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Spatial Analysis of Built-Up Land Suitability in Ternate Island

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Abstract

The population of Ternate City which is increasing every year can certainly cause the need for land as a space for their activities to increase and will lead to a kind of competition to get a suitable space and in accordance with the various interests and needs of the community there. This study aims to spatially analyze the suitability of built-up land on Ternate Island, North Maluku Province. This research uses Spatial Multi Criteria Analysis method using variables of terrain shape, slope, distance from road, distance from river, distance from economic activity center, and disaster prone area of Mount Gamalama. The results showed that 49.12% of the Ternate Island area was in the suitable area, 29.57% of the research area was in the less suitable class and the unsuitable class had an area of 21.31% of the total research area. The results of this study are expected to be a reference and input for the evaluation of the Ternate City RTRW in the future.

Keywords: *Spatial Analysis, Land Suitability, Ternate, Spatial Multi Criteria Analysis*

Abstrak

Jumlah penduduk Kota Ternate yang setiap tahunnya semakin meningkat tentunya dapat menyebabkan kebutuhan akan lahan sebagai ruang untuk tempat aktivitas mereka semakin meningkat dan akan menimbulkan semacam kompetisi untuk mendapatkan ruang yang cocok dan sesuai dengan berbagai kepentingan dan keperluan masyarakat disana. Penelitian ini bertujuan untuk menganalisis secara spasial kesesuaian lahan terbangun di Pulau Ternate, Provinsi Maluku Utara. Penelitian ini menggunakan metode metode Spatial Multi Criteria Analysis menggunakan variabel bentuk medan, kemiringan lereng, jarak dari jalan, jarak dari sungai, jarak dari pusat kegiatan ekonomi, dan kawasan rawan bencana Gunung Gamalama. Hasil penelitian menunjukan bahwa sebesar 49,12% daerah Pulau Ternate berada pada wilayah sesuai, sebesar 29,57% luas wilayah penelitian berada pada kelas kurang sesuai dan kelas tidak sesuai memiliki luas sebesar 21,31% dari total luas wilayah penelitian. Hasil penelitian ini diharapkan dapat menjadi refrensi dan masukan untuk evaluasi RTRW Kota ternate ke depannya.

Kata kunci: Analisis Spasial, Kesesuaian Lahan, Ternate, Spatial Multi Criteria Analysis

Introduction

Ternate City is the capital of North Maluku Province and is also the largest and most populous area in North Maluku Province (Achmadi et al., 2023). Based on population data from the Central Bureau of Statistics (BPS) of Ternate City, it is known that in 2023 the population was 205,001 people with a population density of 1,264.11 per km2 (BPS 2023). The increase in population in Ternate City from year to year triggers the phenomenon of urban growth or urban growth has become an important issue that affects the land use system and land cover in an area for several reasons such as population and economic growth (Latue 2023; Latue & Rakuasa 2023).

According to Almdhun et al. (2018), one of the important factors that drive urban growth is urbanization. Urbanization has become one of the major environmental issues recently due to its adverse impact on urban ecosystems (Wang & Wang 2017; Latue & Rakuasa 2023). Rapid population growth has created many new problems on land (Utami et al., 2018; Latue & Rakuasa 2023). This population growth will cause the need for land as a space for their activities to increase and will create a kind of competition for suitable space according to various human interests and needs (Rakuasa & Somae, 2022; Septory et al., 2023). Latue et al., (2023), added that the increase in population affects the process of development and development activities of an area as well as the increasing need for space or land.

The geographical condition of Ternate City which is located in an active volcano-prone area, namely Mount Gamalama, has an impact on the availability of land for future settlements, therefore a spatial analysis of the suitability of built-up land in Ternate City needs to be carried out which later this information can be used as a basis and foothold in making policies related to structuring and utilizing sustainable space and as a first step in future natural disaster mitigation efforts (Rakuasa & Pakniany, 2022; Pertuack et al., 2023).

