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Research Paper

Land Suitability Assessment for Sustainable Settlement in Serang Regency, Banten Province

Muhammad Junaid[1*], Rifnaldi Bergas Anggara[1], Rakyan Paksi Nagara[1], Adi Wibowo[2]

[1]*Master of Science Program in Geography, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, Jawa Barat, 16424, Indonesia*
[2]*Department of Geography, Faculty of Mathematics and Natural Science, Universitas Indonesia, Depok, Jawa Barat, 16424, Indonesia*
***Corresponding author e-mail**: muhammadjunaidk22@gmail.com

Abstract
Urbanization is the result of persistent population increase, which turns formerly agrarian areas into industrial and service-based hubs. This change prompts concerns about environmental degradation, including flooding, declining agricultural output, and air pollution, as well as a rise in demand for residential real estate, a limited resource. Goal 11 of the Sustainable Development Agenda, "Building Inclusive, Safe, Resilient, and Sustainable Cities and Communities" addresses these problems. However, a comprehensive LSA incorporating local climate aspects has not been conducted for Serang Regency, an area with significant population growth and diverse land characteristics. This study aims to map the spatial distribution of suitable residential land in Serang Regency; evaluate the suitability of current residential areas; and assess the alignment of settlement plans with suitability criteria in the spatial plan. Findings reveal that 65.5% of Serang Regency is suitable for residential use, while 32% is unsuitable. Currently, 71.2% of settlements are in suitable areas, and 28.2% are in unsuitable ones. Future settlement plans show 90.7% alignment with suitable areas. These results indicate that, while spatial planning in Serang Regency has generally guided appropriate residential development, some areas still require attention for sustainability. This study provides valuable insights for policymakers aiming to foster sustainable, safe, and comfortable living environments.

Keywords
Evaluation, Land Suitability, Sustainable Settlement, Spatial Analysis, SMCE

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1. INTRODUCTION

Urbanization rates are rising as a result of the world population explosion in both developed and emerging nations, including Indonesia (Sadiv, 2022; Norrman, 2023; Sari et al., 2023). Indonesia is the fourth most populated nation in the world, behind the United States, China, and India, according to the latest recent figures. Indonesia has experienced a notable acceleration in its urbanization process, with an average population growth rate of 1.08 for the last five years (2019–2023), according to the Central Bureau of Statistics (Buhaug and Urdal, 2013).Urbanization was traditionally understood to be the process of people moving from rural to urban locations.

However, more recently, the term has come to refer to a broader structural transformation from agricultural to industrial and service-based economies (Simpson, 1999; Hussain and Imitiyaz, 2018; Moll et al., 2019; Streule et al., 2020; Dijkstra et al., 2021). Recent research have shed light on the intricacy of urban growth and the frequency with which agricultural lands are converted into residential and industrial zones as a result of this process. This tendency poses serious obstacles to the management of land use sustainably (United Nations United Nations Human Settlements Programme, 2022).

Careful land management is necessary because land is still a scarce resource and because urbanization and population growth are increasing the demand for housing (Liu et al., 2023; Lourenco et al., 2020).Natural environments becoming urbanized increases the likelihood of landslides, flooding, and decreased agricultural production, for example, all of which have an impact on the security of food supply (AbdelRahman, 2023; IPCC, 2023).This is especially true in situations where there has been an unanticipated or unsuccessful conversion. To address these issues, it is imperative that the Sustainable Development Goals (SDGs) be fulfilled, particularly Goal 11, which pertains to the creation of inclusive, secure, resilient, and sustainable urban environments (Klopp and Petretta, 2017). Complete urban planning and land use management that takes social, economic, and environmental considerations into account

is required to maximize sustainability and reduce adverse effects (United Nations United Nations Human Settlements Programme, 2022).

Despite numerous studies on land use and urban planning, there remains a lack of comprehensive research integrating local climate conditions into land suitability analyses (LSA) for residential development. This gap is particularly evident in regions like Serang Regency, Indonesia, where varied topographical conditions and high urbanization rates present unique challenges and opportunities for sustainable development. The novelty of this research lies in its approach to incorporating local climatic factors into the LSA framework to assess the suitability of land for residential purposes. This approach provides a more nuanced understanding of land use dynamics that accounts for both environmental sustainability and the practical needs of urban expansion.

