Sustainable development strategy for agroforestry

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Abstract. This research aims to determine the status of sustainability, key factors that influence, and the strategy of developing sustainable agroforestry farming. The study was conducted from January to December 2016 in the Sodonghilir subdistrict, Tasikmalaya Regency, West Java Province. Data is analyzed using sustainability analysis, prospective analysis, and hierarchy process analysis. The results showed that some of the ecological, economic, and social problems would reduce agroforestry farming's sustainability. The sustainability of agroforestry farming in the Sodonghilir sub-district is less sustainable, both in general and in each sustainability dimension (ecological, social, and economic). Two conclusions were obtained from the study. First, six key factors determine sustainable agroforestry development's success. There is farmers’ knowledge in soil and water conservation, farmer group performance, availability of agroforestry technology packages, farmers’ knowledge in farming activities, level of pest and plant diseases attacks, farming capital sources vital. Second, increasing farmer capacity and strengthening farmer group institutions are priority strategies that the government implement, private, and community in conducting sustainable agroforestry farming development programs in the Sodonghilir subdistrict.

1. Introduction
Agroforestry is a form of multidirectional land use that combines woody, seasonal crops, and/or livestock activities on one stretch of land simultaneously which is resulting in economic and ecological interactions between tree crops and other agroforestry constituents [1,2,3]. Land use with an agroforestry system provides several financial, ecologically, and socially [4]. Economically, agroforestry systems can increase land productivity, increase farmers' income, develop local economies, and meet community needs for clothing, food, and shelter [3,5,6]. Ecologically, the systems can efficiently use natural resources, improve soil fertility, and improve land hydrology functions [2,7]. Socially, agroforestry can create jobs in rural areas, reduce population pressure on natural forests, and reduce the rate of migration of people from villages to cities [2].

The benefits obtained from this system have encouraged various regions in Indonesia to develop agroforestry farming systems to optimize land use [8]. One area that has implemented the agroforestry system is Sodonghilir District, Tasikmalaya Regency, West Java Province.

In general, the dominant and developing agroforestry system in Sodonghilir Subdistrict is involved in a mixed garden form. Complex agroforestry is an agroforestry system consisting of many elements of trees, seasonal crops, and/or grass in one area of land with an unlimited amount and time [3]. Therefore, their physical appearance and dynamics are similar to those of primary and secondary natural forest ecosystems.
The problems faced in implementing the agroforestry system in Sodonghilir Subdistrict, including (1) the high attack of pests on sengon plants as the main crop such as bagworm pests and gall rust disease, (2) fluctuations in the price of seasonal produce, (3) common knowledge of farmers concerning agroforestry, (4) limited farming capital, (5) weak farming institutional system, both government, private and community institutions, and (6) the conversion of land to seasonal crops and/or settlements [9]. These problems will have the potential to reduce the sustainability of agroforestry farming.

Agroforestry farming management using a sustainable agricultural system approach is expected to be one solution to overcome the various problems farmers face in developing the old farming system in Sodonghilir District. Sustainable agriculture is defined as the ability of an agricultural business that is economically viable, safe for the environment, and socially acceptable to the community [10]. In general, the concept of sustainable agriculture is based on a triangular framework of sustainable development, namely development oriented towards three dimensions of sustainability that are mutually supportive and interconnected. The three dimensions are economic, social, and ecological [11].

Based on the background of the problems that have been raised, this research aims to determine the status of sustainability, the key factors that influence, and strategies for developing sustainable agroforestry farming. The research results are expected to be used as a material consideration for policymakers in developing sustainable agroforestry farming policies.

2. Methods
2.1 Time and Location of Research
The research was conducted from January to December 2016 in Sodonghilir District, Tasikmalaya Regency, West Java Province. The selection of research locations was carried out purposively, considering that Sodonghilir District is one of the areas targeted for developing sustainable agroforestry farming in the Tasikmalaya Regency [9].

