Journal Basic Science and Technology vol 14 (1) (2025) pp. 36-43

Published by: IOCSCIENCE

Journal Basic Science and Technology

Journal homepage: www.iocscience.org/ejournal/index.php/JBST

Application of GIS Technology to Analyze the Development of Built-up Land in Ambon City, Indonesia Based on Morphological Land Capability Units

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A R T I C L E I N F O

Article history:

Received: Jan 05, 2025
Revised: Feb 05, 2025
Accepted: Feb 26, 2025

Keywords:

Ambon;
GIS;
Morphological.

ABSTRACT

This study aims to analyze the development of built-up land in Ambon City, Indonesia, using a morphological Land Capability Unit (LCU) approach. In the face of rapid urbanization, it is important to understand the potential and limitations of land to support sustainable spatial planning. The methods used include analysis of Digital Elevation Model (DEM) data to assess slope and morphology, which is then overlaid to produce morphological HCS maps. In addition, Landsat imagery was used to classify developed and undeveloped land. The results of the analysis show that built-up land in Ambon City in 2024 will cover 4,439.25 ha, while undeveloped land will reach 28,133.90 ha. The morphological HCS is divided into five classes, with the high capability area reaching 3,128.21 ha. These findings confirm the importance of understanding morphology in siting development and identifying areas that need to be protected from overdevelopment. This research also highlights the role of GIS technology in supporting better decision-making that is responsive to community needs and is expected to make a positive contribution to sustainable development in Ambon City.

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1. INTRODUCTION

Rapid urban development often leads to significant changes in land use, especially in urban areas such as Ambon City, Indonesia (Rakuasa & Latue, 2023). With increasing population and infrastructure needs, it is important to understand how built-up land can be managed sustainably (Song et al., 2021). Therefore, analyzing the development of built-up land is crucial for effective and efficient spatial planning. Geographic Information System (GIS) technology has become a very useful tool in spatial analysis and land management (Wang et al., 2022). GIS enables the collection, processing, and analysis of geospatial data that can provide deep insights into physical conditions and land use (Fahad et al., 2021). By utilizing this technology, the analysis of built-up land development in Ambon City can be done more accurately and in detail.

Morphological Land Capability Units (LSCs) are an important aspect of land use analysis. Morphological HCS covers the physical characteristics of land, such as slope, elevation and soil type, that influence the ability of land to support development (Irjadi et al., 2020). By understanding

morphological SCS, urban planners can determine the most suitable areas for infrastructure and residential development (Sari et al., 2021). Ambon City, located on an archipelago, has unique challenges in land management. The hilly topography and environmental conditions prone to natural disasters add complexity to spatial planning (Muin & Rakuasa, 2023). Therefore, an in-depth analysis of the morphological HCS is essential to identify land potential and constraints in the city.

In the context of climate change and increased disaster risk, it is important to consider the carrying capacity of the environment in any development plan (Salakory & Rakuasa, 2022). Analysis conducted using GIS can assist in identifying high-risk areas and minimizing negative impacts on the environment. Thus, the use of GIS technology in morphological HCS analysis can support sustainable development in Ambon City. In addition, the results of this analysis can form the basis for better decision-making in spatial planning. Data generated from GIS analysis can be used by local governments and other stakeholders to formulate policies that are more responsive to community needs (Somae & Rakuasa, 2024). Thus, the application of GIS technology not only provides information, but also supports community participation in the planning process.

The importance of this research also lies in its contribution to the existing literature on land management in urban areas. By integrating GIS technology and morphological LCU analysis, this research is expected to provide a model that can be applied in other cities with similar conditions. This will strengthen the understanding of the importance of data-driven approaches in spatial planning. This research aims to provide practical recommendations for the development of built-up land in Ambon City. By utilizing GIS technology and morphological LCU analysis, it is expected to create a better and more sustainable environment for the community. Through this approach, Ambon City can serve as an example for other cities in effectively managing land development.

2. RESEARCH METHOD

This research was conducted in Ambon City, which is the capital of Maluku Province. This research uses slope and morphology variables to create a map of Morphological Land Capability Unit (LCU). Morphological Land Capability Unit (LCU) is a classification system used to assess and classify land based on its physical and morphological characteristics (Wirawan et al., 2019). The main objective of the LCU Morphology analysis is to determine the ability of land to support various types of uses, such as settlements, agriculture and industry, by considering the existing landforms in an area. In this context, HCS Morphology provides important information for spatial planners and policy makers in formulating sustainable land management strategies (Ahmada, 2023).

