Analysis of the Availability of Residential Locations Based on Flood Mitigation in Momunu District, Buol Regency

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ABSTRACT

The population growth and limited land availability for housing have forced some communities to reside in disaster-prone areas, particularly those vulnerable to flooding. This study, presents a spatial-based assessment that integrates physical and regulatory criteria to identify safe and appropriate residential zones. Using spatial analysis through map overlays, scoring, and weighting techniques, the research evaluates seven key physical variables: land slope, drainage, erosion, land use, road accessibility, access to essential facilities, and flood hazard vulnerability. The novelty of this study lies in the integration of flood mitigation into residential suitability mapping that is aligned with the Regional Spatial Plan (RTRW), offering a comprehensive and policy-relevant framework. The findings reveal that 20.85% of the study area is suitable for housing, 61.83% is conditionally suitable, and 17.32% is unsuitable. Based on the land availability and RTRW compliance, residential land is categorized into Available Location I (47 hectares) and Available Location II (423 hectares). These results provide not only a technical basis for guiding safe settlement, but also a strategic reference for planners and policymakers. The study proposes that future research incorporates socio-economic variables and real-time flood data for dynamic risk assessment. Furthermore, stakeholder engagement and community-based mapping are proposed to enhance the local resilience and ensure participatory planning. Ultimately, this research contributes to sustainable urban development by supporting informed decision-making for safer, flood-resilient settlements.

Keywords-flood mitigation; settlement mapping; space utilization

I. INTRODUCTION

The population growth and limited land availability have led to the expansion of residential areas into disaster-prone regions, particularly flood-prone zones [1]. The uncontrolled urbanization and poor land-use planning increase the vulnerability of settlements to natural disasters, resulting in significant economic losses and threats to human safety [2]. This issue is particularly concerning in developing countries, where the rapid development often outpaces the disaster mitigation efforts. To address these challenges, proper spatial planning that integrates disaster risk reduction measures is essential to ensure sustainable and safe residential development [3].

Several studies have highlighted the importance of flood mitigation strategies in urban planning to reduce the risks associated with flooding. For instance, authors in [4] emphasized that integrating hydrological modeling with spatial analysis can enhance flood hazard assessments, thereby improving the land-use planning decisions. Authors in [5] propose the mapping of flood-prone areas using Geographic Information Systems (GIS) and remote sensing to effectively identify the suitable locations for settlement development. However, despite these advancements, many regions still lack comprehensive frameworks that incorporate both flood mitigation and land-use planning, leaving communities vulnerable to flood disasters [5]. The availability of suitable residential locations must consider multiple factors, including

physical characteristics, such as the land slope, drainage conditions, and soil erosion, as well as socio-economic aspects, like road accessibility and the proximity to essential services [6]. While some research has focused on evaluating the physical suitability of land for settlement, there remains a gap in studies that analyze both the physical and policy-based land availability for residential development [7]. Addressing this gap is crucial for ensuring that urban expansion occurs in areas that align with the disaster risk reduction strategies and regional spatial planning regulations.

This study addresses the aforementioned gap by analyzing the availability of residential locations in Momunu District, Buol Regency, focusing on both the physical suitability and compliance with regional spatial planning policies. By employing spatial analysis techniques, such as map overlays, scoring, and weighting, the study offers a systematic approach to identifying safe and sustainable settlement areas, especially as urban expansion encroaches upon flood-prone zones. The novelty of this research lies in combining physical suitability analysis with policy-based land classification, providing a holistic evaluation of settlement feasibility. The significance of this study is its contribution to disaster-resilient urban planning, offering valuable insights for policymakers, urban planners, and local communities to make informed decisions that align with the flood mitigation and spatial planning strategies. The findings will guide the identification of safe residential zones, minimizing disaster risks and supporting sustainable urban development.

