East Asian Journal of Multidisciplinary Research (EAJMR)
Vol. 5, No. 7, 2026: 2743 - 2762

Land Suitability Evaluation of the Transmigration Area: SP Janja, Janja Village, Tolitoli Regency

Arian Musmuliadin[1*], Patta Tope [2], Rifai Mardin[3]
Master's Program in Rural Development, Postgraduate, Tadulako University, Palu, Indonesia.
Corresponding Author: Arian Musmuliadin rijalpratamabangsa@gmail.com

A R T I C L E I N F O

Keywords: Analytical Hierarchy Process, Geographic Information Systems (GIS), Land Suitability, Maize, Transmigration Area

Received : 12, May
Revised : 13, June
Accepted: 18, July

A B S T R A C T

This study aims to evaluate the suitability of land for maize cultivation in the SP Janja Transmigration Area, Tolitoli Regency, by integrating the Analytical Hierarchy Process (AHP) and Geographic Information Systems (GIS). Eight biophysical parameters were analysed using the Weighted Overlay technique in ArcGIS 10.8. The AHP results indicated that temperature was the most influential parameter (29.90%), with a valid consistency ratio (CR = 0.027). Spatial analysis identified two land suitability classes: moderately suitable' (S2), covering 68.71 ha (70.23 per cent), and 'less suitable' (S3), covering 29.12 ha (29.77 per cent), which were influenced by limiting factors such as high rainfall and poor drainage. The integration of these methodologies has proven reliable in producing land suitability maps to support sustainable agricultural planning and productivity policies in Tolitoli.

INTRODUCTION

Maize (*Zea mays* L.) is one of Indonesia's most strategic food commodities, playing a crucial role in strengthening national food security, supplying raw materials for agro-industries, and supporting the livestock sector. The demand for maize continues to increase due to population growth, the expansion of the food processing industry, and the rising need for animal feed. These increasing demands necessitate higher maize production through the optimal utilization of land that meets the crop's growth requirements, thereby ensuring sustainable agricultural productivity.

The success of maize cultivation is strongly influenced by the biophysical characteristics of the land. Each crop species has specific environmental requirements; therefore, inappropriate land utilization may result in low productivity, increased production costs, and accelerated land degradation. Consequently, land suitability evaluation has become an essential component of agricultural land-use planning. According to the Food and Agriculture Organization (FAO, 1976), land suitability evaluation is the process of assessing land characteristics in relation to the growth requirements of a particular crop to determine its suitability. This framework was further refined by FAO (1985), emphasizing that land suitability evaluation should integrate biophysical conditions, land capability, and sustainable resource management to provide reliable information for agricultural planning and decision-making.

Tolitoli Regency, located in Central Sulawesi Province, possesses considerable land resources with significant potential for agricultural development. According to the Statistics Indonesia Office of Tolitoli Regency (BPS, 2024), agriculture remains the primary contributor to the regional economy. One of the priority agricultural development areas is the SP Janja Transmigration Area, situated in Janja Village, Lampasio District. Covering approximately 97.83 hectares, this area has been developed as an agricultural production zone for transmigrant communities. However, variations in land biophysical characteristics—including slope, drainage conditions, soil texture, rainfall, and erosion hazard—have constrained land productivity. These conditions highlight the necessity of conducting a comprehensive land suitability evaluation to identify appropriate agricultural development strategies and optimize land utilization.

The advancement of *Geographic Information Systems* (GIS) has significantly improved spatial analysis in land resource assessment. According to Malczewski (2006), GIS enables the integration of diverse spatial datasets, making land suitability assessment more efficient, accurate, and visually interpretable through thematic mapping. Furthermore, integrating GIS with *Multi-Criteria Decision Analysis* (MCDA) enhances the objectivity of land evaluation because each parameter can be assigned a relative importance based on scientific considerations and expert judgment.

Among various MCDA techniques, the *Analytical Hierarchy Process* (AHP), introduced by Saaty (1980), has become one of the most widely applied methods for land suitability assessment. AHP employs pairwise comparisons to determine the relative importance of each criterion based on expert evaluations. In addition to generating priority weights, AHP evaluates the consistency of expert judgments through the *Consistency Ratio* (CR), ensuring the scientific reliability of the weighting process. Saaty (2008) emphasized that the principal advantage of AHP lies in its ability to integrate both quantitative and qualitative considerations into complex decision-making processes.

Previous studies have demonstrated that climatic factors, topography, soil physical properties, and land use exert different levels of influence on maize productivity. Hardjowigeno and Widiatmaka (2018) identified temperature, rainfall, soil texture, drainage, and slope as the primary determinants of land suitability for food crops. Similarly, Sys et al. (1991) argued that land suitability evaluation should comprehensively consider the relationships between land characteristics and crop growth requirements to ensure effective land-use recommendations.

Numerous studies have confirmed that integrating AHP and GIS provides more accurate spatial information for land suitability assessment. Zolekar and Bhagat (2015) reported that this integrated approach improves the objectivity of agricultural land evaluation through systematic parameter weighting. Likewise, Abuzaid et al. (2022) demonstrated that combining AHP with GIS produces more reliable land suitability models than conventional approaches because it incorporates the relative importance of each biophysical parameter. Chen et al. (2021) further concluded that GIS-based multi-criteria analysis effectively supports land-use planning and spatial decision-making.

