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Original research article

Assessment of Suitability and Potential of Rural Settlement Land in Tanah Datar Regency, Indonesia: A Method Based on Comprehensive Criteria for Physical Factors

Eggy Arya Giofandi[1,*], Dhanu Sekarjati[2]

[1] *Graduate Program of Regional Planning Science, Faculty of Agriculture, IPB University, West Java 16680, Indonesia*
[2] *Geoinformatics, Department of Computer Science, College of Computing, Khon Kaen University, Khon Kaen 40000, Thailand*

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ABSTRACT

Anthropogenic activities interact with the structure of rural dwellings and metabolic processes, affecting the livability of villages. This study aims to assess the suitability and potential of rural settlement land using a method of comprehensive criteria to support sustainable rural development. The research method employed in this study involves a Multi-Criteria Decision-Making (MCDM) procedure, which is chosen for its capability to integrate multiple factors in decision-making. This approach enables the evaluation of land suitability based on topographic and soil characteristics, ensuring an in-depth and objective assessment. The Analytical Hierarchy Process (AHP) was used to assign weights to criteria. The findings classify land suitability for settlements into four zones: highly suitable, suitable, marginally suitable, and unsuitable. The potential land suitability for rural settlements is approximately 1,234 hectares, while existing settlements span 1,260 hectares (highly suitable), 1,700 hectares (suitable), 344.64 hectares (marginally suitable), and 208.54 hectares (unsuitable). This method ensures accurate land suitability assessment, aiding settlement optimization. It supports government spatial planning, disaster risk reduction, and community resilience. The findings serve as a guide for sustainable rural settlement management.

Keywords: Land potential; Rural settlements; Sustainability indicators; West Sumatra

***Corresponding author:** eggyarya@apps.ipb.ac.id
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1. Introduction

Population decline, often referred to as depopulation, is a prominent phenomenon in various regions of Indonesia, especially in West Sumatra. This phenomenon typically occurs when young adults migrate to urban areas in search of better opportunities, leaving their hometowns behind. As a result, many rural areas are experiencing vacant homes and deterioration of local infrastructure [1]. However, this trend has started to shift as young people, after achieving success elsewhere, are beginning to return to their rural origins. Over time, this has led to a shift in dynamics, with younger generations working to improve their hometowns, not only focusing on economic development but also striving to enhance local ecosystems and quality of life. Despite this positive shift, land use inefficiencies and environmental disruptions remain significant challenges, highlighting the need for strategic planning and better land management [2]. Previous studies have similarly observed that rural depopulation can lead to the degradation of local resources and infrastructure, necessitating more sustainable land use practices [3].

The rural environment in Indonesia is increasingly under pressure due to unsustainable land use practices, resulting in land degradation, loss of biodiversity, and inefficient utilization of natural resources. The complexity of these challenges calls for the integration of geospatial technologies, particularly Geographic Information Systems (GIS), to support better decision-making and land use optimization. GIS-based assessments provide essential insights into optimal land utilization by evaluating topographic, soil, and land characteristics in both spatial and temporal contexts [4]. GIS-based approaches can support the process of residential land use planning, ensuring that land is used efficiently while considering environmental sustainability and socio-economic factors [5].

The decision-making process in land use planning has been revolutionized by the advent of GIS technology, which has made the process faster and more accurate by facilitating ease of access and utilization of spatial data [6-8]. This shift in approach represents a significant novelty by providing data access to communities through GIS applications that are publicly available and easy to use [9]. When combined with Multi-Criteria Decision-Making (MCDM) methods, GIS provides an even more powerful tool for solving complex land use problems, allowing decision-makers to evaluate multiple criteria simultaneously [10]. MCDM models have been successfully applied in regions like India to assess land suitability [11], and Greece to assess sustainable electricity technologies, taking into account not only environmental factors but also socio-economic considerations such as accessibility to infrastructure and community preferences [12].

