

SPATIAL ANALYSIS OF BUILT-UP LAND DEVELOPMENT IN 2019 AND 2024 BASED ON SLOPE LEVEL IN TERNATE CITY INDONESIA

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Abstract

Ternate City, located in North Maluku Province, has a high population growth rate and ongoing residential land development. The diverse topography and slope of Ternate City is certainly one of the important factors that must be involved in this research. This study aims to determine the development of built-up land in 2019 and 2024 in Ternate City based on its slope level. This research uses land use data obtained from PlanetScope satellite image interpretation and slope data obtained from Digital Elevation Model analysis. This research uses overlay analysis to determine the distribution and development of built-up land in 2019 and 2023 based on the level of slope. The results showed that slope >45% has the largest area of 29.66% or 3,013.36 ha in Ternate City. In 2019, built-up land in Ternate City had an area of 1,551.14 ha and experienced an increase in area in 2024 of 2,010.78 ha. The results showed that in 2019, 640.08 ha of built-up land was on 0-8% slope, 638.08 ha on 8-15% slope, 218.25 ha on 15-25% slope, 39.91 ha on 25-40% slope, and 6.49 ha of built-up land on >45% slope. In 2024, 693.61 ha of developed land is on 0-8% slope, 826.34 ha on 8-15% slope, 395.16 ha on 15-25% slope, 75.65 ha on 25-40% slope, and 9.39 ha of developed land is on >45% slope. These results show that the growth of built-up land is strongly influenced by the level of slope, with areas with slopes >45% increasing, albeit by a smaller proportion. This conclusion emphasizes the need for special attention in spatial planning to manage settlement expansion in a sustainable manner, especially in areas with high slopes that are vulnerable to landslide and eruption risks of Mount Gamalama. Therefore, a practical recommendation for policy makers is to develop land use regulations that consider slope stability and environmental risks, to ensure safer and more sustainable urban growth.

Keywords: Built-up Land, Spatial Analysis, Sloper, Ternate

A. INTRODUCTION

The development of built-up land in urban areas is an unavoidable phenomenon along with population growth and increased economic activity (Wulandari et al., 2019). Ternate City, as one of the cities in Indonesia, has experienced significant growth in recent years. This is characterized by the increasing need for land for settlements, trade, and other infrastructure (Latue & Rakuasa, 2023). However, this growth may not always align with effective spatial planning, potentially leading to a range of issues, such as adverse effects on the environment and ecosystem balance (Salakory & Rakuasa, 2022). One of the factors that influences the development of built-up land is slope (Xu et al., 2019). The hilly and diverse topography in Ternate City provides its own challenges in land utilization. Steep slopes can increase the risk of erosion and natural disasters, such as

landslides, which can threaten the safety of residents and infrastructure (Sihasale et al., 2023). Therefore, it is important to analyze the development of built-up land by considering the level of slope.

On August 25, 2024, landslides and flash floods occurred in Ternate City, North Maluku Province, Indonesia. The disaster was caused by prolonged heavy rainfall, which led to the flow of debris from the summit of Mount Gamalama. The geological conditions of Ternate Island, consisting of uncompacted volcanic material, as well as deforestation in upstream areas, exacerbated the situation by reducing the soil's ability to absorb water. This disaster caused 19 people to die, while 8 injured people are still being intensively treated in several hospitals in Ternate (CNN Indonesia, 2024). There were 25 houses and places of worship destroyed, and one bridge on the highway between villages on Ternate Island was broken (BMKG, 2024). In general, built-up land affected by landslides is on slopes $>8\%$.

Spatial analysis is an effective tool for understanding the development pattern of built-up land (Zhou et al., 2022). By using geospatial mapping and analysis technology, we can identify areas that experience significant changes in land use from year to year (Zhang et al., 2018). This research aims to analyze the development of built-up land in Ternate City in 2019 and 2024 and relate it to the level of slope. Land use change in Ternate City is not only influenced by physical factors but also by social and economic factors (Latue, 2023). Rapid population growth and urbanization cause the demand for built-up land to increase (Rakuasa et al., 2023). This often results in the conversion of agricultural and forest land into residential and commercial land, which can impact environmental sustainability (Latue et al., 2023).