Despite the extensive application of AHP and GIS in land suitability assessment, studies focusing on transmigration areas in Tolitoli Regency remain limited. Since each region possesses unique biophysical characteristics, land suitability results cannot be generalized across different locations. Therefore, site-specific studies are essential to generate accurate and reliable recommendations for agricultural development.

This study was conducted to evaluate the land suitability for maize cultivation in the SP Janja Transmigration Area by integrating the *Analytical Hierarchy Process* (AHP) and *Geographic Information Systems* (GIS). Specifically, the study aims to identify the spatial distribution of land suitability classes, determine the principal limiting factors affecting maize cultivation, and provide scientific information to support agricultural land-use planning and sustainable regional development in Tolitoli Regency.

Previous research has also emphasized the importance of land suitability evaluation in transmigration areas. Deddy Fitrianto (2019) demonstrated that land suitability assessment provides a scientific basis for determining development priorities in transmigration settlements on Enggano Island. Edwin (2020) reported that GIS significantly improves the accuracy of agricultural zoning in transmigration development planning. More recently, Gunawan (2023) and Roberth Berthy Riry (2023) concluded that spatially based land suitability analysis plays an essential role in supporting sustainable transmigration area development policies.

The novelty of this study lies in the integration of the *Analytical Hierarchy Process* (AHP) and *Geographic Information Systems* (GIS) for evaluating maize land suitability in the SP Janja Transmigration Area, a location that has not previously been assessed using a spatial multi-criteria approach involving eight key biophysical parameters. This integrated framework provides a more objective and scientifically robust basis for agricultural land-use planning and sustainable regional development.

THEORETICAL REVIEW

Transmigration Concepts and Policies

Transmigration is a strategic program of the Indonesian government aimed at achieving a balanced distribution of the population, expanding employment opportunities, increasing the Regional Gross Domestic Product (RGDP), and reducing unemployment rates. Spatially, this program directs the distribution of the population from densely populated areas (particularly Java) to less densely populated regions such as Sumatra, Kalimantan, Sulawesi, Maluku, and Papua, while also serving as an instrument for equitable development and the utilization of natural resource potential.

Regulatory-wise, the implementation of transmigration was initially based on Law No. 15 of 1997, which emphasized the goals of population redistribution, improving welfare, utilizing natural resources, and strengthening national unity. Subsequently, this regulation was updated through Law No. 29 of 2009, which defines transmigration as the voluntary movement of residents to improve their quality of life. This regulatory change also shifted the management paradigm from one previously dominated by the central government to one based on regional autonomy, in which local governments are granted full authority over the provision of resources, regional development, and the oversight of settlements to ensure greater adaptability to local needs and sustainable development. In addition, environmental considerations have become a key principle, requiring that the selection of transmigration sites take into account biophysical conditions such as topography, slope gradient, hydrology, and land carrying capacity.

Concepts of Land and Land Resources

Land is viewed as part of a dynamic landscape. According to the Food and Agriculture Organization (FAO) (1976), land encompasses elements such as climate, topography, soil, hydrology, natural vegetation, and areas that have been influenced by human activities. Optimal land use must take into account its biophysical characteristics, quality, and limitations to prevent environmental degradation (Djaenudin, 2011).

Conceptually, land resources have two main dimensions: as valuable economic assets that can be utilized by humans, and as physical-biological entities within the natural environment (Mega, 2010). The main components that make up land resources include, **Soil**: A medium for plant growth that provides nutrients, water, and a place for roots to grow; **Climate**: Macro factors (temperature, rainfall, humidity, solar radiation) that determine a crop's suitability; **Topography**: Landforms (slopes, elevation) that affect erosion, drainage, and accessibility; **Hydrology:** The availability of surface water and groundwater for domestic and agricultural needs; **Vegetation**: Natural land cover that protects the soil and serves as an indicator of ecological conditions; **Socioeconomic Aspects**: Human activities, policies, and access to technology that influence land-use patterns.

Land Suitability Assessment

Land suitability assessment is the process of estimating the degree to which a piece of land is suitable for a specific alternative use, particularly in the agricultural sector (Wahyunto, 2016). This assessment serves to map the potential and limiting factors of the land, whether conducted manually or using computer-based methods. In Indonesia, the Center for Agricultural Land Resources Research and Development (BBSDLP) applies a matching approach, in which the biophysical attributes of the land are directly matched with the growth requirements of the target crop.

According to the FAO (1976) as cited in Mega (2010), the main activities in a land evaluation survey consist of six systematic stages, The land evaluation survey is conducted through several systematic and interrelated stages. The initial stage begins with an initial consultation, which includes establishing theevaluation objectives, identifying data needs, formulating basic assumptions, and determining the map scale to be used. Next, a land-use analysis is conducted to provide a detailed explanation of the technical, ecological, and socio-economic aspects of the planned land-use types. The subsequent stage is land description, which involves mapping land units and identifying land quality based on existing limiting factors. This information is then compared through a land-use matching process, that is, the process of matching land data characteristics with the growth requirements of the target crops. Based on the results of this matching process, a land suitability classification is conducted to determine the level of suitability or land suitability class. This entire series of activities concludes with the presentation of results in the form of a final report, which serves as the basis for decision-making in sustainable land-use planning.