In this study, we conducted a comprehensive LSA to evaluate the suitability of land for residential use in Serang Regency, considering both current settlement patterns and future development plans. Using Geographic Information Systems (GIS), we used spatial analytic techniques to map the spatial distribution of acceptable and unsuitable areas for residential construction. The three main goals of the study were to: (1) identify the pattern of spatial distribution of suitable settlement land in Serang Regency; (2) assess the suitability of currently existing settlement lands; and (3) determine whether future settlement plans will be in line with the region's spatial development strategy. The results show that while some regions need careful management to prevent unsustainable activities, a sizable section of Serang Regency is still eligible for residential development.These insights provide valuable guidance for policymakers and urban planners aiming to balance growth with sustainability.

2. EXPERIMENTAL SECTION

2.1 Materials

The formation of a land suitability map is carried out by taking into account several factors such as physical environmental conditions, disaster potential, accessibility, microclimate, protected areas. The physical aspect of the environment plays an important role in describing the shape of the land, where the flatter it is, the easier and safer it is to use as a settlement (Sulistiyanto et al., 2020). Slope data is obtained from the processing of the National Digital Elevation Model (DEMNAS) provided by the Geospatial Information Agency. Disaster aspects are no less important in determining settlement land that determines the level of security (Wulandari and Idramsyah, 2021). Disasters can cause comfort disturbances at low intensity, property losses at moderate intensity, and loss of life at high intensity. Disaster data is obtained from InaRISK, which has presented disaster risk maps for landslides, earthquakes and tsunamis. In addition to the safety aspect, residential feasibility is also determined by comfort, which can be represented by surface temperature (Economist Intelligence Unit, 2012). A lower average temperature will result in a more comfortable environment, making it suitable for residential use. Land Surface Temperature (LST) distribution is obtained from Landsat 8 data processing. As an environment with a fairly high intensity of activities, accessibility is an important factor for determining residential land (Mallick et al., 2013). Settlement accessibility is determined by the distance to the network as basic infrastructure. Road network data was obtained from Open Street Map (OSM). Finally, as a limitation, residential areas should not be located in forest areas and productive agricultural land (Mardiana and Pratomo, 2014). Forest areas are areas that are designated as forest areas through government stipulations, so they cannot be used as settlements. Meanwhile, the LP2B (Sustainable Food Agricultural Land) program based on government regulations, namely Government Regulation No. 44/2017 on the Protection and Empowerment of Farmers, is a food security program, thus protecting productive agricultural land from being converted, including into settlements.

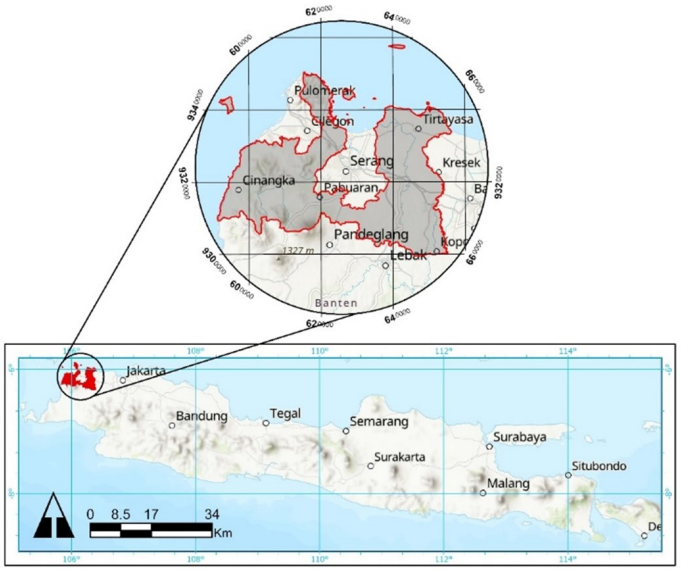


Figure 1. Research Location

The land suitability map that has been developed will be used to evaluate settlement land. There are two settlement land conditions that will be evaluated, namely the existing settlement conditions and the settlement area development plan contained in the spatial plan. The assessment of existing settlements aims to determine the spatial distribution of settlements that are ideal or not based on the factors that cause them, so that it can be a concern for the authorities. Meanwhile, the assessment of settlement development plans was conducted to assess how far the Serang district spatial plan was able to direct the development of residential areas carried out by all sectors, including the government, private sector, and individuals. Overall, the list of data required can be seen in Table 1.