II. RESEARCH METHOD

Momunu District in Buol Regency is a flood-prone area experiencing an annual population growth of 3.15%, with the population having been expected to reach 48,126 by 2032. However, the available land for residential use, according to the Regional Spatial Planning Regulation (RTRW) No. 19 of 2019, is limited to 1,148 Ha, leading to land-use expansion into unsuitable, disaster-prone areas. The Regional Disaster Management Agency (BPBD) recorded 145 landslides between 2016 and 2018, highlighting the area's vulnerability [8, 9]. This study uses a spatial approach to assess the residential suitability, analyzing seven key variables: slope gradient, drainage, erosion, land use, road accessibility, access to key facilities, and landslide hazard levels. The data collection involved map interpretation, field observations, and secondary sources, with scoring and weighting techniques applied to evaluate suitability. The final analysis overlays suitability maps with existing settlements and the RTRW plan to identify the priority residential zones, with suitability classified based on scores and weights [10, 11]. The classification of suitability criteria based on scores and weights is presented in Table I.

After calculating the total score, the next step is to determine the residential suitability classes based on the FAO (1967) and IFC (2002) frameworks with adjustments. The classification considers limitations and necessary improvements for each class. These suitability levels are divided into three categories, as shown in Table II.

$$Total\ dignity = V_1 \times b_1 + V_2 \times b_2 \ldots V_n \times b_n \quad (1)$$

where V_1 and V_2 are the score values of the first and second variables, respectively, and V_n is the score value of the n^{th} variable. Similarly, b_1 and b_2 are the weights of the first and second variables, respectively and b_n is the weight value of the n^{th} variable.

TABLE I. CLASSIFICATION CRITERIA FOR WEIGHT AND SCORE VARIABLES

Variables	Weight	Classification	Criteria	Score
Slope	3	2-15%	High conformity	3
		15-40%	Medium conformity	2
		>40%	No conformity	1
Drainage	1	Never flooded	High conformity	3
		Periodically flooded	Medium conformity	2
		Continuously flooded	No conformity	1
Erosion	1	No erosion	High conformity	3
		Medium erosion	Medium conformity	2
		High erosion	No conformity	1
Land-use	3	Field, garden	High priority	3
		Settlement	Medium priority	2
		Rice fields/ Reservoirs/Forests	No priority	1
Road accessibility	3	0-100 m	High potential	3
		100-200 m	Medium potential	2
		>200 m	Less potential	1
Accessibility	2	0-750 m	High conformity	3
		750-1500 m	Medium conformity	2
		>1500 m	Less suitable	1
Landslide vulnerability	3	Low vulnerability	High conformity	3
		Moderate vulnerability	Medium conformity	2
		High vulnerability	No conformity	1

TABLE II. LOCATION SUITABILITY CLASSES FOR SETTLEMENT

Class	Levels
I	Suitable for residential area development
II	Conditionally appropriate for residential area development
III	Not suitable for residential area development

After determining the criteria for the suitability class levels, the next step is to determine the Class Interval (*CI*) of suitability using:

$$CI = \frac{Max.amount\ of\ dignity - Min.amount\ of\ dignity}{Number\ of\ classes\ created} \quad (2)$$

The criteria for the settlement location availability classes can be seen in Table III, while the conceptual framework is presented in Figure 1.

III. RESULTS AND DISCUSSION

The classification of residential suitability is determined by overlaying seven variables as part of the spatial decision-making process. Each variable has a different level of influence on residential suitability.

TABLE III. CRITERIA FOR CLASS AVAILABILITY OF LOCATIONS FOR RESIDENTIAL AREAS

Availability class	**Criteria**		
	Location suitability	Existing conditions of use	Spatial pattern allocation
Available I	Suitable	Residential and non-residential	Residential area
Available II	Conditionally appropriate		
Not available	Compliant, conditionally compliant, and not compliant		Protected areas and non-residential cultivation areas