In establishing these evaluation criteria, the land suitability classification structure is divided into four main classes (FAO, 1976, as cited in Djaenudin, 2011). Class S1 (Highly Suitable) describes land that has no significant constraints or only minor limiting factors that do not significantly affect productivity. Meanwhile, Class S2 (Moderately Suitable) includes land with limiting factors that have the potential to reduce productivity; however, these constraints can still be overcome through the application of reasonable inputs or management practices by farmers. At a more limited level, Class S3 (Marginally Suitable) has severe limiting factors that have a tangible impact on yield levels; consequently, its utilization requires high capital inputs and often necessitates intervention or assistance from the government or the private sector. Class N (Unsuitable), on the other hand, refers to land with very severe or permanent limiting factors, making it technically and economically impossible to use the land for that purpose on a sustainable basis.

Agricultural Land Suitability Parameters

The land evaluation process uses land characteristics (measurable or estimable land properties) as assessment parameters to identify limiting factors (Djaenudin, 2011). The main parameters commonly used include air temperature, drainage, soil texture, alkalinity (soil pH), erosion risk, and susceptibility to flooding/waterlogging. The selection of the types and number of these parameters is dynamic and varies among researchers or institutions (such as PPT staff, Bunting, Sys et al., CSR/FAO, and Driessen) depending on the purpose of the analysis, agroecological conditions, and the specific crops being cultivated.

Growth Requirements of Corn Plants

Corn (Zea mays L.) is a strategic food commodity in Indonesia that plays a vital role as the primary source of carbohydrates after rice, a component of animal feed, and a raw material for industry. The development of corn cultivation in transmigration areas holds great potential for strengthening national food security while improving community well-being through additional income.

The success of corn cultivation depends heavily on adapting the crop to the biophysical conditions of the land and ensuring its economic viability. According to Wahyunto (2016), the selection of crop types and the application of land management technologies must be based on land characteristics and the surrounding environment. A regional zoning approach based on soil properties and environmental conditions (at the plot level) is crucial for determining the appropriate application of practical technology packages. The sustainability of agricultural systems can only be achieved if land use and management are carried out in accordance with the land's biophysical carrying capacity. If, during implementation, there is a discrepancy between the results of land suitability evaluations and actual crop growth conditions in the field, verification and a review of the following four main aspects are necessary: (1) land suitability criteria and parameters, (2) land characteristics, (3) the application of land management technologies, and (4) crop growth dynamics and production yields (Wahyunto, 2016).

Transmigration Areas and Agricultural Development

Under Law No. 29 of 2009 on Transmigration, the transmigration program is aimed at improving community welfare, accelerating regional development, strengthening national unity, and advancing these areas through the optimization of resources. In the context of agricultural sector development, transmigration areas are positioned as centers of growth for food production and plantations that support national food security. The agricultural sector serves as a main pillar in these regions, given that the majority of transmigrants come from rural areas with farming backgrounds and skills, supported by the availability of relatively vast tracts of land (Sutanto, 2005).

The development of food commodities, particularly corn, in transmigration areas plays a strategic role that includes: providing a primary food source and livelihood for transmigrants; increasing the productivity of marginal land through the application of technology and agricultural inputs; driving local economic growth through the integration of the feed and livestock industries; and supporting national food diversification and food security programs.

Potential and Challenges in the Development of Corn Farming in Transmigration Areas

Corn is a crop with high adaptability to a wide range of soil conditions, including dry and marginal lands. The contribution of corn production from outside Java—which consists largely of transmigration areas—continues to show a significant increase in meeting national demand (Central Statistics Agency, 2022). The main drivers of corn development in these transmigration areas include high market demand (as a raw material for animal feed and human consumption) and the availability of vast tracts of land to be optimized.

Nevertheless, agricultural development in transmigration areas often faces various biophysical and technical constraints. Hardjowigeno and Widiatmaka (2007) emphasize that the majority of transmigration land outside Java is dominated by Ultisol (Red-Yellow Podzol) soils, which have natural limitations such as high acidity, low nutrient content, and susceptibility to erosion. In general, the main problems facing agricultural development in transmigration areas include: Low soil fertility: Low levels of macronutrients (N, P, K) and organic matter; High soil acidity: Soil pH levels range from 4.0 to 5.0, requiring liming; Drainage constraints: Potential for waterlogging or obstructed drainage systems in some locations; Infrastructure limitations: Inadequate irrigation networks, road access, and post-harvest facilities; Environmental pressures: Risk of ecosystem degradation due to land clearing that is not managed wisely.

METHODOLOGY

Research Design

This study employed a descriptive quantitative approach integrated with *Geographic Information Systems* (GIS)-based spatial analysis. The quantitative approach was applied to assess land suitability based on the biophysical characteristics of the study area, while the descriptive approach was used to explain the existing land conditions and identify the factors influencing land suitability for maize cultivation. The integration of the *Analytical Hierarchy Process* (AHP) and *Geographic Information Systems* (GIS) was selected because it provides a systematic and objective framework for land suitability evaluation by combining multi-criteria weighting with spatial analysis.