2.2 Data Collection and Analysis Techniques
The data collected in this study consisted of secondary data and primary data. Secondary data were obtained from the literature studies and documentation studies on various related data such as research results, data from the Central Statistics Agency, village monographs, sub-district monographs, extension programs, and associated agency programs.

Primary data were obtained from interviews, research questionnaires, and discussions. Purposive sampling was used to identify respondents and they were categorized as an involved men, master, and people with knowledge of agroforestry farming in Sodonghilir District. Thirty respondents were assigned from the Sodonghilir District Agricultural Extension Center, village government, community leaders, sub-district government, Tasikmalaya Regional Forestry Service Branch VI, and agricultural / forestry traders products, farmer groups, and farmer group associations.

There are three data analysis tools used in this research, namely sustainability analysis consisting of multidimensional scaling (MDS) and leverage analysis, prospective analysis, and analytical hierarchy process (AHP) analysis. The analysis stages are shown in Figure 2.

The sustainability analysis was carried out using the Rapid Appraisal for Fisheries approach developed by the University of British Columbia. This sustainability analysis consists of Multidimensional Scaling (MDS) analysis and leverage analysis. MDS analysis serves to determine the index and status of the sustainability of agroforestry farming. The study identifies various factors that influence agroforestry farming in social, economic, and ecological dimensions. There are three final values generated from the MDS analysis: the sustainability index value, the coefficient of determination ($R^2$), and the s-stress value ($S$). The value of the agroforestry farming sustainability index in the data analysis is grouped into four levels of sustainability status, namely 0-25.00 (unsustainable), 25.01-50.00 (less sustainable), 50.01-75.00 (moderately tolerable), and 75.01-100.00 (ongoing) [13]. The model obtained from MDS analysis is said to be good enough (goodness of fit) if it has a value of $S < 0.25$ and $R^2 > 80\%$ or close to 100\% [12,14].
The sensitivity analysis (leverage analysis) is carried out to determine the research attributes that function as a leverage factor in agroforestry farming development. The Root Mean Square (RMS) change is the value obtained from the leverage analysis's final results. The more significant the difference in RMS value, the more sensitive this attribute's role is in increasing agroforestry farming's sustainability status [13]. The leverage factor is determined from an RMS value higher than half the sustainability dimension's highest weight [12].

These sensitivity analysis results are used to conduct a prospective analysis in determining the critical factors for agroforestry farming's sustainability by mapping the level of influence and the level of dependence between factors. The results of the prospective analysis are mapped in a diagram divided into four quadrants, namely [12]: a) the first quadrant contains the driving variables that have a strong influence with low inter-factor dependence, b) the second quadrant contains the leverage variables with the power strong and high inter-factor dependence, c) the third quadrant contains the dependent factor (output variables) which has a small effect with high inter-factor dependence, and d) the fourth quadrant contains marginal variables which have a little impact with support between factors low. Factors that enter into quadrants I and II are the critical factors in systems with strong influence characteristics with quiet/strong dependence on systems [12].

Analytical Hierarchy Process Analysis (AHP) analysis was used to determine priority strategies in agroforestry farming development. The priority strategy is determined based on the strategy's level of ability, described in priority weights in managing and meeting the critical factors generated in the prospective analysis. AHP analysis simplifies the various complex, strategic, dynamic, and multicriteria problems into a hierarchy consisting of three levels: goals, criteria, and alternative strategies [15,16,17]. The goal is a strategy to be achieved in conducting AHP analysis. The requirements are filled with all the key factors resulting from the leverage analysis and alternative designs are determined based on the results of discussions with various parties.