Ternate City has unique geological characteristics, with the presence of an active volcano that affects land use patterns. Volcanic activity can affect land availability and soil quality, which in turn affects land use decisions by communities (Achmadi et al., 2023). This research will explore how slope factors in the context of built-up land development. In addition, it is important to involve the community in the land planning and management process. Community participation can help in identifying local needs and priorities, as well as raising awareness of the importance of maintaining environmental balance. Based on the above background, this research is expected to make a significant contribution to the understanding of built-up land development in Ternate City.

B. RESEARCH METHOD

This study was conducted in Ternate City, North Maluku Province, Indonesia. This study used PlanetScope high-resolution satellite images recorded in 2019 and 2024 to analyze the development of built-up land during this period. The 3-meter resolution PlanetScope High Resolution Satellite Imagery was obtained from Planet Labs. PlanetScope is a network of satellites owned by Planet Labs, a company focused on earth sensing using a constellation of satellites that aim to provide continuous, high-resolution imagery of the entire Earth's surface (Frazier & Hemingway, 2021). Launched by Planet Labs, PlanetScope provides the possibility of observing the earth in high detail in short time intervals. This research also uses the National DEM data obtained by the Geospatial Information Agency, which has a spatial resolution of 8 meters, to analyze the slope in Ternate City. Arc GIS 10.8 software was used in this research to analyze the development of built-up land in 2019 and 2024 as well as slope analysis.

The process of data processing and analysis starts with the interpretation and digitization of PlanetScope satellite imagery into land use maps in 2019 and 2024, which are classified into two classes, namely built-up land and non-built-up land. Slope data is classified into 5 classes consisting

of 0-8% slope, 8-15%, 15-25%, 25-40%, and >40%. The 2019 and 2024 built-up land data were then overlaid with slope data to determine the development of built-up land in the 2019-2024 period based on slope in Ternate City.

The choice of slope ranges such as 0-8%, 8-15%, and beyond is crucial for effective land use planning and environmental management, as these categories directly correlate with the stability and suitability of land for development. Slopes in the 0-8% range are generally considered ideal for urban development due to their stability, which minimizes the risk of erosion and landslides, making them safer for construction and infrastructure. In contrast, slopes between 8-15% may still be manageable for development but require careful planning and engineering to mitigate potential risks associated with increased runoff and soil instability. As the slope increases beyond 15%, the likelihood of erosion and natural disasters rises significantly, necessitating stricter regulations and conservation measures to protect both the environment and public safety. By categorizing land into these slope ranges, planners can make informed decisions that balance development needs with ecological sustainability, ensuring that urban growth does not compromise the integrity of the landscape or the safety of its inhabitants.

C. FINDINGS AND DISCUSSION

The results of the interpretation and analysis of Planetscope Satellite Imagery of Ternate City show that in 2019, the built-up land area reached 1,542.81 hectares. In the following five-year period, namely until 2024, the built-up land area experienced a significant increase, reaching 2,000.13 hectares. This represents an increase of 457.32 hectares, reflecting the rapid growth of development in Ternate City. This increase in built-up land area can be attributed to several factors (Kusrini et al., 2023). First, the increasing population growth in Ternate City drives the need for housing, public facilities, and other infrastructure. According to data from the Central Bureau of Statistics, high population growth in urban areas often contributes to an increase in demand for built-up land (BPS, 2023).