According to Saaty (1980), the *Analytical Hierarchy Process* (AHP) is a multi-criteria decision-making method that determines the relative importance of each criterion through pairwise comparisons. Meanwhile, Malczewski (2006) stated that GIS is an effective tool for integrating various spatial datasets to support spatial decision-making. Land suitability classification in this study followed the technical guidelines proposed by Djaenudin et al. (2011), ensuring that the matching process between land characteristics and maize growth requirements was conducted systematically and consistently.

Study Area

The study was conducted in the SP Janja Transmigration Area, Janja Village, Lampasio District, Tolitoli Regency, Central Sulawesi Province, Indonesia. This area was selected because it has considerable potential for maize cultivation but has not yet been evaluated comprehensively in terms of land suitability.

Geographically, the study area is located between 0°48′58.90″ N and 120°53′01.32″ E, covering approximately 97.83 hectares. Administratively, the area is bordered by Kokobuka Village to the north, Tinading Village to the east, Sibea Village to the south, and Janja Village to the west.

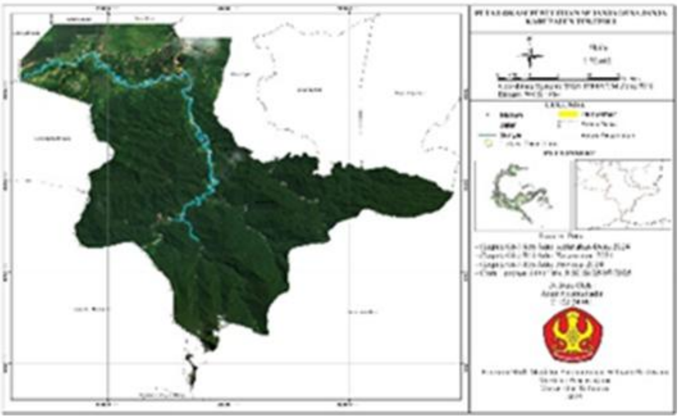

Figure 1. Location of the Study Area

Source: Processed by the authors (2025).

Data Collection

This study employed both primary and secondary data to evaluate land suitability for maize cultivation. Primary data were collected through field observations, Global Positioning System (GPS) surveys, documentation of land characteristics, and structured interviews with experts in soil science, climatology, and regional planning. The expert assessments served as the basis for constructing the pairwise comparison matrix used in the *Analytical Hierarchy Process* (AHP) to determine the relative importance of each evaluation criterion.

Secondary data were acquired from official government institutions, including the Statistics Indonesia (BPS) of Tolitoli Regency, the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG), the Geospatial Information Agency (BIG), and the Indonesian Center for Agricultural Land Resources Research and Development (BBSDLP). These data consisted of administrative boundary maps, land-use maps, soil maps, digital elevation models (DEM), rainfall and air temperature records, and other spatial datasets required for GIS-based land suitability analysis.

These datasets included administrative maps, land-use maps, soil maps, digital elevation data, rainfall records, air temperature data, and other supporting spatial information.

Research Variables

The land suitability evaluation was conducted based on the maize growth requirements established by the Food and Agriculture Organization (FAO, 1976), BBSDLP (2011), and Hardjowigeno and Widiatmaka (2018**)**.

Eight biophysical parameters were analyzed:

Table 1. Research Variables

Code	Parameter	Unit	Data Source
C1	Slope	%	National DEM
C2	Wet Months	Month	BMKG
C3	Temperature	°C	BMKG
C4	Rainfall	mm year^{-1}	BMKG
C5	Drainage	Class	Field Survey
C6	Soil Texture	Class	Soil Map
C7	Erosion Hazard	Class	GIS *Overlay*
C8	Land Use	Class	Satellite Image Interpretation

Source: FAO (1976); Hardjowigeno & Widiatmaka (2018).

Analytical Hierarchy Process (AHP)

The *Analytical Hierarchy Process* (AHP) was employed to determine the relative importance of each evaluation criterion through pairwise comparisons based on expert judgments. The hierarchical structure of the AHP model consisted of three levels. The first level represented the overall objective, namely the evaluation of land suitability for maize cultivation. The second level comprised the eight biophysical criteria used in the analysis, including slope, wet months, temperature, rainfall, drainage, soil texture, erosion hazard, and land use. The third level represented the decision alternatives, which consisted of the land suitability classes defined by the Food and Agriculture Organization (FAO): Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), and Not Suitable (N).

The hierarchical framework was designed to systematically organize the decision-making process by establishing relationships between the research objective, evaluation criteria, and land suitability classes. This structure facilitated the calculation of criterion weights and ensured that the land suitability assessment was conducted objectively and consistently.

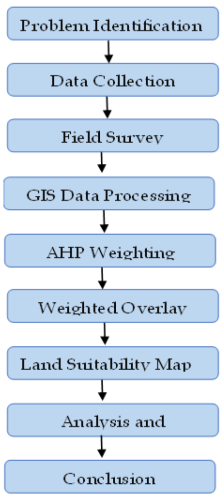

Figure 2. Research Workflow
Source: Authors' analysis (2025).

