IOSR Journal of Multidisciplinary Research (IOSR -JMR)
ISSN: 3048-7439 Volume 2, Issue 5, Series 1, Sept. - Oct. (2025), PP 11-17
www.iosrjournals.org

Multi-Criteria Decision Making (MCDM) Approach For Sustainable Dusung Pattern Farming Management In Ambon Island

Jan Willem Hatulesila, Gun Mardiatmoko, Ludia Siahaya, Edom Bayau
(Forest Department, Pattimura University, Indonesia) [4](Hein Namotemo University, Indonesia)

Abstract:
The dusung agriculture development model, a traditional form of agroforestry in Central Maluku, remains largely underexplored. In this model, the dynamics of land utilization evolve alongside the farming practices carried out in the land area according to climate conditions and transitional seasons. Over time, these cultivated areas are allowed to develop naturally into a new ecosystem resembling a forest garden with a pattern of annual crops, monoculture crops, and mixed plants (MPTs). Therefore, this study aims to observe the form of land use for dusung agriculture in supporting decision-making for sustainable land resource management in small island areas. Multi-Criteria Decision Making (MCDM) approach was used for decision-making, including the geometric mean method in AHP (Analytical Hierarchy Process) comparisons to convert the scale from the processed input responses. The eigenvector values were then determined through the data normalization stage, building a repetition without any differences. The prioritization of commodity crop types for development in agroforestry patterns was guided by 5 criteria parameters namely land suitability, land use type, labor force, land ownership status, and erosion hazard index. AHP analysis with an inconsistency ratio score of 0.07 indicates that the results can be accepted because the value is less than 0.10 (10%). In conclusion, land use analysis in the dusung agriculture development model effectively supports decision-making for sustainable land resource management in small island areas.
***Background**: MCDM approach was developed to assist decision makers in selecting between several alternatives. This application was designed to assist in decision-making through AHP method, which can receive input from direct comparison values based on respondent data analysis. In this study, the prioritization of sustainable dusung farming management was analyzed using AHP analysis following the basic principles of problem solving, which include decomposition, comparative judgement, synthesis of priority, and logical consistency (Setiawan, 2016).*
***Materials and Methods**: AHP method helps solve complex problems by determining criteria arranged in a hierarchy and then providing numerical weight values as a substitute for expert views or perceptions. Data on criteria comparison were collected from the results of a questionnaire distributed to 32 stakeholders consisting of experts and parties directly related to the management of sustainable dusung farming patterns, namely the Department of Agriculture, Department of Agriculture, Forestry Service, City/Regency BPS, Village Staff, Farmer Groups, Academics, and Non Governmental Organizations (NGOs). Subsequently, the weight of the parameter type criteria was calculated using Multi-Criteria Analysis (MCA) to determine the influence of each factor on the management of dusung farming patterns in Ambon Island.*
***Results**: The first level AHP analysis produced priority vector weights of criteria for sustainable dusung pattern farming management. The calculation was continued with the determination of assumptions and parameters of criteria weights in MCA. The results showed that the greater the weight value given to a parameter, the higher the level of importance in influencing dusung pattern farming management. The weighted score value described the effect of each parameter, forming the basis for the development of a model.*
Keywords: *Multi-Criteria Decision Making (MCDM); Sustainable Dusung; Pattern Farming; Ambon Island.*

Date of Submission: 02-09-2025 Date of Acceptance: 12-09-2025

I. Introduction

The potential of sustainable land resources is based on the capacity to maintain the benefits of biological and biophysical resources while preventing ecosystem damage. This requires prudent use to ensure the continuity of biodiversity and the sustainability of the resources. According to Cardozo et al. (2015) [1], biodiversity can reduce the risk of vulnerability and resilience to disturbances through mechanisms of plant species productivity and diversity, with interactions of various dominant and mutually beneficial species. Weerasekara C. et al. (2016) [2] stated that from a biophysical and ecological perspective, aspects of environmental degradation due to resource depletion, deforestation, as well as degradation of agricultural and forestry land related to global climate change issues have been ongoing in most rural landscapes.

To address these problems, Tahir, Z., et al. (2025) [3] Underscored the need for more effective land management, where land protection measures must consider ecological, social, cultural, and economic dimensions. It is also important to evaluate the implementation of farming systems as conservation goals and sustainable land use. The impacts of climate change due to the limited area of the island indicate the need for integrated management concerning biodiversity aspects, land use, and sustainability Hatulesila, J. W., Silaya, T. M., & Nirawati, N. (2022) [4]. Ambon Island region, as a small island, has an area of 803.9 km² consisting of two Peninsulas, namely the Leihitu and Leitimor, separated by Ambon Bay.