According to previous research, the rapid economic development in Ternate City also plays a role in the increase of built-up land. With the increase in economic activity, both in the trade, tourism, and industrial sectors, the need for space for economic activities also increases (Chen et al., 2021). This encourages the conversion of previously undeveloped land into built-up land. Kirby et al. (2023) argues that local government policies that support infrastructure development and regional development also contribute to the growth of built-up land. Development programs designed to improve people's quality of life and support economic growth often involve the expansion of built-up areas (Rakuasa, H., & Latue, 2023). However, this increase in built-up areas also needs to be balanced with attention to environmental impacts. Unplanned development can cause problems such as degradation of environmental quality, increased risk of natural disasters, and loss of green open spaces. Therefore, it is important to conduct a more in-depth analysis of the impact of this increase in built-up land on local ecosystems and environmental sustainability.

The results of the research on the development of built-up land in Ternate City show that the distribution of slope plays an important role in determining land use patterns. The data obtained indicates that 0-8% slope covers an area of 1,041.78 ha (10.25%), while 15-25% slope covers 2,077.30 ha (20.45%). The 25-40% slope has an area of 2,255.56 ha (22.20%), and the area with a slope of more than 40% reaches 3,013.36 ha (29.66%). The dominance of areas with a slope of more than 40% indicates a challenge in the development of built-up land, given the higher risk of erosion and natural disasters in the area. Therefore, spatial planning that considers topographic

characteristics is essential to ensure development sustainability and reduce negative impacts on the environment

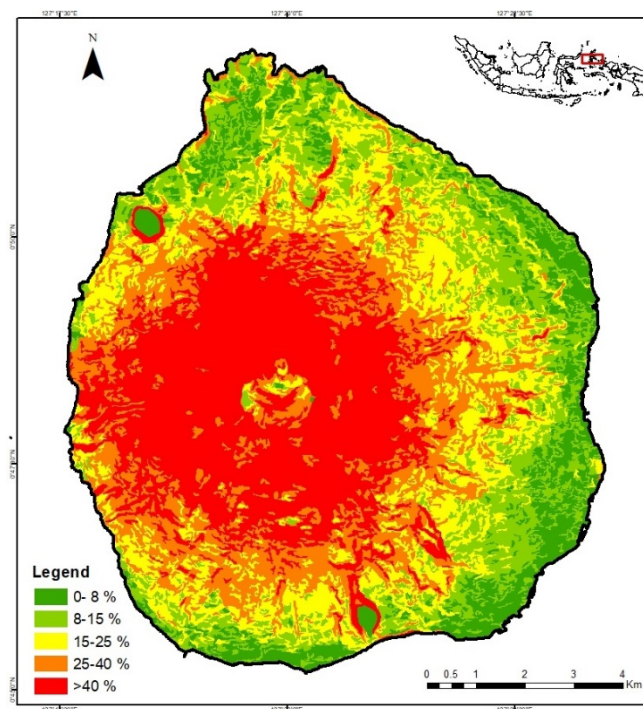


Figure 1. Slope of Ternate City

The overlay result between built-up land in 2019 and the slope map in Ternate City in Figure 2 shows that most of the built-up land is located on lower slopes, with 0-8% slope covering an area of 640.08 ha (41.49%) and 8-15% slope covering an area of 638.08 ha (41.36%). Meanwhile, built-up land on 15-25% slopes only reached 218.25 ha (14.15%), and 25-40% slopes covered 39.91 ha (2.59%). Built-up land in areas with slopes of more than 40% is minimal, only 6.49 ha (0.42%). This finding suggests that the development of built-up land in Ternate City tends to focus on areas with lower slopes, which are safer and easier to build on (Zhang et al., 2024). This is important to consider in future spatial planning in order to avoid higher risks of natural disasters in areas with steeper slopes.