Based on the research workflow, the study began with problem identification and literature review, followed by primary and secondary data collection. The AHP method was then applied to calculate parameter weights, which were subsequently integrated with spatial datasets using the *Weighted Overlay* technique in GIS to produce the maize land suitability map.

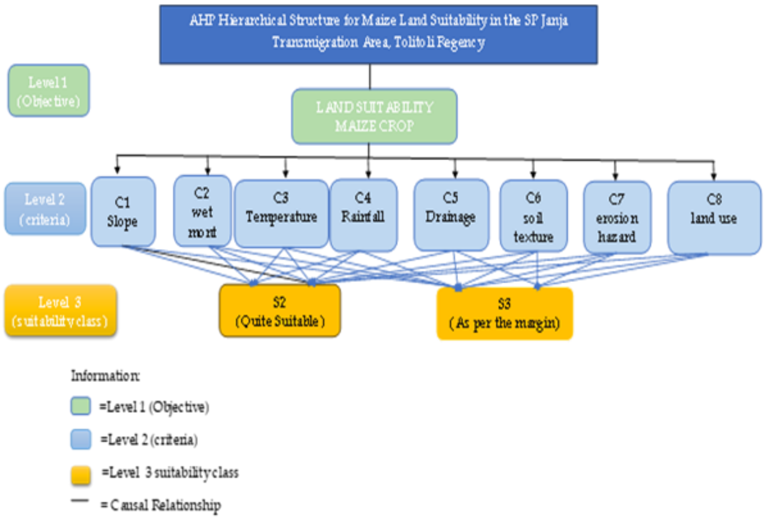

Figure 3. Hierarchical Structure of the *Analytical Hierarchy Process* (AHP)
Source: Authors' analysis (2026).

Pairwise Comparison Scale

The pairwise comparison matrix was developed using the fundamental scale proposed by Saaty (1980).

Table 2. Saaty Fundamental Scale

Value	Interpretation
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values

Source: Saaty (1980).

Land Suitability Classification

The *weighted overlay* results were classified according to the FAO (1976) land suitability classification**.**

Table 3. Land Suitability Classification

Class	Description
S1	Highly Suitable
S2	Moderately Suitable
S3	Marginally Suitable
N	Not Suitable

Source: FAO (1976).

Research Procedure

The research consisted of several sequential stages, including problem identification, literature review, collection of primary and secondary data, field survey, development of the AHP pairwise comparison matrix, consistency testing, parameter weighting, *weighted overlay* analysis using GIS, generation of the land suitability map, and interpretation of the results. This systematic workflow was designed to produce accurate spatial information regarding land suitability for maize cultivation in the SP Janja Transmigration Area, thereby providing scientific support for sustainable agricultural land-use planning.

RESULTS

Characteristics of the Study Area

The SP Janja Transmigration Area, located in Janja Village, Lampasio District, Tolitoli Regency, is one of the agricultural development areas established to support food crop production, particularly maize cultivation. The study area covers approximately 97.83 ha and exhibits diverse biophysical characteristics, making land suitability evaluation essential for determining its capacity to support sustainable maize production.

According to the Food and Agriculture Organization (FAO, 1976), land suitability evaluation is the process of comparing land characteristics with crop growth requirements to determine the degree of suitability. This approach ensures that land resources are utilized according to their natural capability, thereby enhancing agricultural productivity while minimizing environmental degradation.

The biophysical characteristics of the study area were evaluated using eight key parameters: temperature, rainfall, wet months, slope, drainage, soil texture, erosion hazard, and land use. These parameters were selected because they are widely recognized as the principal factors influencing maize growth (Hardjowigeno & Widiatmaka, 2018; Sys et al., 1991). Each parameter was reclassified in GIS to establish a standardized suitability score before applying the *Analytical Hierarchy Process* (AHP) for weighting.

The spatial analysis indicated that the air temperature ranged from 24°C to 28°C, which falls within the optimum temperature range for maize cultivation. According to FAO (1976), maize grows best at temperatures between 24°C and 30°C, as these conditions promote photosynthesis, biomass accumulation, and grain development. Consequently, temperature was identified as one of the most influential variables affecting land suitability.

Annual rainfall across the study area was relatively high and generally sufficient to meet the water requirements of maize. However, uneven rainfall distribution resulted in excessive soil moisture in certain locations, increasing the risk of waterlogging and nutrient leaching. Arsyad (2010) reported that high rainfall on sloping land accelerates surface runoff, thereby increasing the potential for soil erosion in the absence of appropriate conservation practices.

The analysis of wet months revealed a relatively long rainy season throughout the study area. Although this condition ensures adequate water availability, prolonged wet periods may lead to soil saturation where drainage is inadequate. Sys et al. (1991) emphasized that maize requires a balance between soil moisture availability and aeration to support healthy root development. Similarly, Oldeman (1975) identified the number of wet months as a key agroclimatic indicator affecting cropping patterns and crop productivity.

Slope analysis showed that most of the study area consists of flat to gently sloping terrain, while a smaller proportion is characterized by undulating topography. These conditions remain suitable for maize cultivation; however, steeper areas require soil conservation measures to reduce erosion risk. Hardjowigeno and Widiatmaka (2018) noted that slope significantly influences infiltration capacity, erosion susceptibility, and soil stability, making it an important criterion in land suitability assessment.