The dusung farming is practiced traditionally by local communities through gardening or horticulture with an area scale of 3 – 5 hectares per household. This system uses multiple cropping systems with 2 to 3 canopy layers, incorporating staple food crops (subsistence) as food security, forestry crops along riverbanks buffer zone/protected area, (firewood as an energy source), and livestock farming practices in open land. The dynamics of land use in this practice occur alongside agricultural practices conducted on land areas according to climate conditions and transitional seasons, allowing it to naturally develop into a new ecosystem resembling a forest garden with seasonal plants, monoculture plants, and mixed crops (MPTs), Irwanto et al,.(2022) [5]. Therefore, this study aims to examine the land use of dusung farming patterns to support decision-making in the sustainable management of land resources in small island regions.

II. Materials And Methods

This study examined the factors influencing the development of farming patterns through descriptive analysis from November 2019 to November 2020. Multi-Criteria Decision Making (MCDM) approach was used for decision-making, including the geometric mean method applied in AHP (Analytical Hierarchy Process) comparisons to convert the scale from the input results of the processed respondents. Furthermore, the eigenvector values were determined from the results by building repetitions without any differences through the data normalization stage.

Study Location: The samples comprised several related stakeholders as key respondents, namely the Agriculture and Plantation Office, Forestry Office, Statistics Office of City/District, Village Staff, Farming Groups, Academics, and NGOs in the Leitimur Selatan and Leihitu Districts, Ambon Island, Maluku Province.

Study Duration: November 2019 to November 2020.

Sample size: 32 respondents.

Sample size calculation: The samples were selected systematically and purposively, consisting of experts and specialists as well as parties directly related to the management of sustainable farming practices.

Subjects & selection method: Comparison data for the criteria for AHP were collected from the results of a questionnaire given to 32 respondents (expert judges) representing 9 selected stakeholders. The identification of priority factors for the management of farming patterns is presented in Table 1.

Table 1. Data Type, Variable, and Unit Requirements Related to Dusung Farming Patterns on Ambon Island

No	Type and Source of Data Needs	Variable	Unit
1.	Government (Department of Agriculture & Plantations, Trade, Forestry, Cooperatives, Micro, Small, and Medium Enterprises (MSMEs), BPS Province/ District /City)	Area of Leitimur Selatan & Leihitu District, Population & Livelihood, Production	ha soul/person kg/ton/year
2.	Collecting Traders and Wholesale Traders	Type of commodity, quantity/volume, market price value	kg/basket/sack
3.	Farmers & Farmer Groups in the Village/Country	Land status, land area, commodity potential, management form, pests & diseases, productivity, income	ha, kg/ton, IDR
4.	Partner Institutions (NGOs/ Foundations, Consultants/ Funding Contractors)	Forms of cooperation and support	Month/year
5.	Academic	Views, knowledge of agriculture /plantation & forestry	

Source: Data Collection Design, 2020

Respondent data collection questionnaire was used to determine the weight of each criterion in assessing prospects using a rating scale, as explained in Table 2.

Table 2. Definitions of Each Assessment Criteria

No.	Criteria	Assessment
1.	Land Suitability Class	S1, S2, S3, N1, N2 (very suitable, suitable, somewhat suitable, less suitable, not suitable)
2.	Land Use Type	Settlements, Fields/Co-patch farming, Mixed Gardens, and Secondary Forests (intensive/non-intensive)
3.	Land Ownership Status	State-owned, customary land (village/state) and community-owned
4.	Labor availability	The number of available workforce (many, moderate, few)
5.	Erosion Hazard Index	Open land, agricultural land (fields/cultivation), mixed gardens, and secondary forests (low, medium, high, very high)

Source: Data Collection Design, 2020

Procedure methodology

MCDM approach was carried out using AHP, through an application called Expert Choice. This is to ensure consistency and specificity in determining preference and weight values. More specifically, a weight value reflects the relative importance of one criterion compared to others. The weight value assigned from the data indicates the increasing level of importance of a criterion as provided by each respondent. The total weight value assigned to all criteria must sum to 1, hence, the decision-making analysis significantly depends on the establishment of the pairwise matrix. Mathematical calculations must be carried out based on the previously validated problem data in the pairwise matrix. This will indicate whether the data is acceptable or not acceptable logically. In this process, an approach was applied based on the value of the input data as an aspect of consistency.