The integration of MCDM with remote sensing data offers a novel advantage in regions with complex topography and varying land capabilities, such as those found in Tanah Datar Regency. The high-resolution remote sensing data combined with MCDM allows for the detailed assessment of land suitability for rural settlements by considering physical factors, as well as current land uses and spatial patterns. A review of the literature shows that the application of MCDM in land suitability analysis has been increasingly prevalent, particularly in rural and sensitive areas where it has helped balance environmental sustainability with socio-economic development [13].

Furthermore, studies have shown

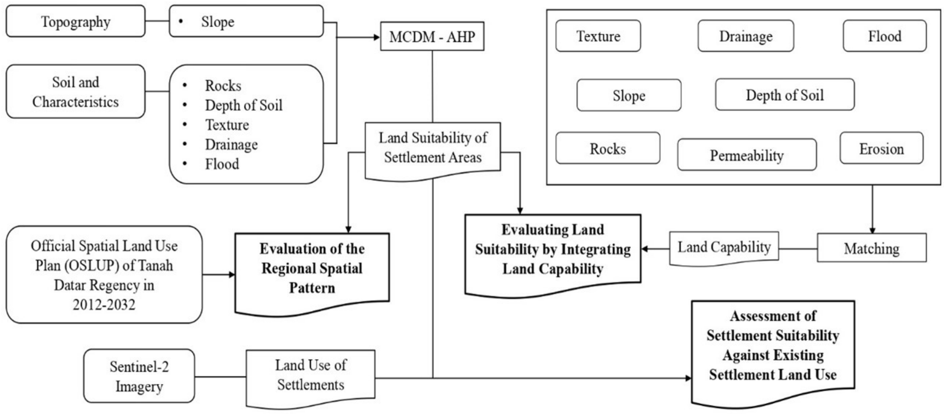

Fig. 1. Flowchart of methodology.

that MCDM, when applied alongside GIS, can accommodate both qualitative and quantitative data, making it highly adaptable to diverse contexts [14]. This study introduces a novel approach by using 10m × 10m spatial resolution remote sensing data to develop a GIS-based model that can evaluate land suitability and offer insights into the potential of rural settlement development in Tanah Datar Regency, West Sumatra.

The research's novelty lies in its ability to integrate both physical environmental factors and remote sensing data to assess land suitability for rural settlements. This approach not only provides a more comprehensive understanding of land use potential but also helps identify areas where sustainable development can be achieved. Additionally, the study emphasizes the importance of considering land capability and current land use patterns in evaluating settlement suitability, offering a more integrated perspective on land development in rural areas. The incorporation of local ecological knowledge and customary land use practices into modern land use planning could further enhance the sustainability of rural settlements.

2. Materials and Methods

The research methodology involved several steps. First, physical data of the study area were collected to calculate land capability, land suitability, spatial plan, and existing settlement land use. Second, potential rural settlement land zones were identified. Third, these zones were overlaid with the spatial plan to create suitable and unsuitable zones for the spatial plan. Fourth, the suitability of rural settlement land was overlaid with existing settlement land use to determine whether the existing settlement is suitable for the land suitability of rural settlement areas. This process is based on a comprehensive indicator system (Fig. 1).

2.1 Study area

Tanah Datar Regency is one of the regions in West Sumatra with rapid growth, through the leading agricultural sector (Fig. 2). Development conditions with the need for land for residential settlements have increased the need for more space; this has the potential to erode agricultural land into residential areas. The population is increasing from year to year, reaching 373,693 people in 2021 [15]. Geographi-

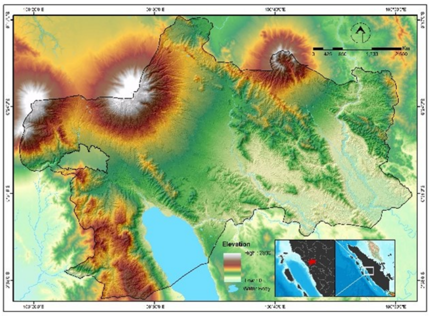

Fig. 2. Research location.

Table 1. Scale of Importance.