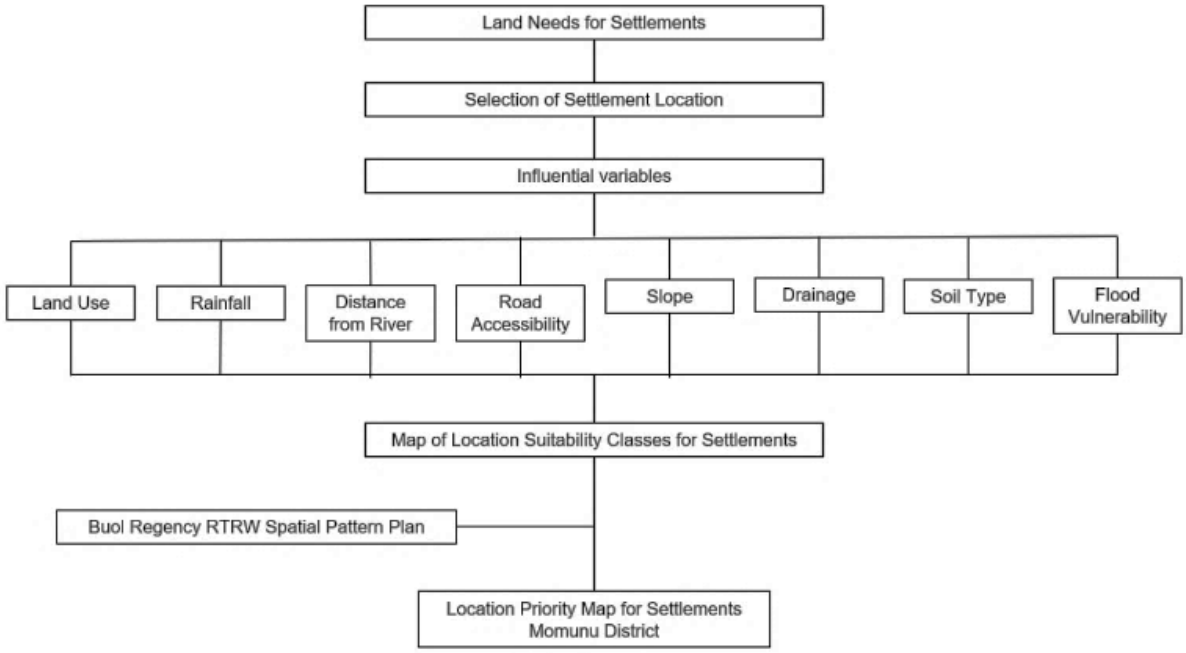

Fig. 1. Methodology flow diagram.

A. Slope Gradient

The slope gradient is a key factor in determining the suitability of land for residential development, as steep slopes increase the risk of landslides and flooding. This study categorizes the slopes in Momunu District into three classes: 2–15%, 15–40%, and >40%, as illustrated in Table IV. Table IV indicates that the areas with slopes between 15–40% cover 28.56% of the total area and are considered moderately suitable due to their flood risk, requiring additional measures, like soil stabilization for safe development. Slopes greater than 40% are deemed unsuitable for housing due to significant flood hazards, while areas with slopes of 2–15% are ideal for residential construction, being safe from floods and highly suitable for housing. These findings emphasize the importance of prioritizing flatter areas for settlement to reduce the disaster risks and ensure long-term sustainability.

TABLE IV. SLOPE CRITERIA

Slope class	**Criterion**	**Area (Ha)**	**%**
2 - 15 % (flat)	High suitability	10,889.87	61.52
15 - 40 % (steep)	Medium fit	5,055.19	28.56
>40% (very steep)	Not suitable	1,757.33	9.93
Total		17,702.39	100.00

B. Drainage

Drainage plays a crucial role in determining the suitability of land for residential development, as it affects the soil's water absorption and surface runoff. The drainage conditions in Momunu District are displayed in Table V. In Momunu District, 52.41% of the area experiences periodic waterlogging, indicating poor drainage and an increased risk of flooding. Areas with good drainage are ideal for residential development, as they efficiently channel the surface runoff and reduce the flood risks. In contrast, areas with continuous waterlogging, due to poor drainage, are unsuitable for settlements and should be avoided to prevent potential flooding and waterlogging issues.

TABLE V. DRAINAGE IN MOMUNU DISTRICT

Drainage conditions	**Criterion**	**Area (Ha)**	**%**
Continuously flooded	Low compatibility	7,179.10	40.55
Periodic waterlogging	Medium fit	9,278.16	52.41
Never flooded	High suitability	1,245.09	7.03
Total		17,702.35	100.00

C. Land-Use

Land use is a critical factor in determining suitable areas for residential development. In Momunu District, forested areas

make up 29.30% of the region, and these areas, along with reservoirs, are not prioritized for settlement development due to their role as protected conservation zones that maintain environmental sustainability and water resources. Additionally, irrigated rice fields have a low priority for development, as converting agricultural land into residential areas could threaten the food security. The land use classification in Momunu District is presented in Table VI.