Basically, people have a basic need for land to be used as settlements or other buildings to carry out socio-economic activities (Manakane et al., 2023). The higher the population, the higher the need for land to be built, resulting in land conversion (Latue & Rakuasa, 2022; Pertuack et al., 2023). Physical conditions and accessibility conditions are factors that need to be considered in the selection of developed land in the study area. Physical factors are elevation, slope, land shape, and distance from rivers, while accessibility factors are distance from highways, and distance from the center of disaster economic activities (Utami et al., 2018; Rakuasa & Somae, 2022).

The existence of disaster-prone areas will be another factor in the selection of areas to be occupied, which of course settlements should not be built in these areas or the existence of built settlements is minimized in these areas to avoid high risk of disasters (Rakuasa & Latue 2023). Based on this, this research aims to spatially analyze the suitability of built-up land on Ternate Island, North Maluku Province.

Research Method

Data and Location

This research was conducted in Ternate Island, North Maluku Province which has an area of 10,162.12 ha. The analysis of the suitability of developed land on Ternate Island uses variables modified from research (Utami et al., 2018) and Rakuasa & Somae, (2022). The variables in this study consist of terrain shape, slope, distance from roads, distance from rivers, distance from the center of economic activity and distance from the disaster-prone area of Gamalama volcano. The software used for data processing and analysis in this research consists of Arc GIS software and Microsoft Office.

This research uses terrain shape data, and slope data obtained from the processing of DEMNAS data obtained from the Geospatial Information Agency, data on distance from roads, distance from rivers, distance from the center of economic activities obtained from the processing of Indonesian Earth Shape vector data of Ternate City - Geospatial Information Agency and Gamalama volcano disaster prone area data obtained from BNPB.

Methodology

Data processing and analysis was done spatially using the overlay method or using the Spatial Multi Criteria Analysis (SMCA) method. The scoring of each variable refers to Table 1 and is based on the level of suitability for built-up areas. The weighting of the suitability of developed land on Ternate Island is calculated using a modified formula from the research of Utami et al. (2018) and Rakuasa & Somae (2022), which is as follows;

$$\mathrm{BLS} = \mathrm{TS} + \mathrm{S} + \mathrm{DFR} + \mathrm{DFRR} + \mathrm{DFCEA} + \mathrm{DPA} \quad (1)$$

BLS : Built-up Land Suitability
TS : Terrain Shape
S : Slope
DFR : Distance From Road
DFRR : Distance From River
DFCEA : Distance From Center of Economic Activity
DPA : Disaster Prone Area

Table 1. Matrix of variable scores for suitability of Built-up Land

Variables	Class	Score
Terrain Shape	Ramps - Highlands	3
	Steeply Hilly - Mountainous Ramps	2
	Somewhat Steep Mountainous - Steep Mountainous	1
Slope	< 8 %	3
	9 % -15 %	2
	>1 5 %	1
Distance from Road	< 100 m	3
	101-750 m	2
	> 750 m	1
Distance from River	> 100 m	3
	100-50 m	2
	< 50 m	1
Distance from the center of economic activity	< 2000 m	3
	2001 - 2500 m	2
	> 2500 m	1

Disaster Prone Areas of Mount Gamalama Eruption	Not Disaster Risk Assessment and Disaster Risk Assessment I	3
	Disaster Risk Assessment II	2
	Disaster Risk Assessment III	1

Source:Utami dkk., (2018) dan Rakuasa & Somae, (2022)

The built-up land suitability areas are divided into 3 suitability classes, namely suitable, less suitable and unsuitable.

Table 2. Suitability Class of Built-up Area

Total Score	**0 s/d 6**	**7 s/d 12**	**13 s/d 18**
Suitability Class	Not suitable	Not quite right	Sesuai

Sumber: Utami et al., (2018)

The result of the summation of the maximum score of the 6 existing variables has a maximum value of 18, therefore, the suitability class is divided into 3 classes as in Table 2 The tendency of the formation of built-up land adjusts to the physical conditions and accessibility conditions of the research area. As explained earlier, the prediction of the spatial dynamics model is done by developing built-up areas by following the distribution of areas suitable for built-up land, which has a total score of 13 to 18. If the availability of land suitable for built-up land is full, then built-up areas are assumed to develop in areas that are less suitable for built-up land, which have a total score of 7 to 12. Meanwhile, areas that are not suitable for built-up land are avoided as much as possible, given that their physical conditions and accessibility conditions have a low weight for built-up land, because their total score only ranges very low, which is only worth 0 to 6.