Most Important	Extremely	9
	Very Strongly	7
	Strongly	5
	Moderately	3
Equally Important		1
Less Important	Moderately	1/3
	Strongly	1/5
	Very Strongly	1/7
	Extremely	1/9

cally Tanah Datar Regency has an area of 1,337 Km2 with diverse topographic characteristics [16], which creates dynamics in the growth of residential areas temporally.

2.2 Data collection

Topographic data of Tanah Datar District was obtained from the extraction of digital elevation model data with a resolution of 8 meters which can be downloaded from the Geospatial Information Agency website. Furthermore, soil data and soil characteristics with a scale of 1:50,000 were obtained from the Indonesian Land Center, Research and Development. Then the data of the Official Spatial Land Use Plan (OSLUP) of Tanah Datar Regency in 2012-2032 was obtained from the Ministry of Public Works and Housing of West Sumatra Province, and existing residential land use data was obtained from Sentinel-2A remote sensing data recording in 2022.

2.3 Analysis

The analysis of settlement land suitability and existing settlements was conducted sequentially. The suitability of settlement land was assessed using the Multi-Criteria Decision Making (MCDM) approach. Initially, the Analytical Hierarchy Process (AHP) was employed to determine the weights of the criteria. These criteria represent parameters considered influential in assessing the suitability of rural settlement land. The AHP method, introduced by Saaty in 1977, utilizes a pairwise comparison matrix to evaluate the relationships among the main factors involved in decision-making [17]. Saaty's importance scale served as the basis for comparisons during the research process (Table 1).

When a factor exerted a greater and more significant influence compared to others, it received a higher value, resulting in an increased weight. Consequently, the six thematic layers identified as key factors were analyzed using the pairwise comparison matrix, with adjusted weightings reflecting the relative importance of each layer. This process facilitated the determination of rural settlement land suitability. In the AHP assessment, the process begins with identifying potential uncertainties that may arise during ranking and scoring. These uncertainties are quantified using the consistency index and the principal eigenvalue, as calculated according to Eq. (2.1).

$$CI = \frac{\lambda \max - n}{n - 1}, \tag{2.1}$$

where, $\lambda \max$ represents the principal eigenvalue derived from the matrix, while n denotes the total number of criteria involved in the analysis process. Consistency analysis and evaluation of the rating scale are further refined through the calculation of the Consistency Ratio (CR) using Eq. (2.2). This approach is employed to assess the consistency of experts in the pairwise comparison matrix.

$$CR = \frac{CI}{RCI}. \tag{2.2}$$

Subsequently, the RCI value, referring to the Randomized Consistency Index, was calculated based on the guidelines established by Saaty. In determining the consistency value, if the Consistency Ratio (CR) is less than 10%, the findings are considered consistent. Conversely, if the CR exceeds 10%, it indicates inconsistency in the assessment, necessitating a reevaluation by the experts [18]. Once the criterion weight values were determined, other sub-criteria for settlement land suitability were identified. The subsequent step involved calculating the score of each sub-criterion using geographic information system (GIS) software. Each score was derived by multiplying the weighted values of the criteria. It is noteworthy that no specialized software was utilized during the analysis. The resulting scores were then input into the polygons, arranged sequentially from the smallest to the largest value.

Using the MCDM approach, based on the AHP calculations, the involvement of experts was crucial in determining the suitability of rural settlement land. The experts included individuals from various organizations: universities with expertise in geography, civil engineering, and hydrology; spatial planning and settlement development agencies with backgrounds in regional economics and regional and urban planning; regional development and research agencies with expertise in regional and urban planning; public works agencies with backgrounds in civil and geological engineering; and indigenous communities with deep knowledge of customary rules and historical context in the observation area.