The existing settlements in the district are sparsely populated, but further development in these areas could lead to overcrowding and reduced living quality. Dry fields and plantations, however, are more suitable for residential expansion, as they are vacant and easier to develop. These areas offer better opportunities for settlement planning, ensuring higher quality of living conditions and sustainable urban growth.

TABLE VI. MOMUNU LAND-USE

Land use	Criterion	Area (Ha)	%
Forest	Not priority	5,187.06	29.30
Paddy		1,053.92	5.95
River		208.53	1.18
Wetlands		0.130	0.00
Settlements	Medium priority	309.10	1.75
Field		8.940	0.05
Field/Garden	High priority	4,970.65	28.08
Oil palm plantations		1,212.81	6.85
Bushes		4,633.90	26.18
Meadow		117.31	0.66
Total		17,702.35	100.00

D. Road Accessibility

The road accessibility classification in the study area is presented in Table VII. Road accessibility is a key factor in determining the suitability of the areas for residential development. The locations closer to roads are more attractive for housing, with areas within 0-100 m (Class I) having high suitability due to easy access, which improves the travel efficiency. Areas 100-200 m from roads (Class II) have moderate suitability, while locations more than 200 m away (Class III) are less suitable due to limited access, longer travel times, and reduced attractiveness for settlement. This classification highlights the importance of the road proximity in determining the potential for residential development.

TABLE VII. MOMUNU DISTRICT RAOD ACCESS CLASS

Road access class	Criterion	Broad	%
Class I (0-100 m)	High potential	1,540.66	8.70
Class II (100-200 m)	Low potential	1,264.20	7.14
Class III (>200 m)	Less potential	14,897.49	84.16
Total		17,702.35	100.00

E. Rainfall

The land suitability and environmental carrying capacity are closely related to the soil conditions and erosion, which impact the land use activities. Based on the analysis, the rainfall intensity in the low category (13.6-20.7 mm/day) dominates the entire Momunu District. This includes all villages, covering a total area of 17,702.35 Ha or 100% of the district. The rainfall intensity classes in Momunu District are detailed in Table VIII.

TABLE VIII. RAINFALL INTENSITY CLASSES

CH Class (mm)	Criterion	Broad	%
2200 - 2250	High suitability	331.93	1.88
2250 - 2300	Low compatibility	5,188.86	29.31
2300 - 2350	Not suitable	12,181.55	68.81
Total		17,702.35	100.00

F. Distance From River

The distance from the river is an important factor in determining the suitability of land for settlements, as areas too close to the river are prone to flooding. Table IX shows the classification of the settlement suitability based on the distance from the river.

TABLE IX. DISTANCE FROM RIVER

River Distance Class	Criterion	Area (Ha)	%
Class I (0-100 m)	High potential	543.97	3.07%
Class II (100-200 m)	Low potential	464.14	2.62%
Class III (>200 m)	Less potential	16,694.24	94.31%
Total		17,702.35	100.00%

G. Soil Type

To determine the suitability of an area for residential use, it is necessary to analyze the soil characteristics of the region. The scored parameters serve as the basis for an overlay analysis, producing a soil type map using digital mapping tools, like ArcGIS. The first method applied is the overlay (union) technique in ArcGIS, incorporating the soil type map from the RTRW. A detailed classification of soil types in Momunu District based on this overlay analysis is presented in Table X.

TABLE X. GRADES, CATEGORIES, AND SOIL TYPE SCORES

Soil type	Criterion	Area (Ha)	%
Alluvial, hydromorphic alluvial, organosol	High suitability	7,741.07	43.73
Podsolik red yellow, podsolik red yellow	Medium fit	1,093.70	6.18
Rendzina, the red and yellow Mediterranean	Not suitable	8,867.58	50.09
Total		17,702.35	100.00

H. Flood-Prone Areas

The classification of flood disaster vulnerability levels in Momunu District is depicted in Table XI. The level of flood disaster vulnerability is a critical factor in determining the suitability of residential development in the study area. Since the main goal of housing is to ensure safety, areas with high flood risk—typically characterized by steep slopes and rapid water movement—are considered unsuitable for settlement. In contrast, areas with low flood vulnerability, which make up only 1.05% of the total area, have gentle slopes and minimal water movement, making them highly suitable for safe residential development. Moderately vulnerable areas can still be developed, provided that protective measures, like effective drainage systems or water barriers, are implemented, although

this raises construction costs [12, 13]. Therefore, a flood vulnerability analysis is essential in guiding the identification of safe, sustainable residential zones in Momunu District.