Drainage conditions varied from well-drained to moderately drained soils. Good drainage facilitates the removal of excess water from the soil profile, ensuring adequate oxygen supply to plant roots. Conversely, poor drainage causes prolonged waterlogging, which restricts root respiration and nutrient uptake. According to FAO (1985), drainage is one of the primary limiting factors in evaluating land suitability for food crops because it directly affects both soil water availability and aeration.

The dominant soil textures in the study area were sandy clay loam and clay loam, both of which are considered suitable for maize cultivation. These soil textures possess favorable water-holding capacity while maintaining sufficient porosity for root growth. Sys et al. (1991) explained that soil texture affects water retention, nutrient availability, and root development, whereas Sutanto (2005) emphasized its importance in determining overall land productivity.

The erosion hazard within the study area ranged from low to moderate. The degree of erosion risk was primarily influenced by the interaction among slope, rainfall intensity, and land use. Higher erosion hazard values indicate greater loss of nutrient-rich topsoil, which may significantly reduce soil fertility. Arsyad (2010) identified topsoil erosion as one of the major causes of declining agricultural productivity in tropical regions.

Land use in the study area is predominantly characterized by agricultural land, shrubland, and small areas of open land. These land-use patterns indicate that the SP Janja Transmigration Area still possesses considerable potential for maize cultivation, provided that land management practices are adapted to local biophysical conditions.

Results of the Analytical Hierarchy Process (AHP)

The relative importance of each evaluation criterion was determined using the *Analytical Hierarchy Process* (AHP) through pairwise comparisons based on expert judgments. According to Saaty (1980), AHP transforms qualitative expert assessments into quantitative priority weights, allowing each criterion to be evaluated objectively according to its contribution to the research objective.

The analysis revealed that temperature received the highest priority weight because of its direct influence on maize physiological processes. The remaining parameters were ranked in descending order as follows: rainfall, drainage, wet months, soil texture, slope, erosion hazard, and land use.

Table 4. Priority Weights of Land Suitability Parameters Derived from the AHP

Parameter	Weight	Percentage (%)
Temperature	0.299	29.90
Rainfall	0.202	20.20
Drainage	0.132	13.20
Wet Months	0.120	12.00
Soil Texture	0.112	11.20
Slope	0.057	5.70
Erosion Hazard	0.045	4.50
Land Use	0.031	3.10

Source: Authors' AHP analysis (2025).

The dominance of temperature indicates that climatic conditions constitute the primary determinant of maize suitability within the study area. This finding is consistent with Abuzaid et al. (2022), who reported that climatic variables contribute the greatest influence in GIS–AHP-based land suitability models.

Consistency Test of the AHP Model

The reliability of the pairwise comparison matrix was evaluated using the Consistency Index (CI) and the Consistency Ratio (CR).

Table 5. Consistency Test Results

Parameters	Value
λmaks	8.266
CI	0.038
CR	0.027

Source: Authors' calculation (2025).

The *Consistency Ratio* (CR) of 0.027 is substantially lower than the acceptable threshold of 0.10, indicating that the expert judgments are highly consistent and that the weighting results are reliable for subsequent spatial analysis (Saaty, 2008).

GIS-Based Weighted Overlay Analysis

The AHP-derived weights were integrated with all spatial datasets using the Weighted Overlay technique in ArcGIS 10.8 to generate the maize land suitability map. The *overlay* analysis identified only two land suitability classes, namely Moderately Suitable (S2) and Marginally Suitable (S3). No areas were classified as Highly Suitable (S1) or Not Suitable (N).

Table 6. Distribution of Land Suitability Classes

Land Suitability Class	Area (ha)	Percentage (%)
S2 (Moderately Suitable)	68.71	70.23
S3 (Marginally Suitable)	29.12	29.77
Total	97.83	100.00

Source: GIS weighted overlay analysis (2025).

The predominance of the S2 class indicates that most of the SP Janja Transmigration Area possesses favorable biophysical conditions for maize cultivation. According to FAO (1976), Moderately Suitable (S2) land contains moderate limitations that can generally be overcome through appropriate land management practices.

Conversely, areas classified as Marginally Suitable (S3) are affected by more severe limiting factors, particularly excessive rainfall, inadequate drainage, steeper slopes, and moderate erosion hazard. Hardjowigeno and Widiatmaka (2018) stated that S3 land remains suitable for cultivation but requires additional management interventions, including soil conservation measures, drainage improvement, and more intensive fertilization.

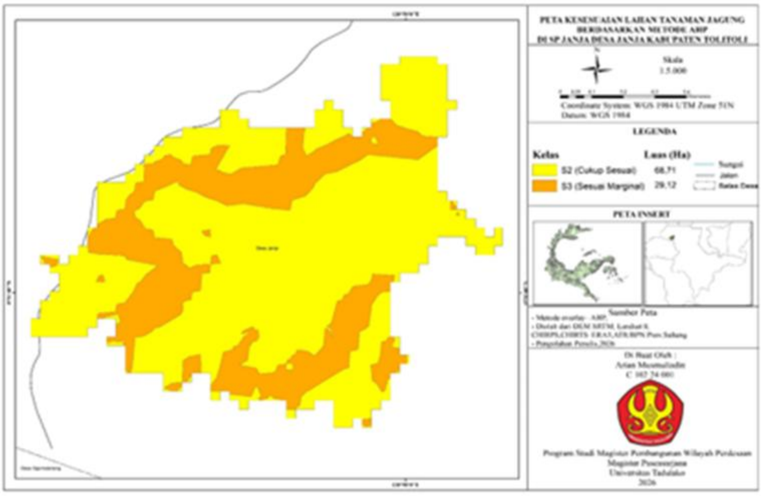

Figure 4. Land Suitability Map for Maize Cultivation in the SP Janja Transmigration Area

Source: Authors' GIS analysis (2025).

