    |
| 3  | Community needs                       | 0.153        | 5    |
| 4  | Community knowledge of plants         | 0.237        | 1    |
| 5  | Public welfare                        | 0.193        | 4    |

Table 3. Ranking of respondents selection results based on alternatives.

| No | Alternative                     | Value weight | Rank |
|----|---------------------------------|--------------|------|
| 1  | Durian (*Durio zibethinus*)     | 0.164        | 4    |
| 2  | Avocado (*Parqia speciosa*)     | 0.165        | 3    |
| 3  | Mango (*Mangifera indica*)      | 0.105        | 6    |
| 4  | Rubber (*Hevea brasiliensis*)   | 0.233        | 1    |
| 5  | Sengon (*Paraserianthes falcata*)| 0.199        | 2    |
| 6  | Teak (*Tectona grandis*)        | 0.133        | 5    |

Based on Table 2, the community's knowledge of plants has the highest value with a value of 0.237. While the weight of the smallest element value is found in the community needs factor with a value of 0.153. This shows that the knowledge factor of the people in Sari Laba Jahe Village has good knowledge in terms of selecting plant types that can increase income. As for other factors, namely the characteristics and quality of land with a weight value of 0.194; pest resistance factor with a weight value of 0.223 and community welfare factor with a weight value of 0.193 which determines the selection of superior plants in Sari Laba Jahe Village.

Based on Table 3, it can be seen that the highest alternative that is most in demand by the people in Sari Laba Jahe Village for planting and increasing community income is rubber, followed by sengon, avocado, durian, teak, and mango. Based on the results of interviews with expert respondents, rubber was chosen because it can increase people's income compared to other crops.

Selection of superior plants with the AHP method can help make decisions more powerful and flexible because it can help in making choices consisting of several aspects in the assessment. AHP can help make choices about priorities and make decisions where qualitative and quantitative aspects are involved and both must be have considered [19].

4. Conclusions

Based on the criteria, the highest rank to preferred types of plants to be planted on agroforestry land is community knowledge about plants (0.237), followed by resistance to pests and diseases (0.223), characteristics and land quality (0.194), public welfare (0.193), and community needs (0.153). Based on alternatives, the most preferred types of plants to be planted, namely: rubber, sengon, avocado, durian, teak and mango. Rubber was chosen as a top priority because the community have a long time to planted rubber in combination with other types of plants.

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References

[1] Marsono 2014 The use of the AHP Method in Research (Bogor : Media Publisher)
[2] Rahmawaty, Teodoro R V, and Myrna G C 2011 Participatory Land Use Allocation Case Study in Besitang Watershed, Langkat, North Sumatra, Indonesia (Saarbrucken, Germany: Lambert Academic Publishing GmbH and Co. KG)
[3] Mustika 2017 Use of analytical hierarchy process method in Mangrove Park Location selection palomtech polytechnic Palembang Computer Science Journal Collection (CLICK) 4
[4] Tominanto 2012 Decision support system with Analytical Hierarchy Process (AHP) method for determining doctor’s performance achievement in RSUD Sukoharjo Infokes Journal 2 1-15
[5] Makkasau K 2012 The use of the Analytic Hierarchy Process (AHP) method in prioritizing health programs health promotion program case study Jati Journal Diponegoro University 7 105-112
[6] Saaty T L 2008 Decision making with the analytic hierarchy process Int J. Services Sciences 1
[7] Saaty T L and G Vargas 2012 The seven pillars of the analytic hierarchy process, models, methods, concepts and applications of the analytic hierarchy process International Series in Operations Research and Management Science 175
[8] Wedayani, Ni M, Widyasari, and Ni L 2020 Palasari forest management strategy planning with AHP method Journal of Environmentally Friendly Technology 4
[9] Rahmawaty, Abdul R, and Idasari S 2013 Application of Analytical Hierarchy Process to determine salak-based agroforestry system that most appropriate and sustainable for community proceedings of the international symposium on Tropical Forest Ecosystem Science and Management 11-13
[10] Rahmawaty 2011 Application of Analytical Hierarchy process (AHP) for land use allocation Indian Journal of Ecology 38 159-165
[11] Saraan M, Rahmawaty, and Harahap R H 2020 Analysis of community participation at community forestry group (CF) in Forest Management Unit (FMU) region XIV Sidikalang North Sumatra Province international conference on agriculture, environment and food security (AEFS) IOP Conf. Series Earth and Environmental Science 454
[12] Rahmawaty, Najmatul K, and Abdul R 2015 Land use change assessment as an effort to mitigate climate change and Belawan watershed using integrated approach 2 nd international conference on tropical biology “ecological restoration in Southeast Asia: challenges, gains, and future directions”, SEAMEO BIOTROP, Bogor-INDONESIA
[13] Piri I, Moosavi M, Taheri A Z, Alipur H, Shojaei S, and Mousavi S A 2019 The spatial assessment of suitable areas for medicinal species of Astragalus (Astragalus hypsogeton Bunge) using the Analytic hierarchy process (AHP) and Geographic information System (GIS) Egypt J. Remote Sens. Sp. science
[14] Kurniawati A T and Munir M, 2017 Analytic hierarchy Process (AHP) for determining land use ranking J. Res. Technol 3 54–62
[15] Gumus, S 2017 An evaluation of stakeholder perception differences in forest road assessment factors using the Analytic Hierarchy Process (AHP) Forests 8
[16] López-Upton, J, Valdez-Lazalde, J R, Ventura-Rios, A, Vargas-Hernández, JJ, Guerra-de-la-Cruz, V 2015 Extinction risk of Pseudotsuga menziesii populations in the central region of Mexico: An AHP analysis Forests 6 1598–1612
[17] Nilsson H, Nordström E M, Iman K 2016 Decision support for participatory forest planning using AHP and TOPSIS Forests 7 100
[18] [BPS] Badan Pusat Statistik Statistics of Deli Serdang Regency 2019 Deli Serdang Regency in Figures 2018 Lubuk Pakam

[19] Gustina D and Siahaan R H 2016 Analysis of android jelly bean quality selection using the AHP Method Mcdm J. Ilm. FIFO 8 15