TABLE XI. FLOOD DISASTER VULNERABILITY LEVEL

Flood Vulnerability	Criterion	Area (Ha)	%
Not affected	High suitability	10,545.83	59.57
Low vulnerability	High suitability	185.84	1.050
Medium vulnerability	Medium fit	2,552.36	14.42
High vulnerability	Not suitable	4,418.31	24.96
Total		17,702.35	100.00

I. Identification of Settlement Location Suitability Classes

The area distribution for each suitability class in Momunu District is presented in Table XII. The classification of settlement location suitability in Momunu District evaluates the land feasibility for residential development based on seven variables: slope gradient, drainage, erosion, land use, road accessibility, proximity to key facilities, rainfall intensity, and flood disaster risk. These variables are analyzed using GIS by overlaying spatial data from maps, secondary sources, and field observations. Each variable is weighted according to its influence on settlement feasibility, ranging from 1 (least influential) to 3 (most influential), and the final suitability score is calculated from the combined weights. This process results in a comprehensive suitability map that guides decision-making for safe and effective housing development.

The analysis shows that most of the area (61.83%, or 10,945 Ha) is classified as "Conditionally suitable," indicating moderate development constraints, such as drainage problems, erosion risks, flood hazards, or limited access to key facilities. "Suitable" areas have few restrictions and are ideal for residential expansion, while "Not Suitable" areas face major environmental or infrastructural limitations that hinder safe settlement. This classification supports more informed spatial planning by clearly identifying areas that require mitigation or are better preserved. The spatial distribution of settlement suitability, based on the seven determining variables, is illustrated in Figure 2.

TABLE XII. SETTLEMENT LOCATION SUITABILITY CLASSES

Class	Criterion	Area (Ha)	%
Class I	Appropriate	3,691	20.85
Class II	Conditionally compliant	10,945	61.83
Class III	Not suitable	3,067	17.32
Total		17,702	100.00