After completing the initial calculations, further assessment was conducted to assign scores based on the contribution level of each sub-criterion to the characteristics of rural settlement land suitability. A land suitability map for residential areas was developed by translating the criterion weights into sub-criteria. The residential land suitability was classified into four categories: highly suitable, suitable, marginally suitable, and unsuitable, as updated according to Eq. (2.3).

$$S = \sum_{i=1}^{N} W_i X_i, \tag{2.3}$$

where, S is the suitability of the area, W_i is the weight of the criteria for the suitability of the area, X_i is the score of sub-criteria i, and n is the number of criteria for the suitability of the area.

2.4 Land capability

The classification of land capability follows the framework developed by the USDA [19, 20], which has been modified to suit the land characteristics of Indonesia. Land is utilized for various purposes, primarily agriculture, plantations, and settlements. Soil characteristics are categorized based on their formation, with parent materials, organisms, time, and climate identified as the main factors influencing soil development [21]. In Indonesia, the limiting factors for land capability classes are divided into eight categories: texture, slope, drainage, soil depth, erosion, rock, flooding, and permeability. The land capability classification comprises eight classes, where (*) indicates no limiting factors, and

Table 2. Limiting Factors of Land Capability Classification.

No	Limiting Factors	Capability Class							
		I	II	III	IV	V	VI	VII	VIII
1	Texture (t)	t2/t3	t1/t4	t1/t4	(*)	(*)	(*)	(*)	t5
2	Slope (%)	i0	i1	i2	i3	(*)	i4	i5	i6
3	Drainage (d)	d0/d1	d2	d3	d4	(**)	(*)	(*)	(*)
4	Depth of Soil (k)	k0	k0	k1	k2	(*)	k3	(*)	(*)
5	Erosion (e)	e0	e1	e1	e2	(*)	e3	e4	(*)
6	Rocks (b)	b0	b0	b0	b1	b2	(*)	(*)	b3
7	Flood (O)	O0	O1	O2	O3	O4	(*)	(*)	(*)
8	Permeability (p)	p2/p3	p2/p3	p2/p3/p4	p2/p3	p1	(*)	(*)	p5

Source: [22]

Table 3. Distribution of criteria for each parameter for land suitability of residential areas.

Parameter	Criteria	Sub Criteria	Area		Rank	Weight (%)
			Hectare	(%)		
Topography	Slope	<8%	41,644	31.82	4	62.0
		8-16%	9,567	7.31	3	46.5
		16-27%	53,419	40.81	2	31.0
		>26%	26,263	20.06	1	15.5
Soil and characteristics	Rocks	Little	46,980	35.89	3	32.6
		Medium	14,241	10.88	2	16.4
		Much	69,672	53.23	1	8.2
	Depth of Soil	Shallow	4,399	3.36	3	30.6
		Moderate	753	0.58	2	20.4
		Deep	125,741	96.06	1	10.2
	Texture	Slightly rough	0	0	3	25.8
		Slightly smooth	47,261	36.11	2	17.2
		Smooth	83,632	63.89	1	8.6
	Drainage	Good to fair	101,733	77.72	3	96.3
		Moderate	24,262	18.54	2	64.2
		Poor to obstructed	4,898	3.74	1	32.1
	Flood	Without	114,947	87.82	3	76.2
		Rarely	15,946	12.18	2	50.8
		Frequently	0	0	1	25.4

(**) signifies land surfaces that are permanently waterlogged. The limiting factors for the land capability classes applicable to the research area are presented in Table 2.

2.5 Land suitability of settlement areas

The spatial distribution of rural residential areas has been influenced by several factors, which are soil factors and topographic conditions of the region. In this study, a statistical analysis of the physical factors of land suitability of rural residential areas in the relevant literature was conducted. The examination of the actual situation in Tanah Datar District consists of four main analyses, where the land suitability analysis of residential areas is included in the main analysis to evaluate the land use plan of settlements and existing settlements.