Results and Discussion

The driving and limiting factors of built-up areas consist of physical and accessibility variables. Physical factors use the variables of slope, terrain shape, distance from rivers, and distance from protected areas. Meanwhile, the accessibility factor is based on distance from roads, and distance from economic activity centers. Based on the suitability matrix of built-up areas, the higher the weight, the more suitable the variable classification.

Built-up Area Suitability Variables

1. Slope

Based on the Procedures for Implementing Built Environment Planning, slopes that have a high weight for creating built-up areas are slopes with a slope of 0%-8%, because they do not require technical engineering of the land, then those with a medium weight are slopes with a slope of 9% - 15% with a note that technical engineering of the land is required, and finally the slope with the lowest weight is a slope with a slope value of >15% because it certainly requires further technical engineering of the land.

Table 3. Extent of Slope

Classification	Area (ha)	Percentage (%)
<8%	1.267,42	12,47
9%-15%	1.725,6	16,98
>15%	7.167,03	70,54
Total Area	10.162,12	100,00

In general, based on Table 3, the research area is dominated by areas that have a slope of >15%, then in second place are areas with a slope of 9-15%, and the last is an area with a slope of <8%. According to Arimjaya et al. (2022), in analyzing the suitability of land for settlement, the physical variables of the research area (slope) must certainly be considered, given that settlements located on slopes >15% are very prone to landslides Rakuasa et al. (2022). The spatial slope of Ternate Island can be seen in Figure 1.

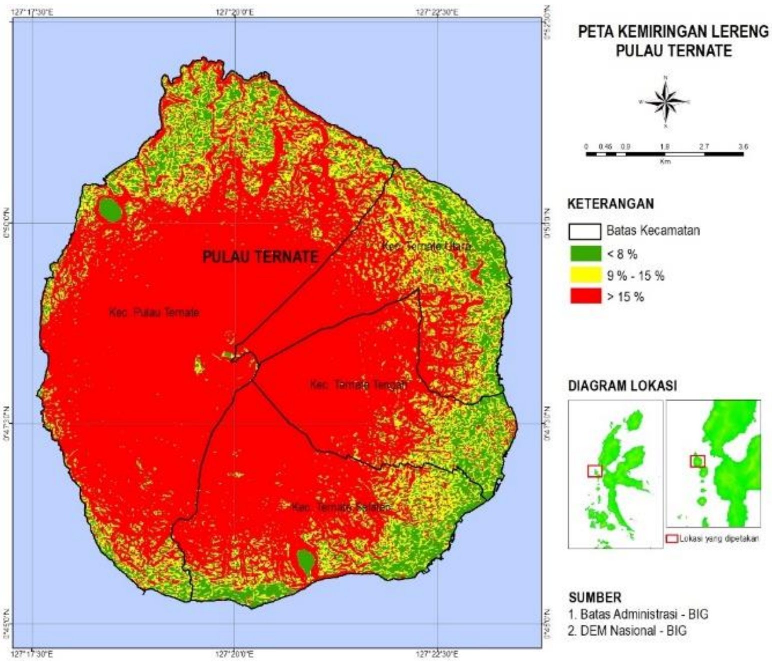

Figure 1: Ternate Island Slope Map

2. Terrain Shape

The shape of the terrain is the result of morphometric work between altitude variables and slope variables. In the classification of Utami et al.'s terrain form (2018), the terrain form is systemized based on its altitude region, starting from the low region (< 500 m above sea level), the middle region (500 - 1000 m above sea level), and the high region (> 1000 m above sea level). In the study area, it consists of sloping to steep mountainous terrain. The terrain that has a large weight for built-up land is the sloping terrain and plateau, because the slope class is less than 15% and the altitude is in the low and middle areas. The undulating to gently mountainous class of terrain has a medium weight, and the rest, from the slightly steep to steeply mountainous class of terrain has a low weight for developed land. The spatial terrain of Ternate Island can be seen in Figure 2.