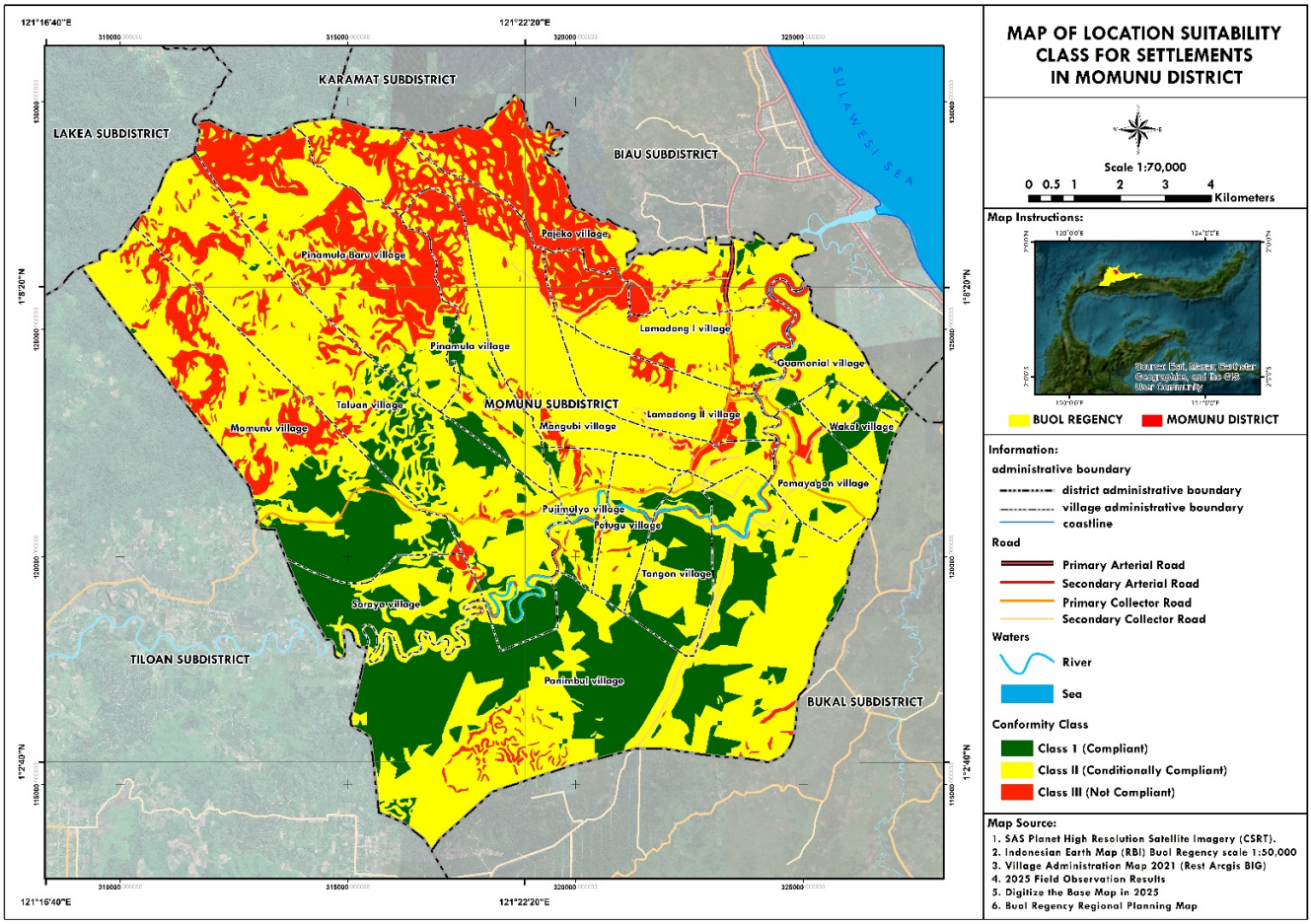

Fig. 2. Map of settlement suitability class in Momunu District.