The residential land suitability analysis was used to determine the level of suitability based on physical factors considered important in proposing the delineation of residential areas [23]. The selected physical factors were then analyzed for suitability within the study area such as slope, rock, soil depth, texture, drainage and flooding criteria. This assessment uses the equation in [24]. Based on the characteristics of the area that are not much different from the research location. Each factor is divided into sub-criteria to produce more specific boundaries, with the sub-criteria with the most suitable characteristics for residential areas placed at the top and unsuitable characteristics placed at the opposite (Table 3). Therefore, sub-criteria that provide suitable characteristics will encourage greater land suitability for settlements in Tanah Datar District.

The results of the distribution of factors deepened into sub-criteria will reflect the relative importance in determining the suitability of residential development activities. Slope <8% is assumed to have characteristics that can be used for residential area development which will minimize the occurrence of land movement on steep slopes. If there are many rocks on the ground surface, buildings are unable to stand stably. This also affects soil depth, texture, and drainage. Flood criteria with areas that do not have flooding are better for building residences by minimizing the risk of natural disasters [25].

2.6 Land use planning

Spatial planning is an external form of arrangement and organization of regional spatial planning for the purpose of allocating or utilizing natural resources on a regional and national scale. In addition, spatial planning is an integrated land use scheme that is linked to future uncertainties, requiring a more sophisticated goal orientation. As a result, spatial planning has multiple objectives, and the effectiveness of its implementation is often interpreted from different perspectives by different practitioners. Planning stems from rational decision-making, and the rationality of outcomes is an important value orientation for evaluating the effectiveness of planning implementation [26]. Experts who subscribe to the concept of outcome rationality believe that the purpose of planning is to eliminate the impact of future uncertainty, and the degree of consistency between planning outcomes and planning expectations can be used as a criterion for evaluating the effectiveness of planning implementation.

3. Results

3.1 Evaluating land suitability by integrating land capability

Land characteristics that have differences in composition will produce soil diversity with different conditions. Soil properties such as texture, soil depth, drainage, permeability are characteristics that often can be distinguished on the surface. This will provide assistance for soil classification in knowing the ability of land so that land utilization on the surface can be done optimally [27]. These conditions form an indication of land characteristics commonly called land suitability. In the results section, land capability is an assessment of a land to be categorized based on its characteristics so that it can be limited to land that is utilized and land that must be protected as a conservation zone. Land capability class I-IV is a category of land that can be utilized by humans for all activities be it cultivation or agriculture; the land area that can be utilized reaches 6.53 kilometers. Classes V-VII are parts that must be desig-