Table 4. Area of Terrain Shape

Classification	Area (ha)	Percentage (%)
Ramps-Highlands	3.184,87	31,34
Sloping mountainous-Slightly steep mountainous	3.722,42	36,63
Mountainous Steep steep - Mountainous steep	3.253,82	32,02
Total Area	10.162,12	100,00

In general, based on Table 4, the research area is dominated by areas that have a terrain shape of Sloping Mountainous - Slightly Steep Mountainous at 36.63% then in second place is an area with a terrain shape of Steep Mountainous - Steep Mountainous at 32.02%, and the last is an area with a terrain shape of Sloping-Highland which is 31.34% of the total research area.

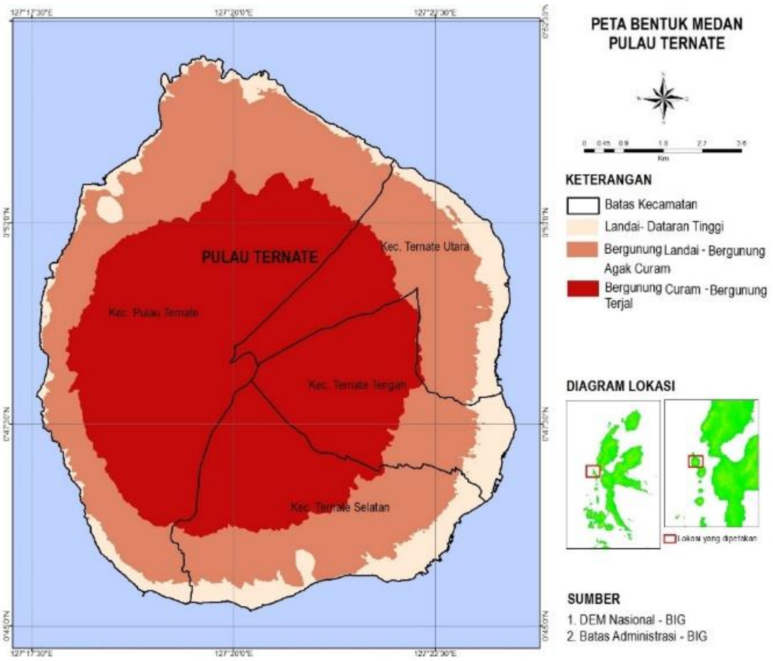

Figure 2. Ternate Island Terrain Map

3. Distance from Road

According to Utami et al. (2018) and Rakuasa & Somae (2022), distance from roads is one of the important elements determining the formation of built-up land. The road will act as a means of transportation to make it easier for residents to mobilize people, goods, or services by means of transportation in the form of the road. Based on the predetermined classification, the further the distance of developed land from the road, the more it has a small weight for the suitability of developed land. A distance of 0 - 100-meters from the road has a high weight for the suitability of developed land, then a distance of 100 - 750-meters is considered an area that has a medium weight for the suitability of developed areas, finally a distance of more than 750-meters is considered an area that has the lowest weight for the suitability of developed land. The spatial map of distance from roads can be seen in Figure 3.

Table 5. Extent of Distance from Road

Classification	Area (ha)	Percentage (%)
<100 m	3.184,87	31,34
101-750 m	3.722,42	36,63
>750 m	3.253,82	32,02
Total Area	10.162,12	100,00

In general, based on Table 5, the research area is dominated by areas that have a distance of 101-750 m from the road by 36.63% then in second place are those that have a distance of >750 m from the road with an area of 32.02%, and the last is the area that has a distance of <100 m from the road which has an area of 31.34% of the total research area. Based on the results of research by Sarihi et al. (2020), it shows that in general the development of residential land on Ternate Island follows an elongated pattern (linear) elongated pattern formed following the road.