Figure 1. Data analysis stages

START

- Attribute review (various categories and scoring criteria)
- Identify and define attributes
- Score scoring (for each attribute)
- Multidimensional scaling ordination (for each dimension)
- Sustainability index and status
- Leverage analysis
- Prospective analysis
- Hierarchy process analysis

Sources: Modified from [12,13]
3. Results and discussion

3.1 Agroforestry Farming Sustainability

Based on the results of the sustainability analysis using MDS (Table 1 and Figure 4), it can be seen: 1) the level of agroforestry farming sustainability in Sodonghilir District is in a less sustainable status, both in general and each of the dimensions of sustainability (ecological, social, economic). Three critical factors cause the result. First, the index value on all dimensions of sustainability is in the range of 25.01-50.00. Second, the model generated from the MDS analysis has a value of S <0.25. It shows the effect of the error on assessing an attribute is minimal to be ignored. Lastly, the coefficient of determination ($R^2$) generated by each sustainability dimension has a value between 0.9320-0.9487. The resulting value shows that all the attributes (social, economic, and ecological) used in measuring agroforestry farming's sustainability status have explained 93% - 95% of the current system. The sustainability index for each sustainability dimension is presented in the kite diagram, as shown in Figure 4b.

**Table 1.** Results of analysis of the sustainability of agroforestry farming

| Dimensions     | Sustainability index | The coefficient of determination ($R^2$) | s-stress value |
|----------------|----------------------|-----------------------------------------|---------------|
| Multidimensional | 42.80                | 0.9572                                  | 0.1305        |
| Economic       | 40.11                | 0.9544                                  | 0.1343        |
| Ecology        | 35.03                | 0.9453                                  | 0.1338        |
| Social         | 43.25                | 0.9516                                  | 0.1308        |

![Figure 2](image1.png)  
**Figure 2.** Sustainability index of agroforestry farming in multidimensional (a) and kite diagrams of sustainability index in each dimension (b).

The sustainability analysis for the ecological dimension considers 12 research attributes that affect agroforestry farming's sustainability, as presented in Figure 5. Based on the sustainability analysis results using MDS analysis, the ecological dimension has a sustainability index of 35.03, so that its status is categorized as less sustainable. The resulting S and $R^2$ values are 0.1338 and 0.9453, which means that the MDS analysis model on the ecological dimension is good enough (goodness of fit). The model that uses these attributes can explain 94.53 percent of the real condition.

The leverage analysis results show that there are two attributes in the ecological dimension that function as leveraging factors for agroforestry's sustainability status, namely pest and plant disease attacks and organic material in cultivation activities agroforestry system. Management of these two leverage factors is expected to improve agroforestry farming's sustainability status in the future. The results of the leverage analysis for the ecological dimension are presented in Figure 5.
The ordination analysis results for the economic dimension involving 14 research attributes revealed a sustainability index value of 40.11 with an s-stress value of 0.1343 and a determination coefficient of 95.44. There were two pieces of information based on the research criteria. First, the sustainability index value was 25.01 - 50.00 and predicted it as a less sustainable category. Second, the s-stress value and the coefficient of determination implied the resulting model has a good enough value (goodness of fit) to predict the level of sustainability in the current research condition.

Leverage analysis of the economic dimension attributes produces three leveraging factors for agroforestry farming's sustainability: farming's ability to generate tiered income for farmers, a farming capital source, and the contribution to farmers' total revenue. The leveraging attributes that affect the sustainability of the economic dimension are presented in Figure 6.

Kite diagram in Figure 2b. shows that agroforestry farming in the social dimension, the result of the analysis of sustainability with MDS, is less sustainable because it has a sustainability index of 43.25 with an s-stress value of 0.1308 and a coefficient of determination of 95.16 percent. The s-stress value and the coefficient of determination show that the model with 18 attributes that make up the social
dimensions analyzed can explain 95.16 percent of agroforestry farming's sustainability conditions in the research location.