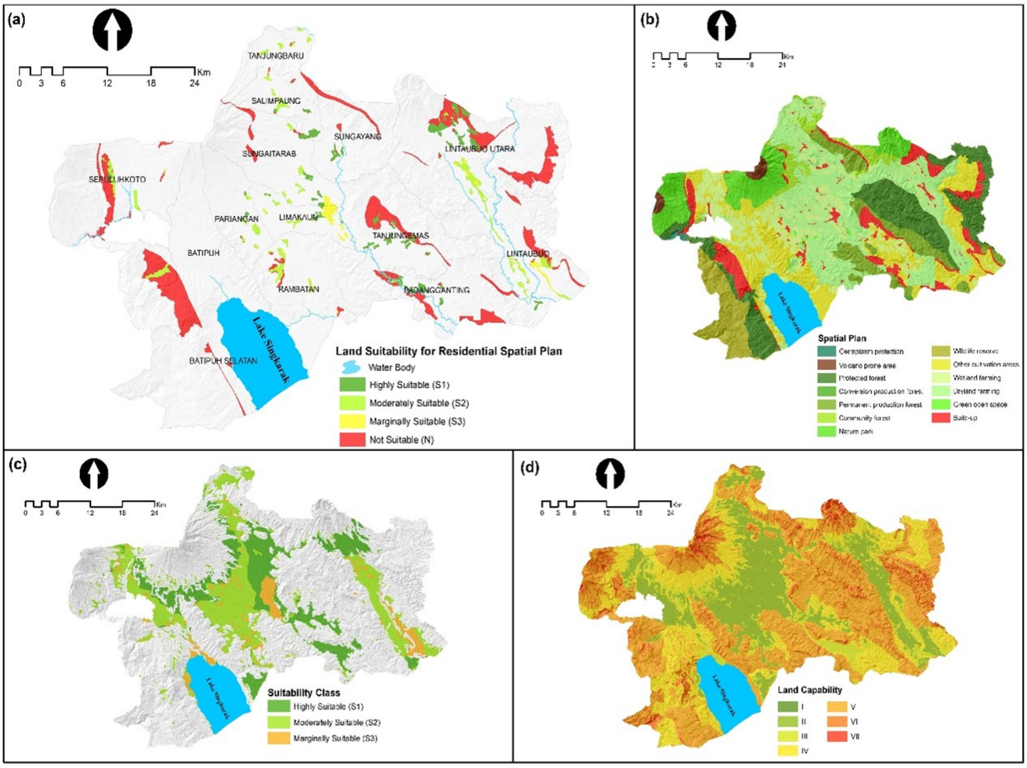

Fig. 3. Map information (a) land suitability for residential spatial plan, (b) spatial plan, (c) suitability class, and (d) land capability.

nated as protected zones based on characteristics that have many shortcomings and topography that is prone to natural disasters; this zone area reaches 6.55 kilometers (Table 4).

The land suitability of settlements calculated based on soil characteristics and topography provides the output results of the land suitability class of rural residential areas (Table 4) with the division of highly suitable zones, suitable zones, marginal suitable zones, and unsuitable zones. The land suitability map for rural residential areas can be seen in Fig.3 (c), which is compiled from a combination of land suitability and land capability, establishing the land suitability of rural residential areas.

The land suitability of rural residential areas results in optimizable zones of about 26% of the overall area. The characteristics of the area with unique soil conditions have provided complex limitations in the selection of zones that can be inhabited by the community. The marginal suitability zone is one of the considerations if the highly suitable and suitable zones have already established mass settlements [28]. Through the use of technology, it will be possible to provide solutions in utilizing land for housing in this zone [29]. Generally, land conditions in the marginal suitable zone are on slopes of 16-27% and require special treatment to flatten the land so that it can be built upon. Meanwhile, soil conditions and characteristics in the marginal suitable zone category, such as

Table 4. Distribution of results and extent of land capability, land suitability, spatial pattern, and settlement land suitability to spatial pattern.

Parameters	Category	Area	
		Hectare	%
	I	1	0.01
Land Capability	II	2,610	19.94
	III	739	5.65
	IV	3,189	24.36
	V	4,788	36.58
	VI	1,624	12.41
	VII	139	1.06
Land Suitability of Settlement Areas	Highly Suitable	1,283	9.80
	Moderately Suitable	2,128	16.26
	Marginally Suitable	382	2.92
	Unsuitable	9,296	71.02
	Protected forest	1,966	15.02
	Conversion production forest	96	0.07
	Permanent production forest	930	7.11
	Community forest	522	3.99
Spatial Plan	Other cultivation areas	2,567	19.61
	Volcano prone areas	121	0.93
	Germplasm protection	28	0.21
	Settlement	1,078	8.24
	Wetland agriculture	1,644	12.56
	Dryland agriculture	2,352	17.97
	Green open space	12	0.09
	Wildlife sanctuary	739	5.64
	Nature park	1,120	8.56
Impact Spatial Plan for Land Suitability of Settlement	Highly Suitable	1,63	15.10
	Moderately Suitable	1,88	17.49
	Marginally suitable	48	4.49
	Unsuitable	6,78	62.92

medium to deep soil depth, will make building foundations if not installed to reach the limit of soil depth, giving the effect of movement so that the foundation is not strong. Likewise, drainage that requires good to somewhat good conditions has an influence on the formation of waterways, so that flood conditions can indirectly minimize property losses in the community [30].