Statistical analysis

AHP method conducted a detailed comparative analysis at both the criteria and the alternative level, which would then be input into the pairwise matrix. This method also measured considerations based on the consistency ratio, namely, less than 5% for a 3x3 matrix, 9% for a 4x4 matrix, and 10% for larger matrices. When this value exceeds the thresholds, the comparison values in the matrix must be recalculated. The consistency index was calculated using the formula. CI = $\frac{\lambda_{max} - n}{n-1}$

Where: CI = Consistency Index, λ_{max} = Eigen Value, and
n = Many elements

Consistency ratio (CR) was calculated using the formula: CR = CI/RC, where CR: Consistency Ratio, CI: Consistency Index, RC: Random Consistency. A random matrix has scale values ranging from 1 to 9, and the inverses as random consistency (RC). By considering the selection of traces, this will determine values starting from the scale 1/9, 1/8, …, 1, 2, …, 9, resulting in the average consistency value for each matrix with differences (Saaty, T. L. (2008)) [6].

III. Result

AHP method can receive input from direct comparison values based on respondent data analysis. It considers both the criteria and alternative levels, then inputs the results into the pairwise matrix (Al-khanaqini, A. D. S. 2024) [7]. The four steps of resolution, according to the fundamental principles of problem-solving using AHP tool, namely decomposition, comparative judgment, synthesis of priority, and logical consistency, (Albayrak, E., & Erensal, Y. C. 2004) [8] are explained as follows:

Decomposition

Decomposition is the definition of a problem used to break down a large issue and simplify into smaller ones, illustrated in a hierarchical form. In this case, AHP was used to determine the weights of the 5 specified criteria, which include 1. Class of Land Suitability, 2. Type of Land Use, 3. Land Ownership Status, 4. Availability of Labor, and 5. Erosion Hazard Index.

Comparative Judgement

At this stage, the first step in determining the priority of elements was to make a pairwise comparison by comparing elements in pairs according to the given criteria using a matrix format. The pairwise comparison matrix was filled by using numbers to represent the relative importance of one element compared to another, expressed on a scale from 1 to 9. This scale defines and explains values from 1 to 9 for considerations in the pairwise comparison of elements at each level of hierarchy against a criterion at a higher level. When an element in the matrix is compared to itself, it is given a value of 1. Meanwhile, when element i compared to j receives a certain value, then j compared to i is the inverse of the value. The quantitative scale from 1 to 9 for assessing the importance of one element compared to another is shown below:

a. Scale 1: Both elements are equally important.

b. Scale 3: One element is slightly more important than the other.
c. Scale 5: One element is more important than the other.
d. Scale 7: One element is clearly significantly more important than the other elements.
e. Scale 9: One element is absolutely significantly more important than the other elements.
f. Scales 2, 4, 6, 8: The middle value between two adjacent comparisons
h. The opposite: When element x has one of the values above in comparison to element y, then element y has the opposite value compared to x.

Since the data were obtained from 32 respondents, the questionnaire responses were subsequently arranged in a criteria comparison matrix as shown in Table 3.

Table 3. Average Rating of the Criteria Comparison Matrix

Criteria	A	B	C	D	E
A	**1.00**	0.40	2.44	0.22	0.32
B	2.53	**1.00**	3.31	1.42	3.52
C	0.41	0.30	**1.00**	0.18	0.30
D	4.56	0.71	5.44	**1.00**	2.28
E	3.10	0.28	3.35	0.44	**1.00**

Source: Data Processing, 2021

Notes: A = Land Suitability Class B = Land Use Type, C = Land Ownership Status
D = Labor Availability E = Erosion Hazard Index

Table 3 shows the results of pairwise comparisons among the criteria provided by 32 respondents. For example, the value of 2.53 means that the criterion "Land Use Type" is 2.53 times more important than the criterion "Land Suitability Class."

Synthesis of Priority

Considerations for pairwise comparisons in synthesis to obtain overall priorities are as follows:
Adding the values from each column in the matrix in Table 4.