The overlay between built-up land in 2024 and the slope map in Ternate City in Figure 2 shows a significant change in the distribution of built-up land compared to 2019. In 2024, built-up land on 0-8% slope covers an area of 693.61 ha (34.68%), while 8-15% slope increases to 826.34 ha (41.31%). Built-up land on 15-25% slopes also increased to 395.16 ha (19.76%). However, areas with slopes of 25-40% and more than 40% still show small proportions, totaling 75.65 ha (3.78%) and 9.39 ha (0.47%), respectively. This change reflects the trend towards more intensive development in areas with lower slopes, which can reduce the risk of natural disasters and improve the sustainability of development. Therefore, it is important for urban planners to consider topographic characteristics in the development of future built-up land.

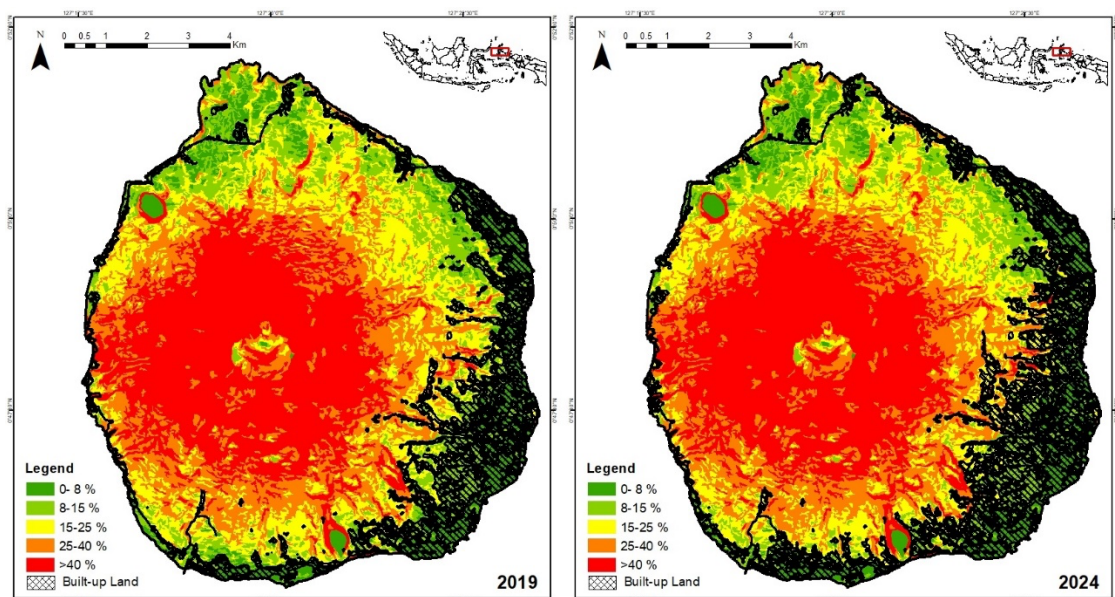


Figure 2. Development of Built-up Land in 2019 and 2024 against Slope of Ternate City