The results of the leverage analysis on the social dimension (Figure 7) show that of the 18 attributes analyzed, seven features can be used as leveraging factors for the sustainability status of agroforestry farming, namely farmer group performance, availability of agroforestry technology packages, farmer's knowledge in agroforestry farming, farmer's knowledge in soil and water conservation, frequency of agroforestry extension, farmer's experience in controlling pests and plant diseases, and participation of farmers in farmers groups. The seven attributes were chosen as leverage factors because they have a Root Mean Square (RMS) value higher than half the maximum RMS value. Therefore, the management of these three leverage factors will affect the improvement or improvement of agroforestry farming's sustainability status.

![Leverage attributes affecting the sustainability of social dimension.](image)

**Figure 5.** Leverage attributes affecting the sustainability of social dimension.

### 3.2 Key Factors in Agroforestry Farming Development

A prospective analysis revealed each leverage factor could be distributed in four quadrants: the determinants in quadrant I, connecting factors in quadrant II, dependent factors in quadrant III, and free factors in quadrant IV. Based on the results of a prospective analysis (Figure 8.), six key factors have a dominant influence on the development of agroforestry farming, namely: 1) five key factors that have a substantial effect between factors with low dependence, namely farmers' knowledge in soil and water conservation, farmer groups performance, availability of agroforestry technology packages, farmer's knowledge in agroforestry farming, level of pest and plant disease attacks and 2) one key factor that has a strong influence among factors with high dependence is the source of farming capital. The management of these six key factors will strongly influence agroforestry farming's sustainability in Sodonghilir District.

Farmers' knowledge in soil and water conservation is the first leverage factor that affects sustainable agroforestry development. Farmers need knowledge of soil and water conservation in conserving the carrying capacity, quality, function, and ability of soil, water and biodiversity resources in a harmonious and balanced manner [18]. Farmers who know soil and water conservation will always consider aspects of ecological sustainability and their farming's economic factors.
Based on the discussions with relevant stakeholders and field observations, it can be seen that farmers' knowledge about soil and water conservation is still lacking. One indication of the lack of knowledge about soil and water conservation is the presence of several sloping lands owned by farmers that have been converted into settlements and/or seasonal crops. Some land is still owned by farmers who have not been perfect in applying soil and water conservation principles, both vegetative, chemical, and mechanical conservation methods [9].

The performance of farmer groups is the second leveraging factor that affects the sustainability status of agroforestry farming. Farmer group performance is defined as the level of farmer group ability to plan, manage, and evaluate group activities [19]. Farmer groups that have high performance will be able to achieve the group goals that have been formulated jointly by all members of the farmer group.

In general, farmer groups in Indonesia have low performance and are passive, so that it becomes a significant problem in the success of farming development [20]. This problem also occurs in several farmer groups in the Sodonghilir District area.

Availability of technology packages and farmers' knowledge about agroforestry farming are vital factors affecting agroforestry farming's sustainability. Agroforestry technology packages are a collection of innovations produced by research and development institutions. Those collaborations aim to answer various stakeholders' various problems, especially farmers, in agroforestry management [13]. The Sodonghilir Subdistrict is still not available, so an agroforestry technology package is needed, which contains various technical, social, economic, and ecological innovations.

One of the other determining factors for agroforestry farming's sustainability is the level of pest and plant disease attacks. The attack of pests of agroforestry composting plant diseases, bagworms, and tumor rust on sengon plants is a serious problem that threatens agroforestry farming's sustainability in Sodonghilir District [9]. The inability of farmers to cope with these pests will threaten the sustainability of agroforestry farming. Due to damage caused by pests and diseases, which are already epidemic and have not been resolved, the losses are quite significant [21].

Farming capital is one of the factors of production that determines the success of agroforestry farming. The inability of farmers to provide farming capital will risk failure or low income earned by farmers to affect the sustainability of agroforestry farming [22]. Farmers can use two capital sources for the farming process, namely, external and internal farmers.