Table 1. Data Requirements

Data	Source
Slope and Aspect	DEMNAS from Indonesia Geospatial Agency
Landslide potential hazard	InaRISK
Earthquake potential hazard	InaRISK
Tsunami potential hazard	InaRISK
LST	Landsat 8
Road	OSM
Forest area	Ministry of Environment and Forestry
Paddy fields area	Ministry of Agriculture
Built-up area	Sentinel 2
Spatial Planning of Serang	Bappeda Kab. Serang

Source: Data information, 2024

2.2 Methods

The settlement land suitability map is formed from physical environment, disaster, microclimate, accessibility, and protected area factors combined into one. The process of combining all these variables uses the Spatial Multi Criteria Evaluation (SMCE) method. SEMCE is a spatial-based evaluation method used to combine multiple variables with certain weights and constraints (Setiawan and Salam, 2021). In determining residential areas, some variables have a more dominant role than others. The determination of the weight of each variable is based on a literature review (Hidayat and Rustiadi, 2018). Then the evaluation process of existing and planned settlements will be overlaid with the intersect method to get a slice of the settlement area with its level of suitability. The flow of thought of this research can be seen in Figure 1. While the detailed process flow of land suitability, including the evaluation of existing and planned settlements, is represented in Figure 2.

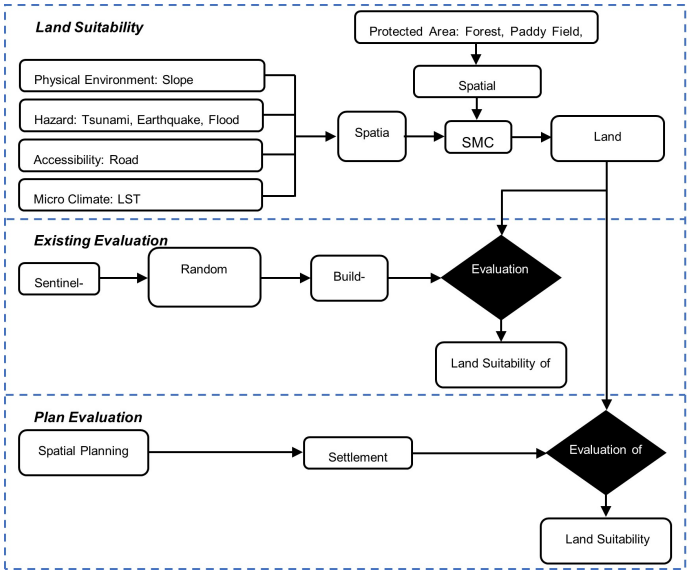


Figure 2. Research Flow Chart

3. RESULT AND DISCUSSION

3.1 Settlement Suitability

Settlement land suitability analysis was built with the Weighted Overlay tool available in ArcGIS. Weighted Overlay is capable of calculating land suitability variables based on raster data. Each variable has a score to distinguish the most suitable and unsuitable land for settlement (Table 2). In the slope criteria, it will be divided into 5 classes, namely 0-2%, 2-15%, 15-25%, 25-40%, and more than 40%. The lower the land slope, the more suitable it is for settlement because the land is sloping, and conversely the more sloping the land, the more dangerous it will be for building (citation). Flood distribution criteria are divided into 4 classes, namely an index of less than 0 no risk, 0-0.3 low risk, 0.3-0.6 medium risk, and 0.6-1 high risk. The earthquake distribution criteria are divided into 4 classes, namely an index of less than 0 very low risk, 0-0.3 low risk, 0.3-0.6 moderate risk, and 0.6-1 high risk. The earthquake distribution criteria are divided into 4 classes, namely an index of less than 0 very low risk, 0-0.3 low risk, 0.3-0.6 medium risk, and 0.6-1 high risk. Tsunami distribution criteria are divided into 4 classes, namely an index of less than 0 very low risk, 0-0.3 low risk, 0.3-0.6 medium risk, and 0.6-1 high risk. For accessibility, it is divided into 3 classes, 0-100 m, 101-750 m, and more than 750 m. The closer the land is to the road network, the better the accessibility, regardless of the road class (citation). The constraining criteria are forest areas, agricultural land, and areas around rivers. There are legal regulations that require these areas to ideally not be used as settlement land. Furthermore, each criterion requires a weight that must be adjusted to its level of urgency. The results of a review of some literature place criteria according to the level of urgency including accessibility, flood hazard, slope, earthquake, tsunami, and LST.