DISCUSSION

The integration of the *Analytical Hierarchy* Process (AHP) and *Geographic Information Systems* (GIS) proved to be an effective approach for evaluating land suitability for maize cultivation in the SP Janja Transmigration Area. This integrated framework combines expert-based decision making with spatial analysis, enabling a more objective assessment of the relative importance of each biophysical parameter and producing an accurate spatial representation of land suitability.

The AHP analysis demonstrated that temperature was the most influential factor affecting maize land suitability, accounting for 29.90% of the total weight. This finding indicates that climatic conditions play a dominant role in determining maize productivity within the study area. Temperature directly influences physiological processes such as seed germination, photosynthesis, nutrient absorption, and grain filling. According to FAO (1976), the optimum temperature for maize ranges from 24°C to 30°C, which closely corresponds to the climatic conditions observed in the SP Janja Transmigration Area. This result is also consistent with the findings of Hardjowigeno and Widiatmaka (2018), who identified temperature as one of the principal determinants of land suitability for food crops.

Rainfall ranked as the second most influential parameter, contributing 20.20% of the overall weight. Although adequate rainfall is essential for maize growth, excessive precipitation may become a limiting factor because it increases soil moisture beyond the optimum level, promotes nutrient leaching, and elevates the risk of soil erosion. These observations agree with Arsyad (2010), who reported that high rainfall intensity significantly accelerates surface runoff and soil erosion, particularly in areas with inadequate conservation measures. Therefore, effective water management practices are essential to sustain agricultural productivity in the study area.

Drainage received a weight of 13.20%, emphasizing its importance in maintaining favorable soil aeration and preventing prolonged waterlogging. Well-drained soils facilitate healthy root development by ensuring sufficient oxygen availability, whereas poorly drained soils reduce root respiration and nutrient uptake. These findings support the conclusions of FAO (1985), which recognized drainage as one of the primary limiting factors in agricultural land evaluation.

The number of wet months also contributed substantially to land suitability, with a weight of 12.00%. Extended wet periods increase soil moisture availability but may simultaneously reduce soil aeration and delay field operations. Oldeman (1975) emphasized that the distribution of wet and dry months strongly influences cropping patterns and agricultural productivity in tropical regions. Consequently, seasonal rainfall patterns should be considered when determining planting schedules for maize cultivation.

Soil texture, with a relative weight of 11.20%, plays an important role in regulating water retention, nutrient availability, and root penetration. The predominance of sandy clay loam and clay loam soils in the study area provides favorable physical conditions for maize growth because these textures balance moisture retention with adequate soil permeability. This finding agrees with Sys et al. (1991), who reported that soil texture is a key determinant of crop performance owing to its influence on soil physical properties.

Although slope received a relatively low weight (5.70%), it remains an important factor affecting erosion risk and agricultural management. Most of the study area is characterized by flat to gently sloping terrain, which is generally favorable for mechanized cultivation and minimizes runoff. However, localized steeper areas require appropriate conservation practices, including contour farming, terracing, and vegetative cover, to prevent soil degradation. Similar observations were reported by Hardjowigeno and Widiatmaka (2018), who emphasized the influence of slope on erosion susceptibility and long-term land productivity.

The relatively low weights assigned to erosion hazard (4.50%) and land use (3.10%) do not imply that these factors are unimportant. Instead, their lower contribution reflects the comparatively homogeneous conditions observed within the study area. Nevertheless, inappropriate land use may accelerate erosion processes and reduce soil fertility over time. Arsyad (2010) emphasized that sustainable land management practices remain essential for maintaining long-term agricultural productivity regardless of current erosion levels.

The AHP consistency analysis produced a Consistency Ratio (CR) of 0.027, which is considerably lower than the maximum acceptable threshold of 0.10 recommended by Saaty (1980). This result confirms that the expert judgments used in the pairwise comparison matrix were logically consistent and scientifically reliable. A low CR value enhances confidence in the resulting criterion weights and strengthens the credibility of the land suitability assessment.

The GIS-based *weighted overlay* analysis classified the study area into two suitability categories: Moderately Suitable (S2) and Marginally Suitable (S3). Approximately 70.23% of the total area was classified as S2, indicating that most of the land possesses favorable characteristics for maize cultivation but is constrained by moderate limitations. These limitations primarily include high rainfall, prolonged wet periods, drainage conditions, and localized erosion risk. According to FAO (1976), land classified as S2 remains economically suitable for cultivation provided that appropriate management practices are implemented.