Table 4. Initial Matrix of Pairwise Comparison

Criteria	A	B	C	D	E
A	**1.00**	0.40	2.44	0.22	0.32
B	2.53	**1.00**	3.31	1.42	3.52
C	0.41	0.30	**1.00**	0.18	0.30
D	4.56	0.71	5.44	**1.00**	2.28
E	3.10	0.28	3.35	0.44	**1.00**
Amount	11.60	2.69	15.55	3.26	7.42

Source: Data Processing, 2021

Divide each value in the column by the total of that column to obtain the normalization of the matrix.

Sum the values of each matrix and divide by the number of elements to obtain the average value presented in Table 5.

Table 5. Normalization Matrix Table and Eigen Vector Values for Priority Determination Scale

Criteria	A	B	C	D	E	Amount	Eigen Vektor (Bobot)
A	0.09	0.15	0.16	0.07	0.04	0.50	**0.10**
B	0.22	0.37	0.21	0.43	0.47	1.71	**0.34**
C	0.04	0.11	0.06	0.06	0.04	0.31	**0.06**
D	0.39	0.26	0.35	0.31	0.31	1.62	**0.32**
E	0.27	0.11	0.22	0.13	0.13	0.86	**0.17**
Amount	1.00	1.00	1.00	1.00	1.00	5.00	**1.00**

Source: Data Processing, 2021

Logical Consistency

The important decision is to understand the existing consistency to avoid making decisions based on considerations with low consistency. The measurement was performed once for each comparison matrix. The first measurement was carried out for the main criteria, in the form of eigen vector calculations as presented in Table 6.

Table 6. Result of the Eigen Vector Multiplication

	A	B	C	D	E		Eigen Vector		Value
A	1.00	0.40	2.44	0.22	0.32		0.10		0.51
B	2.53	1.00	3.31	1.42	3.52		0.34		1.86
C	0.41	0.30	1.00	0.18	0.30	x	0.06	=	0.32
D	4.56	0.71	5.44	1.00	2.28		0.32		1.75
E	3.10	0.28	3.35	0.44	1.00		0.17		0.93

Source: Data Processing, 2021

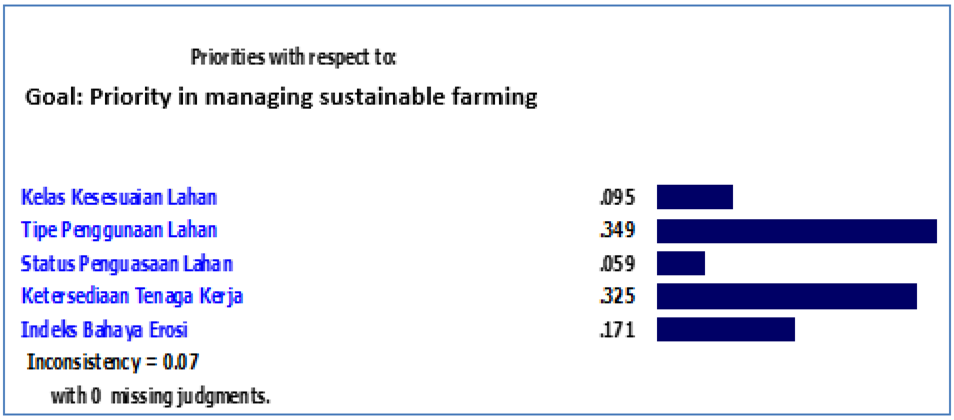
Each value in the first column was multiplied by the relative priority of the first element, and each row was summed. The result of the row sum was divided by the corresponding relative priority element, and the quotients were summed with the number of existing elements, yielding the maximum λ.

0.51		0.10		5.12
1.86		0.34		5.44
0.32	:	0.06	=	5.13
1.75		0.32		5.40
0.93		0.17		5.41
			Eigen maks	5.30

a. Hitung Consistency Index (CI).
CI = (λmax – n) / (n – 1) (5,30 – 5) / (5 – 1) = 0,075
b. Hitung Consistency Ratio (CR), untuk n = 5 maka RI = 1,12
CR = CI / RI
= 0,075 / 1,12 = 0,067

The calculations above can also be compared with the results of weighting using the Expert Choice program. The results obtained are shown in Figure 1.

Figure 1. Priority Criteria Values (AHP); Note: AHP Processing Results (Expert Choice)



Source: Average Median Value

AHP analysis results at the first level obtained the priority vector weight from the criteria for sustainable pattern farming management (Figure 1), namely:
(1) Land Use Type (0.349)
(2) Labor Availability (0.325)
(3) Erosion Hazard Index (0.171)
(4) Land Suitability Class (0.095)
(5) Land Ownership Status (0.059)

The analysis results from AHP regarding the highest priority value indicate land use type. The inconsistency ratio value for the above criteria is 0.07, suggesting the results are acceptable because the value is less than 0.10 (10%).