The results of the settlement land suitability analysis show that the Serang Regency area is divided into 4 classes, namely high suitable, moderately suitable, low suitable, and unsuitable. The research area is dominated by the moderately suitable class with an area of 945.5 km^2 or 65.6%

Table 2. Criteria for Settlement Land Suitability

Type	Criteria/Weight		Class	Score	Source
Spatial	Pysical	Slope (20%)	0-2%	5	Permen PU
Factors	Environment		2-15%	4	No. 20; 2007
			15-25%	3	
			25-40%	2	
			> 40%	1	
	Potential	Flood (25%)	< 0 (No risk)	4	PP No. 12; 2021
	Hazard		0 - 0,3 (Low risk)	3	
			0,3 - 0,6 (Medium risk)	2	
			0,6 - 1 (High risk)	1	
		Earthquake (10%)	< 0 (Very low risk)	4	
			0 - 0,3 (Low risk)	3	
			0,3 - 0,6 (Medium risk)	2	
			0,6 - 1 (High risk)	1	
		Tsunami (10%)	< 0 (No risk)	4	
			0 - 0,3 (Low risk)	3	
			0,3 - 0,6 (Medium risk)	2	
			0,6 - 1 (High risk)	1	
	Acessibility	Road (25%)	0 - 100 m	3	Tanjung et al. (2022)
			101 - 750 m	2	
			> 750 m	1	
	Micro	LST (10%)	18-30 °C (comfortable)	2	Kepmenkes No.829/
	Climate		> 30 °C (not comfortable)	1	Menkes/ SK/VII/1999
Spatial	Protected	Forest area	Forest area	0	PP No. 23; 2021
Constrains	Area	Paddy fields area	Paddy area	0	UU No. 41; 2009
		River	< 50 m	0	Permen PUPR No. 28; 2015

Source: Analysis, 2024

(Figure 3). The second largest is the unsuitable class with an area of 460.6 km^2 or 32%. The third is the low suitable class with an area of 34.5 km^2 or 2.4%. While the last class, high suitable, is very small, only 0.2 km^2 or almost 0% (Figure 4). The moderately suitable class is the recommended location for settlement areas. Moderately suitable is found in Cikande, Kibin, Jawilan, Waringinkurung, and Bojonegara sub-districts. The second dominance, namely unsuitable, is also found in Serang Regency. The unsitable class is not intended for settlement areas because it is a protection for forest areas, productive agricultural land, and river borders. Ideally, settlements should not be placed in these areas as an effort to preserve the environment and food security as an effort to achieve sustainability. Unsettled areas that are mostly found in the sub-districts of Tirtayasan, Pontang, Ciruas, Lebak Wangi, Carenang, Kragilan, Cikeusal, Bandung, Tunjung Teja, Pamarayan, Petir, Baros, Pabuaran, Padarincang, Cinangka, Anyar, Mancak, and Kramatwatu are agricultural lands that have been legally designated to be protected and preserved as granaries. Meanwhile, unsettled areas that are mostly found in the sub-districts of Ciomas, Padarincang, Gung Sari, Mancak, and Pulo Ampel are forest areas to maintain environmental functions.