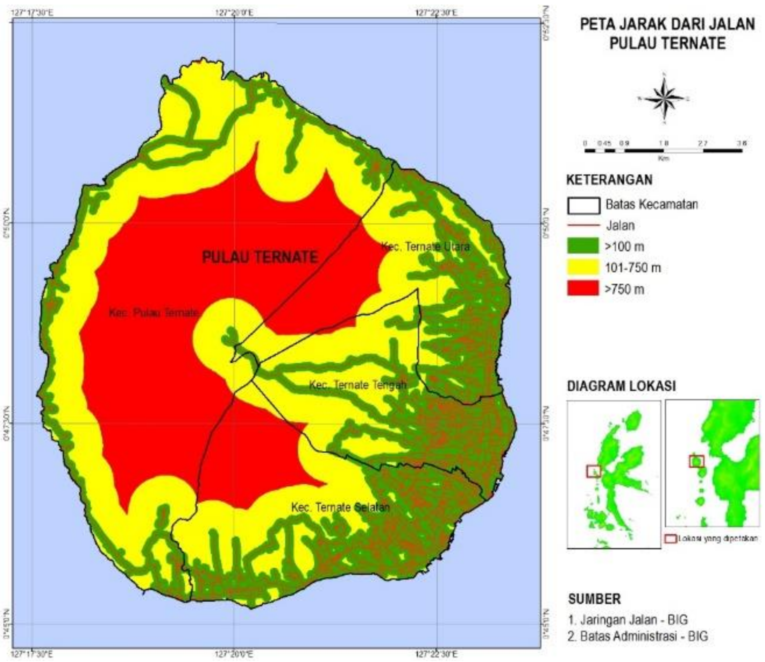

Figure 3. Distance Map from Ternate Island Road

4. Distance from the River

According to Government Regulation No. 37/2012 on Watershed Management, the ideal setback is 0-50 meters. Boundaries with a distance of 0-50 meters in this study are considered as areas that have the least weight for the suitability of built-up land. Furthermore, areas with a distance of 50 - 100 meters are considered as areas that have a medium weight. Meanwhile, areas with a distance of more than 100-meters from the river are considered as areas that have the highest weight for the suitability of built-up areas. This classification is done to maintain the function of the river so that it remains good and preserve the river itself. Rakuasa et al. (2022), also added that residential areas near rivers are very vulnerable to flooding during the rainy season. In the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 28/PRT/M/2015 concerning the Determination of River Boundary Lines and Lake Boundary Lines, it is strongly recommended for people to live close to riverbanks (Ministry of Public Works and Public Housing 2015).

Table 6. Extent of Distance from River

Classification	Area (ha)	Percentage (%)
< 50 m	1.380,72	13,59
50-100 m	1.392,84	13,71
> 100 m	7.388,56	72,71
Total Area	10.162,12	100,00

In general, based on Table 6, the research area is dominated by areas that have a distance of >100 m from the river amounting to 72.71% then in second place are those that have a distance of 50-100 m from the river with an area of 13.71%, and the last is an area that has a distance of <50 m from the river which has an area of 13.59%. The spatial map of distance from the river can be seen in Figure 4.