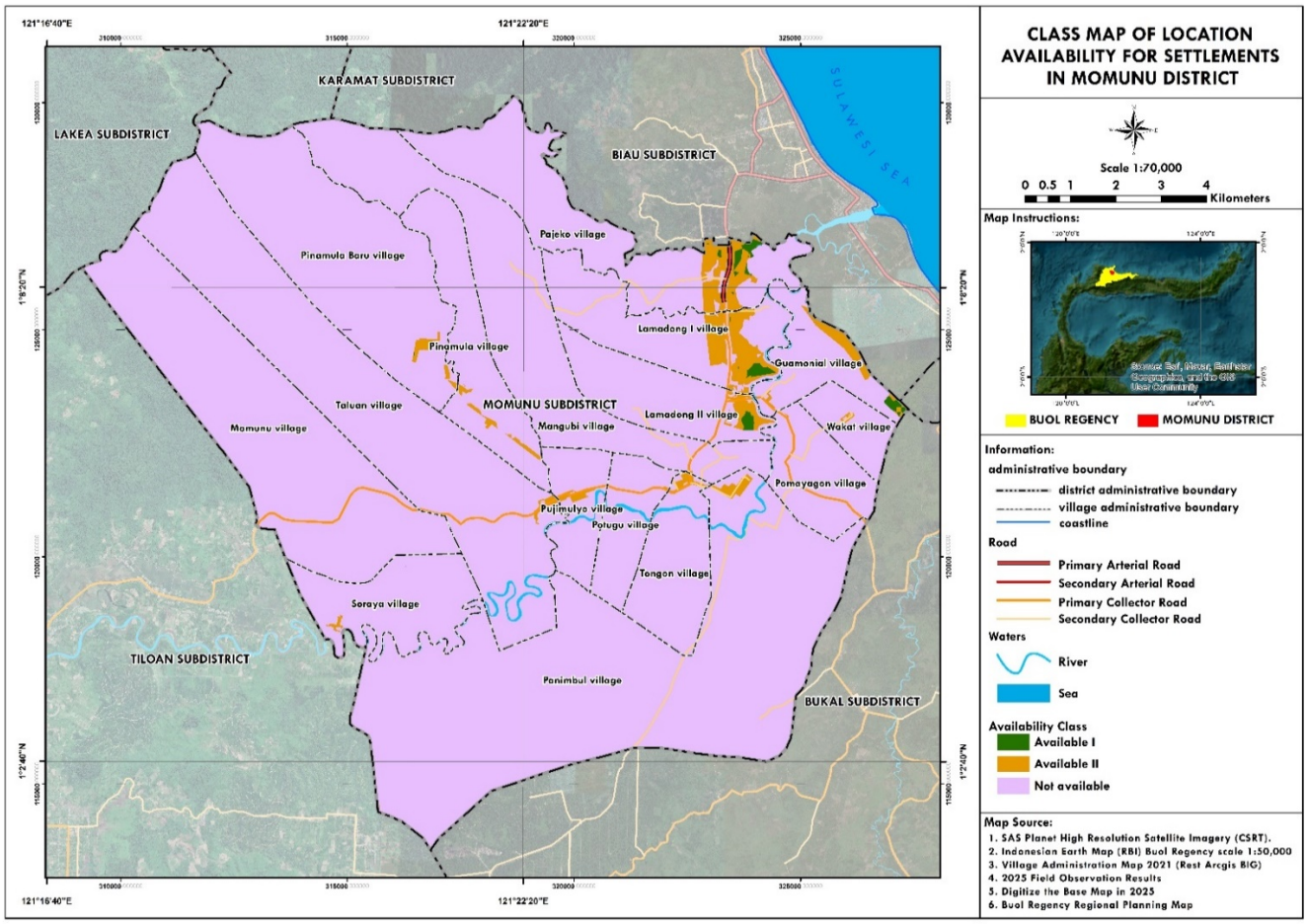

Fig. 3. Location availability class map for Momunu District settlements.

J. Availability of Location for Settlement

The land availability for settlement in Momunu District refers to areas suitable for residential development, determined by analyzing the existing settlements, land suitability, and the spatial plan for 2013–2032. This classification uses overlay analysis of three maps: the settlement suitability map, existing settlement conditions, and the RTRW spatial planning map. The land is divided into three classes—Available I, Available II, and Not Available—which help identify the priority areas for housing development. This analysis provides a clear reference for selecting safe and appropriate locations for future residential expansion. The area distribution for each land availability class in Momunu District is presented in Table XIII.

The spatial distribution of settlement availability is presented in Figure 3. Although Momunu District covers a broad area, many parts are unsuitable for settlement due to steep terrain and protected zones designated in the RTRW. For instance, Lamadong II and Pomayagon villages are dominated by steep to very steep slopes, posing serious constraints for development. Conservation areas further limit the expansion options. Therefore, careful planning is essential to avoid high-risk zones. The distribution map of available land serves as a useful guideline for both the community and authorities to promote a safe, sustainable, and environmentally responsible residential development, in line with expert recommendations on disaster risk and spatial planning. This approach ensures that future housing development aligns with the environmental preservation goals while minimizing the potential hazards to residents [14, 15].

TABLE XIII. AVAILABILITY OF RESIDENTIAL LOCATIONS

Class	Criterion	Area (Ha)	%
Class I	Available I	47	0.27
Class II	Available II	423	2.39
Class III	Not available	17,232	97.34
Total		17,702.35	100.00

IV. CONCLUSION

This study shows that while a significant portion of land in Momunu District is physically suitable for settlement, only 2.39% (423 Ha) meets the criteria for suitability and availability based on the Regional Spatial Plan (RTRW) and land capability analysis. This demonstrates a gap between the physical potential of land and its actual suitability for safe settlement development.

The novelty of this study lies in the integrated mapping of land suitability, availability, and disaster risk reduction in early planning stages. The study proposes tightening the settlement development permits, implementing spatial utilization controls, and raising public awareness to ensure that the settlement development follows the RTRW guidelines and avoids disaster-prone areas, such as flood and landslide zones.

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