In general, farmers in Sodonghilir Subdistrict are religious people, so they must accept capital assistance from other parties, especially in interest loans (usury) either from banks or loan sharks. Therefore, it takes efforts from farmers and other stakeholders' support to help farmers capitalize from sources that are following their values. One of these efforts is to implement a business partnership program with a profit-sharing system.
3.3 Sustainable Agroforestry Farming Development Strategy

The agroforestry farming development strategy is carried out to manage the key factors resulting from the prospective analysis using analytic hierarchy process analysis (AHP). Based on the results of AHP analysis, it is obtained a sequence of strategies that can be carried out in the development of agroforestry farming in Sodonghilir District, namely (1) increasing the capacity of farmers with a priority weight of 0.461, (2) strengthening farmer group institutions with a priority weight of 0.331, (3) conducting farming partnerships with priority weights 0.134, and (4) providing farm capital incentives with a priority weight of 0.073. Therefore, increasing farmers’ capacity and strengthening farmer group institutions has the first and second priority weights. It is used as the primary strategy for the development of sustainable agroforestry in Sodonghilir District. The results of the AHP analysis are presented in Figure 9.

Increasing the farmers' capacity in agroforestry farming management (technical, social, managerial capacity) is the priority strategy. There are three capacities that farmers need to improve in agroforestry development, namely technical ability, managerial capacity, and social capacity.

Technical capacity is the ability of farmers to recognize, know, understand, and implement various technical principles, knowledge, and plant cultivation skills [23,24]. Managerial capacity is farmers' ability to plan, manage, implement, and evaluate agroforestry farming. In the decision-making process at each stage of agroforestry farming, managerial skills are needed by farmers, starting from providing business capital, technical crop cultivation, packaging, and marketing of products to manage its resources [23,24]. Social capacity can be defined as farmers' ability to interact with various parties outside of themselves, such as fellow farmers, government, private parties, traders, and others. Farmers' social abilities function to foster cooperation with other parties in overcoming various problems faced by farmers in the agroforestry farming process [23,24].

Strategies for increasing farmers' capacity in agroforestry development can be carried out by optimizing education, training, and counseling programs for farmers in a systematic, planned, targeted, and sustainable manner. The optimization of the education and training program can be done in various ways, including [24]: (1) increasing the performance of extension through expanding the capacity of extension workers and the availability of innovation in training methods and materials, (2) optimizing coordination and intensive communication among various stakeholders related to the program training, such as between extension agents and government and private research and development agencies in updating agroforestry technology innovations and (3) providing policy support in the form of a legal umbrella, programs and budgets for the implementation of an effective, efficient and sustainable education and training program.
Strengthening farmer group institutions is the second priority strategy that can be carried out in agroforestry farming. Strong farmer group institutions are one of the determining factors for the success of agroforestry farming. Strengthening these farmer groups can be done by optimizing the role of farmer groups [25].

There are three primary roles of farmer groups in agroforestry farming: farmer groups as a vehicle for learning, production units, and cooperation [25]. As a learning vehicle, the farmer group functions as a teaching-learning platform for all members to increase their farming knowledge, skills, attitudes, and independence. The farmer group as a production unit serves as a farming unit in achieving more profitable economies of scale, both in terms of quantity, quality, and continuity. Farmer groups as a vehicle for cooperation make farmer groups strengthen relationships between members of one group or different groups in dealing with all farming problems faced by technical, managerial, and social issues [20, 26, 27].

4. Conclusion
Agroforestry farming in Sodonghilir District is still less sustainable due to the inadequate public attention to social, economic, and ecological aspects. Six key factors determine sustainable agroforestry farming’s success: farmers’ knowledge in soil and water conservation, farmer group performance, availability of agroforestry technology packages, and farmer knowledge in agroforestry farming pest and plant diseases attack, and sources of farming capital. The management of these six key factors will have a strong influence on sustainable agroforestry farming’s success. Increasing farmer capacity and strengthening farmer group institutions are priority strategies that can be implemented by all stakeholders (government, private, and community) in managing the six critical factors in agroforestry farming development in Sodonghilir District.

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