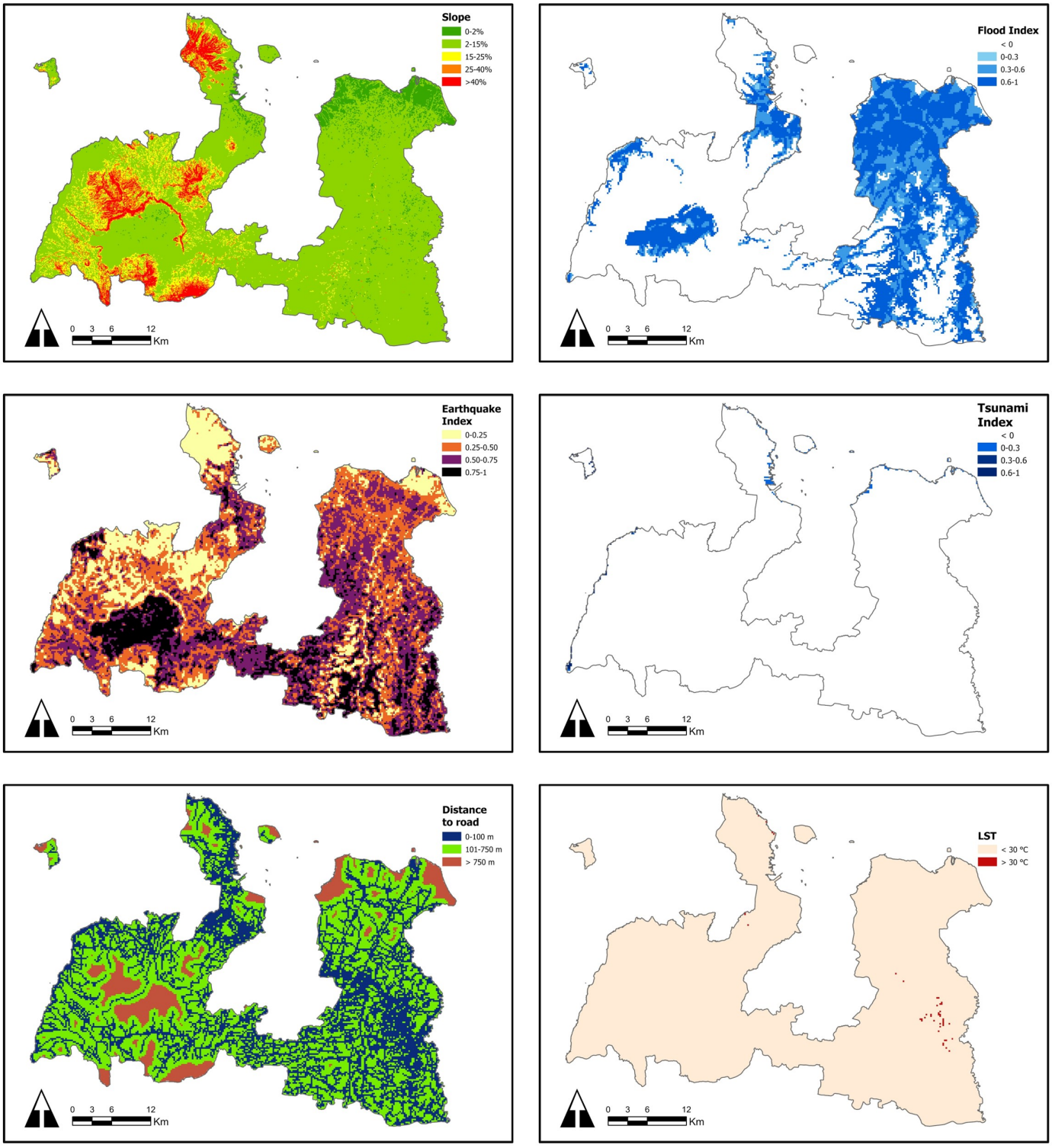
3.2 Evaluation of Existing Settlement

The first evaluation was to assess the suitability of existing settlement land. Existing residential land was obtained from supervised classification extraction of Sentinel-2 imagery in 2023. The results of the LULC extraction of the Serang Regency area in 2023 obtained an overall accuracy of 0.78. In this research, built-up land in the LULC in 2023 is assumed to be settlements. The results of the evaluation of the land suitability of existing settlements show that the dominance of settlement land is in the moderately suitable class, covering 204.9 km^2, or 71.2% (Figure 5). The second most settlements are in the unsuitable class, covering an area of 81.2 km^2, or 28.2%. The remaining settlements in the low suitable and high suitable classes are very few, not reaching 1%.

Spatially, the unsettled settlement areas in the eastern side, including the sub-districts of Tirtayasa, Pontang, Lebak Wangi, Carenang, Cikeusal, Tanjung Teja, and Pamayaran are located in protected agricultural land areas. Meanwhile, many of the unsettled settlements in the western region are located in forest areas. The condition may occur because the settlements have existed before the regulation regarding the protection of agricultural areas and forest areas was established. In addition, the boundaries of forest and non-forest areas are often unclear, so land conversion at the border of forest areas is still common in the field. The government needs to strictly limit existing settlements that are included in unsuitable areas so that they do not increase in size, or even divert outside unsuitable areas.