The remaining 29.77% of the study area was classified as S3 (Marginally Suitable). Land within this category is characterized by more pronounced biophysical limitations that may reduce crop productivity if left unmanaged. Nevertheless, S3 land can still be utilized effectively through improved soil conservation practices, drainage enhancement, balanced fertilization, and appropriate crop management strategies. These findings indicate that agricultural development within the SP Janja Transmigration Area should prioritize adaptive land management rather than land conversion.

Compared with previous studies, the findings of this research are generally consistent with those reported by Zolekar and Bhagat (2015), who demonstrated that integrating AHP with GIS improves the accuracy and objectivity of land suitability evaluation. Similarly, Abuzaid et al. (2022) concluded that multi-criteria spatial analysis provides more reliable agricultural planning recommendations than conventional assessment methods because it explicitly accounts for the relative importance of multiple environmental factors. Chen et al. (2021) also emphasized that GIS-based land suitability analysis is an effective decision-support tool for sustainable land-use planning.

The principal contribution of this study lies in the application of an integrated AHP–GIS framework to evaluate land suitability for maize cultivation in the SP Janja Transmigration Area, where no previous comprehensive spatial assessment has been conducted. By incorporating eight biophysical parameters and expert-based weighting, the resulting land suitability map provides scientifically robust information for agricultural planning, regional development, and evidence-based policy formulation. The methodology presented in this study may also serve as a practical reference for land suitability assessments in other transmigration areas with comparable environmental conditions.

Despite these contributions, several limitations should be acknowledged. The analysis focused primarily on biophysical variables and did not explicitly incorporate socioeconomic factors, infrastructure accessibility, market proximity, or farm management practices, all of which may influence agricultural productivity. Future studies are therefore recommended to integrate socioeconomic and environmental variables using advanced spatial decision-support techniques to generate more comprehensive land suitability models.

CONCLUSION AND RECOMMENDATIONS

This study evaluated the land suitability for maize cultivation in the SP Janja Transmigration Area, Janja Village, Lampasio District, Tolitoli Regency, through the integration of *the Analytical Hierarchy Process* (AHP) and *Geographic Information Systems* (GIS). The results demonstrated that the integrated AHP–GIS approach provides a systematic, objective, and reliable framework for assessing land suitability based on multiple biophysical criteria.

The AHP analysis identified temperature as the most influential parameter, accounting for 29.90% of the total weight, followed by rainfall (20.20%), drainage (13.20%), wet months (12.00%), soil texture (11.20%), slope (5.70%), erosion hazard (4.50%), and land use (3.10%). The calculated Consistency Ratio (CR) of 0.027 confirmed that the expert judgments were highly consistent and satisfied the reliability requirements of the AHP methodology.

The GIS-based *weighted overlay* analysis classified the study area into two land suitability classes. Approximately 68.71 ha (70.23%) of the study area was categorized as Moderately Suitable (S2), while 29.12 ha (29.77%) was classified as Marginally Suitable (S3). No land was categorized as Highly Suitable (S1) or Not Suitable (N). These findings indicate that the SP Janja Transmigration Area possesses substantial potential for maize cultivation; however, agricultural productivity remains constrained by several biophysical factors, including rainfall intensity, prolonged wet periods, drainage conditions, slope, and erosion hazard.

Overall, the integration of AHP and GIS successfully generated a scientifically reliable land suitability model that can support evidence-based agricultural planning and sustainable land management. The resulting land suitability map provides valuable spatial information for optimizing maize cultivation and promoting sustainable agricultural development in Tolitoli Regency.

Recommendations

Future research is recommended to incorporate additional socioeconomic, environmental, and economic variables into the land suitability evaluation framework in order to develop more comprehensive decision-support models. Integrating remote sensing data, high-resolution satellite imagery, and advanced spatial modeling techniques may further improve the accuracy of land suitability assessments.

For practical implementation, local governments and agricultural stakeholders are encouraged to prioritize maize cultivation within areas classified as Moderately Suitable (S2) while implementing appropriate land management practices, including soil conservation, drainage improvement, balanced fertilization, and erosion control measures. Such interventions are expected to enhance agricultural productivity while ensuring the long-term sustainability of land resources.

FURTHER STUDY

This study has several limitations that should be considered when interpreting the findings. First, the land suitability assessment was primarily based on biophysical parameters, whereas socioeconomic factors such as infrastructure accessibility, production costs, market availability, farmers' management practices, and institutional support were not explicitly incorporated into the analysis.

Second, the weighting process relied on expert judgments obtained through the Analytical Hierarchy Process. Although the Consistency Ratio indicated a high level of reliability, different groups of experts may produce slightly different weighting results depending on their knowledge and experience.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Graduate School of Tadulako University for providing academic support throughout this research. The authors also acknowledge the assistance of the Government of Tolitoli Regency, the Office of Statistics Indonesia (BPS) of Tolitoli Regency, the Meteorology, Climatology, and Geophysics Agency (BMKG), and all institutions that provided the spatial and non-spatial data required for this study.

Special appreciation is extended to the expert respondents who participated in the *Analytical Hierarchy Process* (AHP) assessment, as well as to all colleagues and field assistants whose valuable support contributed to the successful completion of this research.

Finally, the authors gratefully acknowledge all individuals who provided encouragement, constructive suggestions, and technical assistance throughout the research process.

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