5. Conclusion of Alternative Strategy Priority

Based on the overall AHP analysis results, the priority for managing sustainable farming patterns is presented in Table 7.

Table 7. Priority Order of Criteria Based on AHP Analysis

Priority	Criteria	Bobot
1	Land Use Type	0,349
2	Labor Availability	0,325
3	Erosion Hazard Index	0,171
4	Land Suitability Class	0,095
5	Land Ownership Status	0,059

Source: Data Processing, 2021 (Modification Setiawan, 2016)

IV. Discussion

The determination of an appropriate farming development model using MCDM approach or MCA serves as an effective tool for decision-making (Malczewski, J,. 2006) [9]. In this study, criterion weight establishment was carried out based on AHP analysis conducted on farming patterns in Ambon Island, South Leitimur Sub-district, which represents Ambon City area, and Leihitu Sub-district representing Central Maluku Regency. The results indicated that the first significant factor based on expert judgment was land use, with the highest weight value of 0.349. This implies that the type of land use contributes the most to determining the priority of commodity development. Similarly, previous studies have shown that various human activities determine the type of land use, including farming activities and inherited patterns (Liu, S. A., et al, 2020) [10]. Labor availability was also identified as the second most significant factor with a weight value of 0.325. This indicates that the presence of labor is key in opening land for both small-scale and large-scale farming operations. Labor is usually needed during the harvest season due to the vastness of the agricultural land, with various commodities being harvested, which requires a large workforce for harvesting activities.

Land use activities for agricultural purposes and conservation are considered a "science and art." This is because agricultural activities comprising the planting of trees and other plants inside and outside the forest must be conducted in a balanced manner to produce goods and services, either individually or collectively (Glück, P., 2000) [11]. The third highest priority was identified to be the management of agroforestry systems, specifically Erosion Hazard Index. The agroforestry systems often revolve around rotation or intercropping of several types of food crops, such as cassava, bitter melon, taro, eggplant, peanuts, corn, sweet potatoes, pineapple, or intensive vegetable farming systems widely cultivated on open land and sloping areas due to minimal soil cover by plants. Therefore, the pattern of dusung planting systems is usually very sensitive to erosion, specifically in sloped areas with various farming activities (Vezina, K., Bonn, F., & Van, C. P., 2006) [12].

According to Roberts, D. A., Keller, M., & Soares, J. V. (2003) [13], the type of vegetation cover and the distribution of biophysical land resources will determine the potential crops that can be developed for land conservation purposes. Land suitability parameter was identified as the fourth highest priority with a score of 0.095. In the land evaluation procedure, the requirements for plant growth or land use are determined by each agricultural or forestry commodity. The minimum, maximum, and/or optimum limits for determining land suitability classes are compared against the primary assessment of land quality and characteristics. Agricultural commodities are generally assigned to a class category based on land suitability criteria (Jaisli, I., et al, 2019) [14]. Finally, land ownership status parameter was the fifth-highest priority factor, with the lowest weight value of 0.059. Land use and control by the community have been passed down through generations. The kinship system in the culture of Maluku archipelago reflects the patterns of relationships in the practices of participatory management for forest and land resources. This paradigm of land use is closely related to cultivation (cultivated land), labor, and market access as part of a unified element in the process of resource management. These three elements are interconnected, forming a system known as agriculture in a broad sense (Law, E.A., et al. 2015) [15]. According to Berebon, C. B., & Amadi, C. C. (2024) [16], the relationship between forest resources, land, and the environment reflects the balance of land use and human activities as the theory of ecological equilibrium.

V. Conclusion

In conclusion, this study carried out criterion weight determination from AHP analysis conducted on farming patterns in Ambon Island, representing Ambon City, and Leihitu District, representing Central Maluku Regency. The prioritization of commodity crop types in the dusung farming pattern was evaluated using 5 criteria parameters, namely land suitability, land use type, labor availability, land ownership status, and erosion hazard index. Based on expert judgment, the analysis yielded an inconsistency ratio value of 0.07, indicating that the results of AHP method are acceptable because the value is less than 0.10 (10%). Therefore, this study supports the use of dusung farming pattern as a basis for sustainable land resource management decision-making in small island areas in line with the priority scale for development.

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