3.3 Evaluation of Settlement Plan

The second evaluation assessed the suitability of the settlement land development plan. The settlement area development plan was obtained from the Serang Regency spatial plan document 2011-2031. The results of the evaluation of the land suitability of settlement plans show that the dominance of settlement land is in the moderately suitable



class, covering 320.9 km^2, or 90.7% (Figure 6). The second most settlements are in the unsuitable class, covering 31.4 km^2, or 8.9%. The remaining settlements in the low suitable and high suitable classes are very small, not reaching 1%. When compared in percentage, unsuitable in the planned settlements is less than in the existing settlements, and the difference is in the moderately suitable class. This condition shows that the spatial plan has worked well to direct the development of residential areas to locations that are more suitable for settlements. Meanwhile, planned settlements

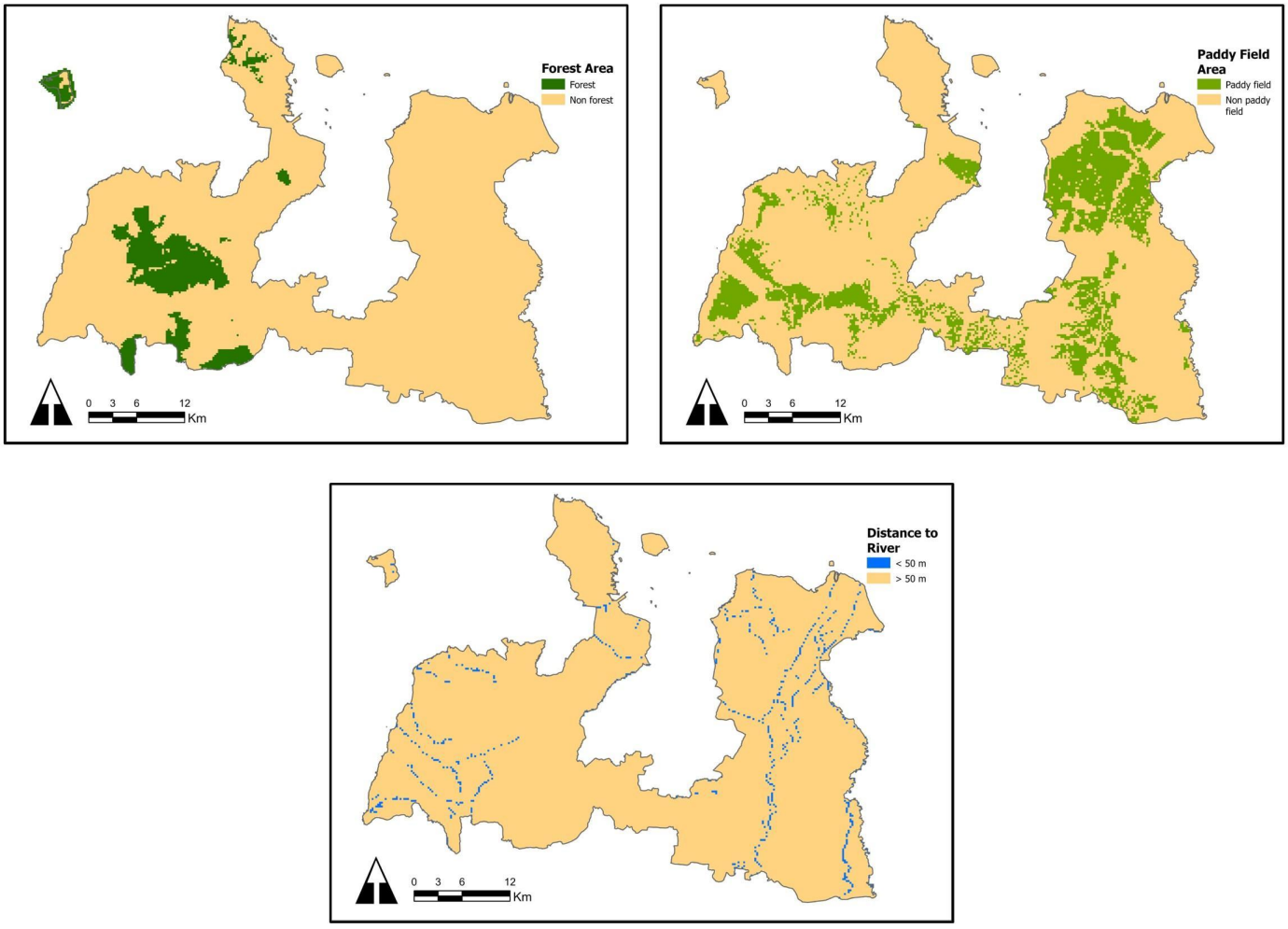


Figure 3. The Map of Criteria for Determining Land Suitability for Residential Areas