3.2 Evaluation of the regional spatial pattern

The land suitability of rural residential areas is then evaluated against land use planning data, which at this stage will produce four zoning criteria. In Table 3 row of land suitability of settlements against the spatial pattern dominates the spatial pattern of settlements in unsuitable zoning of 62.92% of the space designated in the spatial pattern. As seen in Fig. 3(a) contains information in red with unsuitable characteristics covering almost all areas in Tanah Datar District. This condition will have an influence if the regional level spatial pattern is still used in providing building permits for the community. When considering the 1,078 hectare category in Table 3 of the spatial plan section, further evaluation is necessary regarding the zoning of these settlements to optimize zoning suitable for the development of rural residential areas.

Table 5. Distribution of results and area of existing settlements and land suitability of settlements to existing settlements.

Parameters	Category	Area	
		Hectare	%
Existing Settlements	Settlement	3,514	2.68
	Non-Settlement	127,379	97.32
Land Suitability Settlement Against Existing Settlement	Highly Suitable	1,260	35.86
	Moderately Suitable	1,700	48.40
	Marginally Suitable	344	9.81
	Unsuitable	208	5.93

3.3 Assessment of settlement suitability against existing settlement land use

Existing settlement land use is obtained from remote sensing data, where the resulting information describes the distribution of settlement land use in 2022. After the calculation process of the suitability of rural settlement areas, an assessment of existing land use is then carried out which will produce information on the existence of settlements in the suitability classification.

Fig. 3(a) shows the distribution of clustered rural residential areas. Geographically, Tanah Datar Regency has three active volcanic mountains in the north which have relatively fertile soil characteristics to be utilized by the agricultural sector for plantations. This condition makes the community tend to build settlements or villages in the northern part of the research area where almost most of the people make a living as farmers or by farming. Community activities are inseparable from the need for clean water for daily needs [31], as can be seen in Fig. 4(e), with settlements located along the river. Fig. 4(f), the combined suitability of rural settlement areas for existing settlements, shows that most of these settlements are in the very suitable and suitable zones. However, there are also settlements located in the zone of suitability of settlement areas in the marginally suitable and unsuitable categories.

This indicates either a lack of adequate land for settlements or a preference for locations influenced by other factors, such as limited accessibility or proximity to specific resources. Further details on land distribution are presented in Table 5, which reveals that only a small portion of the total area, 2.68%, is utilized for settlements, while the majority of other areas remain undeveloped for settlement purposes.

4. Discussion

The findings of this study indicate that aspects of topography and soil characteristics play a crucial role in assessing land suitability for rural settlements. However, these values alone are insufficient to conclude that the land is truly suitable for sustainable settlement development. Sustainability involves a complex set of criteria, including ecological balance, ecosystem health, ecosystem services, and protected zones, which are critical in determining whether a settlement will thrive in the long term [32]. As highlighted by previous studies, ecological considerations such as the preservation of local biodiversity and the maintenance of ecosystem services must be integrated into land suitability assessments [33]. Moreover, factors such as green planning, socio-ecology, socio-economics, and environmental security need to be considered as complementary elements that support sustainability without compromising the balance of natural resources. These elements must be carefully woven together to ensure the environmental, social, and economic dimensions of sustainability are

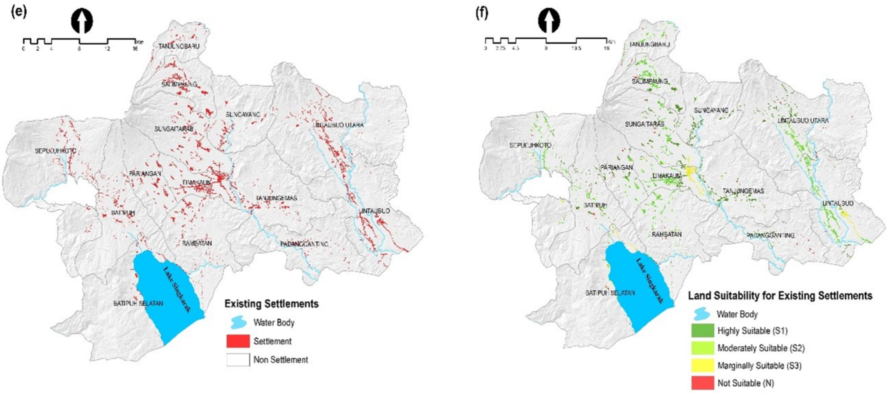

Fig. 4. Map information (e) existing settlements, (f) land suitability for existing settlements.

effectively addressed [34].