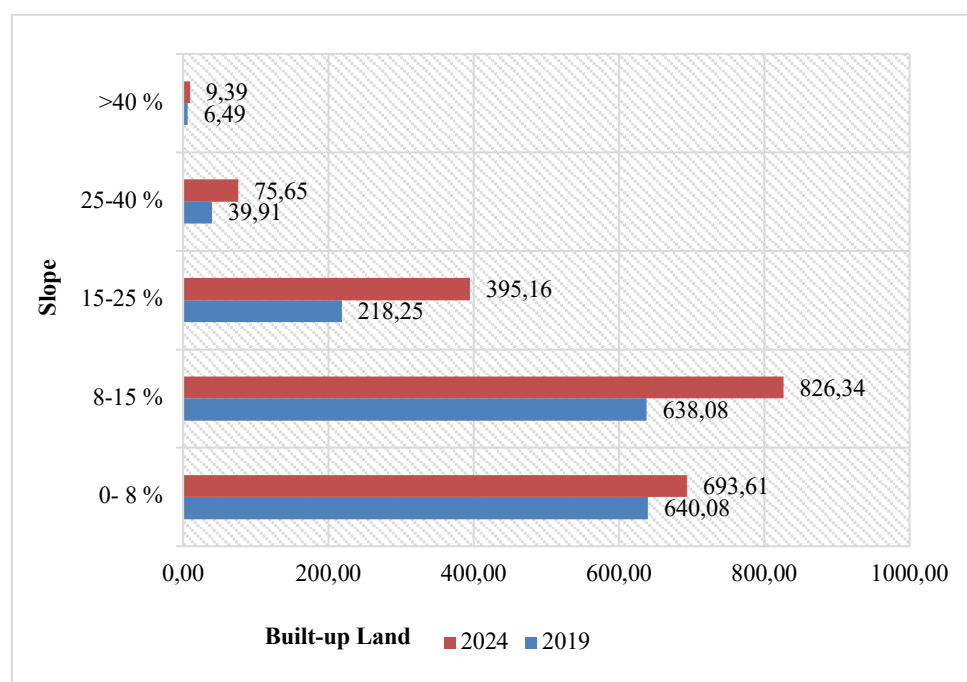


Figure 3. Area of Built-up Land in 2019 and 2024 by Slope

The results of the study on the development of built-up land in Ternate City show a significant increase in the area of built-up land from 1,542.81 hectares in 2019 to 2,000.13 hectares in 2024. This increase of 457.32 hectares reflects the rapid growth of development, largely triggered by population growth and increased economic activity in the trade, tourism, and industrial sectors (Figure 3). The need for space for greater economic activity drives the conversion of previously undeveloped land to built-up land, potentially changing land use patterns in the area (Marisha, 2020).

The slope analysis shows that most of the built-up land is located on lower slopes, with 41.49% of the built-up land on 0-8% slope and 41.36% on 8-15% slope. Meanwhile, built-up land in areas with slopes of more than 40% is minimal, with only 6.49 hectares. These findings suggest that the development of built-up land tends to focus on areas that are safer and easier to build on, which is important to note in future spatial planning. It also highlights the challenges faced in land development in areas with higher slopes, where the risk of erosion and natural disasters is greater (Somae et al., 2023).

In the context of spatial planning, it is important to consider the topographic characteristics and environmental impacts of built-up land growth. Unplanned development can lead to problems such as degradation of environmental quality, increased risk of natural disasters, and loss of green open spaces (Stoian et al., 2019). Therefore, a more in-depth analysis of the impacts of built-up land growth on local ecosystems and environmental sustainability is needed. Involving communities in land planning and management processes is also key to ensuring that local needs and priorities are accommodated and to raising awareness of the importance of maintaining environmental balance (Latue, 2023).

The findings from the study on the development of built-up land in Ternate City reveal significant environmental concerns that must be addressed in spatial planning policy. The rapid increase in built-up areas, particularly on lower slopes, raises issues such as the loss of green spaces, which are essential for biodiversity and climate regulation, and the heightened risk of natural disasters like landslides in steeper regions. These challenges necessitate the implementation of sustainable development practices that prioritize environmental conservation, such as zoning regulations that limit construction in high-risk areas and promote the preservation of natural landscapes. Furthermore, engaging local communities in the planning process is crucial to ensure that development aligns with their needs while fostering awareness of environmental impacts. By integrating these considerations into spatial planning, policymakers can create resilient urban environments that balance growth with ecological sustainability, ultimately safeguarding both the community and the natural resources for future generations.

D. CONCLUSION

The results of this study show that the development of built-up land in Ternate City between 2019 and 2024 experienced a significant increase, with an increase in built-up land area reaching 457.32 hectares. This growth is driven by factors such as increased population and economic activity, which has implications for the conversion of previously undeveloped land into residential and commercial land. However, slope analysis indicates that most of the built-up land is located on lower slopes, which are safer for development. Therefore, it is important to implement sustainable spatial planning, consider topographic characteristics, and involve communities in land management to reduce environmental risks and ensure ecosystem sustainability in Ternate City.

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