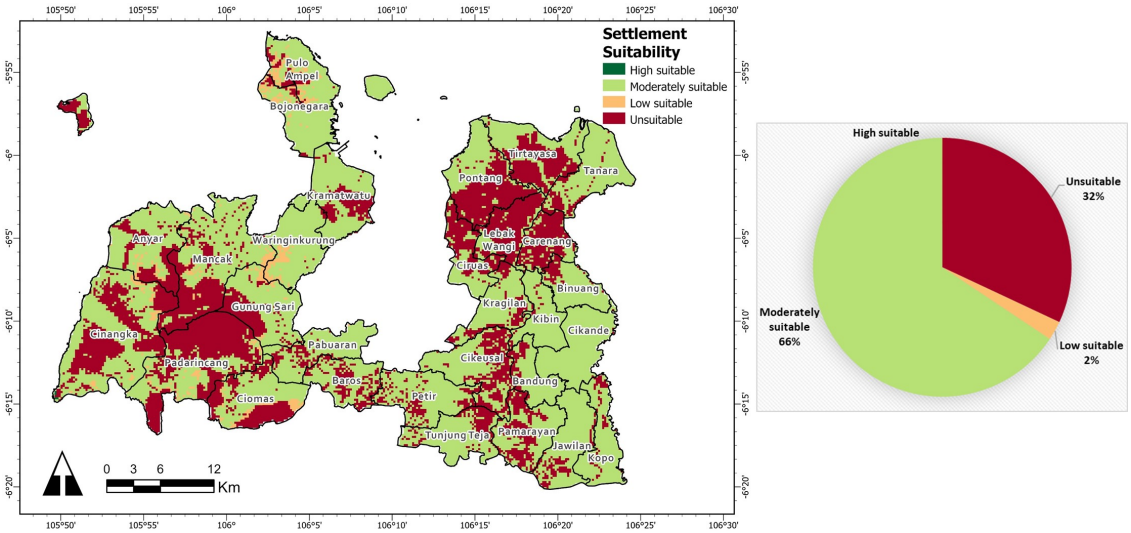


Figure 4. The Land Suitability Map for Residential Areas in Serang Regency (Source: Analysis, 2024)

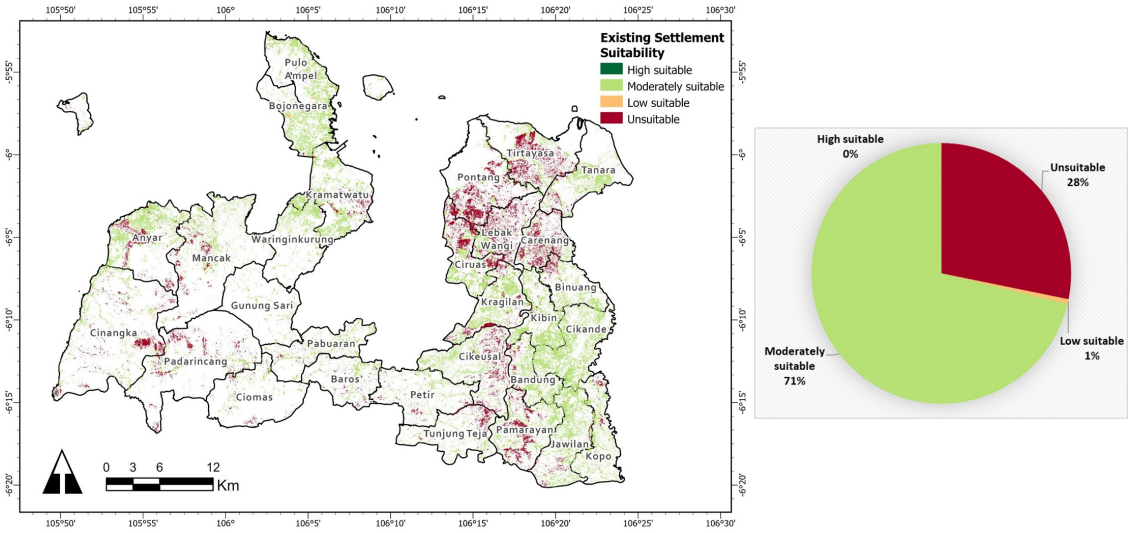


Figure 5. The Map of Land Suitability Evaluation for Existing Residential Areas (Source: Analysis, 2024)