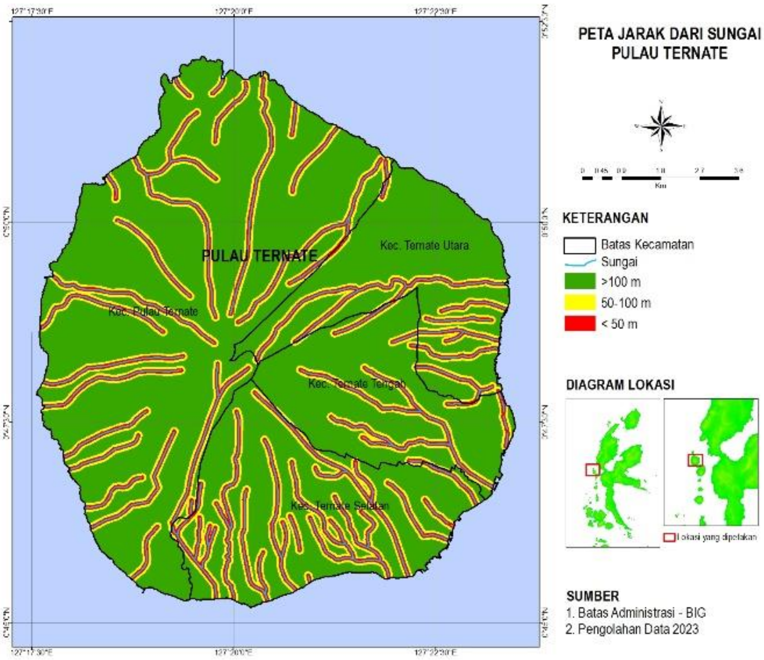

Figure 4. Distance Map from Ternate Island River

5. Distance from the Center of Economic Activity

The existence of a center of economic activity in an area is considered important for the economic activities of the population in that area. Through the center of economic activity, residents can obtain their daily needs, and they can also market the products of their business. In the study area, there are four large centers of economic activity in the form of markets and wholesale centers that provide daily needs for residents.

Ideally, the center of economic activity should be within a 2,000-meter radius of built-up land, to facilitate residents' access to the center of economic activity. A 2,000-meter radius from the center of economic activity has the highest land suitability weight. Then, the 2,500-meter radius has a medium weight, and areas with a radius of more than 2,500-meters have a low weight for the suitability of developed land. Lamonda et al. (2019) added that in general, for the selection of a place to settle or build a house, the distance from the presence of economic activity centers, such as shopping centers, is one of the aspects that is very calculated and considered very important. For this reason, in this study researchers added the variable distance from the center of economic activity as one of the research variables. The spatial map of distance from the center of economic activity can be seen in Figure 5

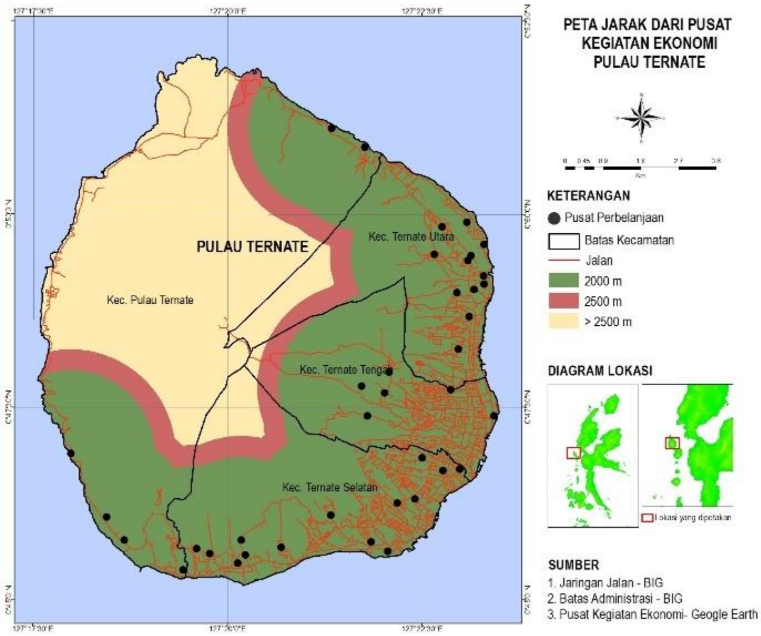

Figure 5. Map of Distance from the Center of Economic Activity of Ternate Island

Table 7. Extent of Distance from the Center of Economic Activity

Classification	Area (ha)	Percentage (%)
<2000 m	5.793,00	57,01
2001-2500 m	8.89,02	8,75
>2500 m	3.480,10	34,25
Total Area	10.162,12	100,00

In general, based on Table 7, the research area is dominated by areas that have a distance of >2000 m from the center of economic activity with an area of 57.01%, then in second place are areas that have a distance of >2500 m from the center of economic activity or 34.25% and the last is the area that has a distance of 2001-2500 m from the center of economic activity which has an area of 8.75%.