While the study provides valuable insights into the physical and environmental characteristics of the land, it also acknowledges limitations in considering climate variables and the social aspects of the community. Future studies should incorporate these critical factors to provide a more holistic view of land suitability. In particular, the role of human activity in land use planning cannot be underestimated, as settlements often expand into areas that may not be ecologically optimal [35]. Therefore, understanding the social dynamics, local wisdom, and community needs is key in fostering the development of settlements that are both ecologically sustainable and socially acceptable. In addition, disaster risk factors, whether meteorological or due to natural disasters, should be included as part of the settlement planning process. This will help mitigate risks associated with hazards such as flooding or landslides, which can have devastating impacts on vulnerable communities.

The study also highlights that livelihood factors, population mobility, and the availability of infrastructure are critical considerations in the development of rural settlements. Changes in population dynamics and access to resources such as transportation and utilities play a significant role in determining where settlements should be established [36]. As rural communities grow, it becomes essential to ensure that infrastructure can meet the needs of these populations. Moreover, accessibility and infrastructure quality influence land value, and these factors must be taken into account when evaluating land for future development [37]. This emphasizes the importance of a multi-faceted approach to land suitability that includes not only physical characteristics but also socio-economic and infrastructural factors.

The study suggests that the selection of appropriate technologies for settlement development should be guided by the economic capacity of the local community. This involves considering both the local needs and the existing conditions of the land to choose technologies that are cost-effective, sustainable, and adaptable to the community's lifestyle [38]. Technologies that support eco-friendly construction methods and sustainable resource management can enhance the ecological sustainability of rural settlements, ensuring that they are not only viable but also resilient to future challenges [39]. In the process of modern residential system development, integrating these technologies will help address lifestyle challenges, such as energy consumption, water management, and waste disposal, while contributing to long-term ecological health [40].

Theoretically, this research process involves assessing the potential for land development in rural residential areas using physical environmental data, supported by additional reference information such as land capability, spatial planning, and current land use patterns. The MCDM procedure employed in this study ensures that non-uniform criteria are considered, providing a more comprehensive assessment of land suitability. This approach links the physical attributes of the land with the existing spatial planning framework, offering a more integrated understanding of land use both now and in the future.

The study also acknowledges the presence of diverse wildlife in the region. This biodiversity underscores the need for careful land use planning that considers the ecological significance of these habitats [41]. The local community has long practiced coexistence with these species, often guided by customary laws that promote the sustainable use of the land. This traditional knowledge and ecological stewardship can be leveraged to create residential spaces that are not only compatible with the environment but also contribute to the conservation of wildlife and ecosystems [42]. Incorporating these local practices into modern land use planning could help strike a balance between human settlement and ecological conservation, ensuring that both the community and the environment thrive together.

5. Conclusion

Theoretically, in the research flow process, the potential for land development in rural residential areas is sought based on physical environment data and additional reference information such as land capability, spatial plans, and existing residential land use. The study aims to identify land suitability and potential zones for rural residential development while addressing spatial planning and existing land use dynamics, in alignment with the study objectives. Through this approach, the research highlights that integrating land capability (e.g., soil characteristics) with regional land use planning and current residential use is crucial for assessing suitability. This integration ensures that land use planning aligns with physical constraints and supports sustainable development in Tanah Datar Regency. Notably, the most significant influence in the land suitability process of rural residential areas is exerted by land capability, combining soil characteristics with regional land use planning and existing residential land use information to depict current and future land use conditions. Furthermore, the findings underscore the importance of marginal zones as alternative development areas when primary zones have been fully utilized, suggesting that technology and engineering innovations can mitigate physical limitations.

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