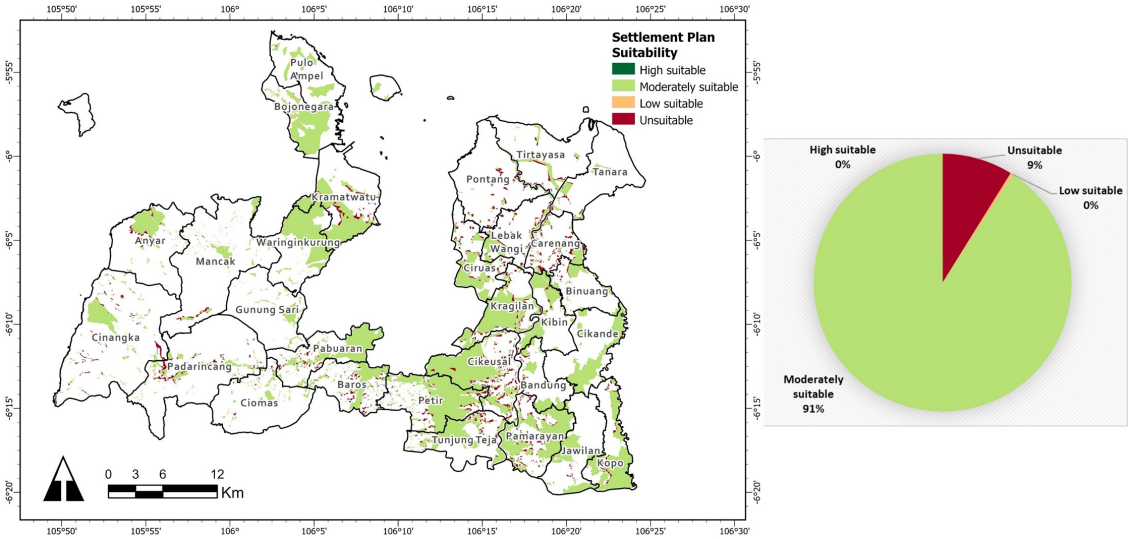


Figure 6. The Map of Land Suitability Evaluation for Planned Residential Areas (Source: Analysis, 2024)

that are still in the unsuitable class are generally settlements that existed before the spatial plan was drafted in 2011. Therefore, the spatial plan only accommodates the existing conditions that have occurred before.

Settlement plans that fall into the unviable class on the western side of the region are generally due to the presence of protected agricultural land. Overdevelopment conditions force the government to accommodate these settlement areas in the spatial plan. Many settlement development plans are directed at the sub-districts of Ciruas, Kragilan, Kibin, Cikande, Cikeusal, Kopo, Jawilan, Pamarayan, Tanjung Teja, Petir, Baros, Pabuaran, Waringinkurung, and Kramatwatu. These locations are appropriate because they fall into the moderately suitable class. Although in general it has been able to direct settlement development well, monitoring of settlement areas that are in the unsuitable class must continue. This is because protected agricultural land is prone to conversion to built-up land, given its higher economic value.

4. CONCLUSIONS

The land suitability analysis for settlement development in Serang Regency provides essential insights for managing land use sustainably. The findings indicate that 65.6% of Serang Regency is suitable for residential development, while 28.2% of existing settlements are in areas deemed unsuitable. The spatial plan has successfully guided 90.7% of future settlement plans to suitable areas, suggesting effective planning efforts. However, there are still concerns regarding settlements in unsuitable areas, highlighting the need for

stricter management to prevent expansion into protected zones. This research underscores the importance of comprehensive land suitability models that account for various factors such as accessibility, microclimate, and land use to enhance the sustainability of urban development.

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