6. Mount Gamalama Disaster Prone Area (DPA)

The Mount Gamalama Disaster Prone Area is one of the variables in determining built-up areas. DPA Zone III is certainly an area with a low built-up area suitability value or an area that is not suitable for built-up areas. As for DPA II, it becomes an area that is less suitable for built-up areas, and for DPA I and non- DPA, it becomes an area that has a high built-up area suitability value, or an area that is suitable for built-up areas. Details of the distance from the Mount Gamalama disaster-prone area can be seen in Table 8 and spatially the distance map from the Mount Gamalama disaster-prone area can be seen in Figure 6.

Table 8. Extent of Distance from Disaster Prone Areas (DPA)

Classification	Area (ha)	Percentage (%)
DPA III	1.127,29	11,09
DPA II	1.567,35	15,42

Not DPA & DPA I	7.466,48	73,48
Total Area	10.161,12	100,00

In general, based on table 8, the research area is dominated by areas located in the non-Disaster Prone Area (DPA) zone of Mount Gamalama and in Disaster Prone Area Zone I which has a percentage area of 73.48% then in second place is the area in zone II with a percentage area of 15.42% and the last is the area in the Disaster Prone Area (DPA) III zone with a percentage area of 11.09%.

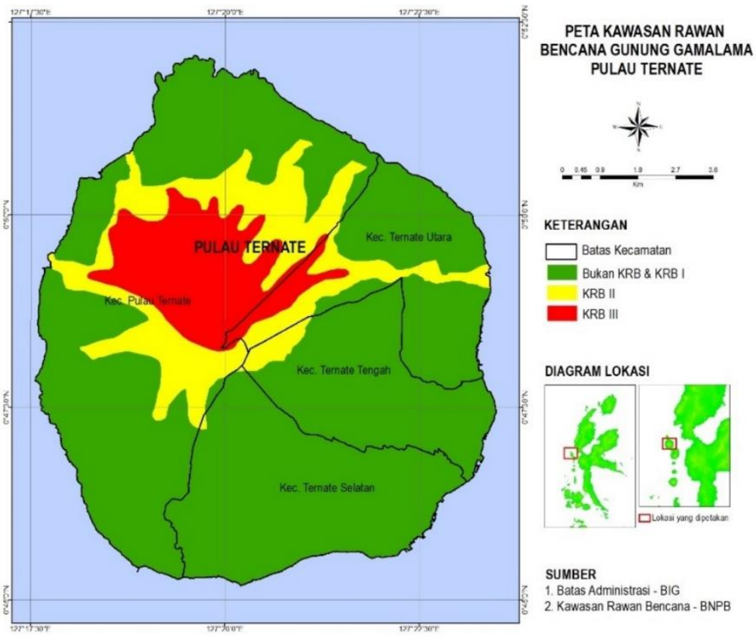

Figure 6. Distance Map from the Mount Gamalama Disaster Prone Area

Built-up Land Suitability Area

Developed land suitability areas are the result of overlay analysis using the Spatial Multi Criteria Analysis (SMCA) method on the six variables used. Areas that have a degree of suitability for built-up land are assumed to be areas that have a tendency to be the first choice in establishing built-up land. Areas that have a less suitable degree are assumed to be areas that are the second choice in establishing built-up land, while the last, namely areas that have a degree of unsuitability, are assumed to be areas that are avoided as much as possible due to land conditions that do not allow besides that they are also included in river boundaries and disaster-prone areas of Mount Gamalama Zone III. Details of the area of suitability of built-up land on Ternate Island can be seen in Table 8 and spatially the suitability of built-up land on Ternate Island can be seen in Figure 7.

Table 9. Area of suitability of built-up land on Ternate Island

Classification	Area (ha)	Percentage (%)
Suitable	4.991,07	49,12
Less suitable	3.004,37	29,57
Not suitable	2.165,66	21,31
Total Area	10.161,12	100,00

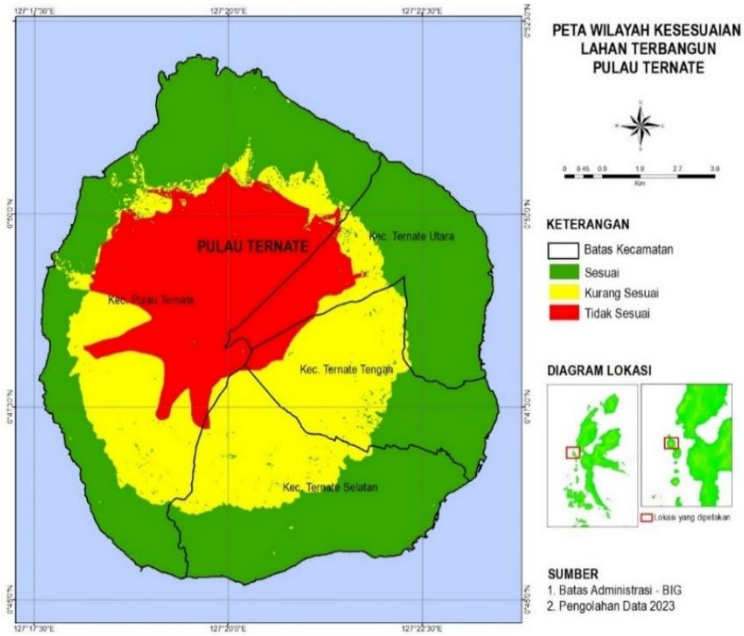

Figure 7. Map of Built-up Land Suitability Areas in Ternate Island

Most of the study area, namely Ternate Island, is included in the suitable area for built-up land with an area of 4,991.07 ha, while the less suitable area is only 3,004.37. Based on Figure 7 and Table 9, it is known that South Ternate sub-district has an area in the unsuitable class of 6.97 ha and Ternate Island sub-district has the highest area in each land suitability class for settlement development on Ternate Island.

Spatial analysis of built-up land suitability in Ternate Island can provide a number of important benefits in regional planning and development. Some of the key benefits of this analysis include:

1. Efficient Spatial Planning: An analysis of built-up land suitability can help governments and regional developers to plan for more efficient spatial planning (Rakuasa & Somae 2022). This helps prevent uncontrolled development that may be detrimental to the environment and existing infrastructure.
2. Natural Resource Management: Ternate Island has unique natural beauty, including attractive mountains and beaches. Land suitability analysis can assist in protecting these natural resources by determining locations that are suitable for built-up land development and those that should be maintained as conservation areas (Salakory & Rakuasa 2022).
3. Infrastructure Alignment: This analysis can help in planning efficient infrastructure, such as roads, bridges, and drinking water systems, by considering the most suitable locations for urban development (Muin & Rakuasa 2023).
4. Economic Development: Determining appropriate locations for shopping centers, industrial estates, and other commercial zones based on land suitability analysis can help improve the economic development of Ternate Island (Harisun 2020).
5. Natural Disaster Management: This analysis can also play a role in natural disaster management. By determining the areas most vulnerable to disasters such as floods or

earthquakes, authorities can take appropriate measures to protect residents and property (Rakuasa et al. 2022; Sugandhi et al. 2023)

6. Local Community Empowerment: Involving local communities in the land suitability analysis process can enable their participation in planning and decision-making regarding the development of their own areas. This can improve their quality of life and reduce potential conflicts
7. Environmental Protection: By selecting suitable locations for developed land development, this analysis can help maintain the ecosystems and natural environment on Ternate Island. This includes the preservation of forests, wetlands, and other natural habitats.
8. Improved Quality of Life: This analysis can help improve the quality of life for Ternate Island residents by creating a safer, more sustainable, and functional environment.

It is important to note that the land suitability analysis should be conducted carefully and consider various factors such as environmental, social, economic, and technical aspects. The results of this analysis should be used as a guide for wise decision-making in the development of the region, taking into account the interests of all stakeholders.

Conclusion

The increase in population that occurs on Ternate Island affects the availability of land for settlements. The increase in population causes the need for land to increase, resulting in an increase in built-up land. Most of the suitable land is located in the Ternate Island sub-district, while most of the unsuitable land is located in the northern part which has steep and hilly terrain and is in the Disaster Prone Area (DPA) class I. Area suitability is based on variables that consider physical data and accessibility data. The results of the analysis of the suitability of built-up land on Ternate Island are expected to help the Ternate City government in evaluating settlement development planning based on disaster mitigation and sustainable development.

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