Morphological HCS is categorized based on five main classifications in accordance with the Minister of Public Works Regulation No. 20/PRT/M/2007 (Ministry of Public Works and Housing, 2007). These classifications include: Plains, which have little slope and are suitable for a variety of activities; Ramps, which are slightly undulating and also support a variety of uses; Moderate Hills, which have moderate slope and are more suitable for plantations and protected areas; Steep Mountains/Hills, which are steep and more suitable for protected forests; and Very Steep Mountains/Hills, which are very steep and ideal for conservation areas. Morphological HCS analysis is very important in spatial planning as it can help prevent environmental damage from inappropriate land use (Kautsar et al., 2020). By understanding morphological characteristics, planners can optimize land use so that land potential can be maximized without causing negative impacts such as erosion, flooding or landslides.

Slope, morphology variables are processed based on National DEM data with a spatial resolution of 8 meters obtained from the Geospatial Information Agency. Slope variables, morphology are classified based on Table 1 which refers to the Regulation of the Minister of Public Works No. 20/PRT/M/2007 on Guidelines for the Analysis of Physical & Environmental, Economic and Socio-Cultural Aspects in the Preparation of Spatial Plans. This research also uses land use data obtained from the results of interpretation, analysis, and classification of Landsat 8 images obtained from the USGS which will be overlaid with the morphological land capability unit map to determine land suitability. This research uses the Weighted Overlay method. The Weighted Overlay method is an analytical technique used in land suitability modeling, in which various data layers (rasters) are combined by giving different weights according to the importance of each criterion (Latue & Rakuasa, 2023). This method is often applied in multi-criteria analysis to determine the

most suitable location for a particular use, such as infrastructure development or business siting.All data was analyzed and processed in Arc GIS 10.8 software.

Table 1. Research Variables

No	Slope (%)	Value	Morphology	Value	Morphological Land Ability Unit Value
1	0-2	5	Plains	5	High
2	2-5	4	Ramps	4	Simplay
3	5-15	3	Medium Hills	3	Medium
4	15-40	2	Steep mountains/hills	2	Less
5	>45	1	Very steep mountains/hills	1	Low

Source: (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2007; Kautsar et al., 2020)

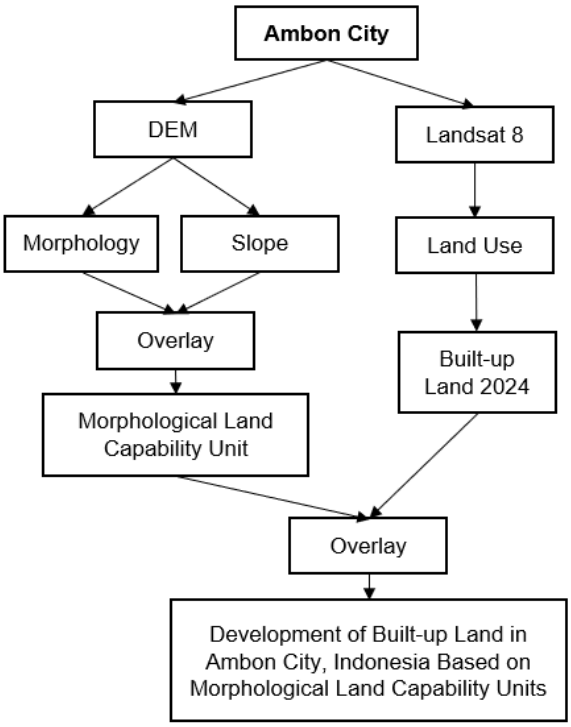

Figure 1. Workflow

The data processing process begins with the analysis of slope and morphology extracted from DEM data, which is then overlaid to obtain a morphological land capability unit map. The land use map is the result of interpretation of Landsat imagery which is classified into built-up land and non-built-up land. Built-up land data is then overlaid with morphological land capability unit data to determine the development of built-up land in Ambon City based on morphological land capability units. The research workflow can be seen in Figure 1.

3. RESULTS AND DISCUSSIONS

3.1. Ambon City Slope

Slope is the angle or degree of inclination of the land surface that indicates how steep a slope is. Slope classifications are usually divided into categories, such as flat, gentle, steep and very steep, which affect erosion potential and land suitability for different types of use. Slope in the Morphological Land Capability Unit (LCU) is a parameter that assesses the angle of land slope that affects the stability and ability of land to support development (Irjadi et al., 2020). Steep slopes can increase the risk of erosion and natural disasters, so areas with high slopes usually have lower HCS values. Conversely, flatter slopes tend to have higher HCS values, making them more suitable for infrastructure development (Sukwika & Firmansyah, 2021). The results of the slope analysis in Ambon City indicate that the 0-2% slope has an area of 2,636.15 ha, the 2-5% slope has an area of

3,625.63 ha, the 5-15% slope has an area of 10,144.10 ha, the 15-40% slope has an area of 15,834.84 ha and the slope with a slope >40% has an area of 321.85 ha. The slope map can be seen in Figure 2.

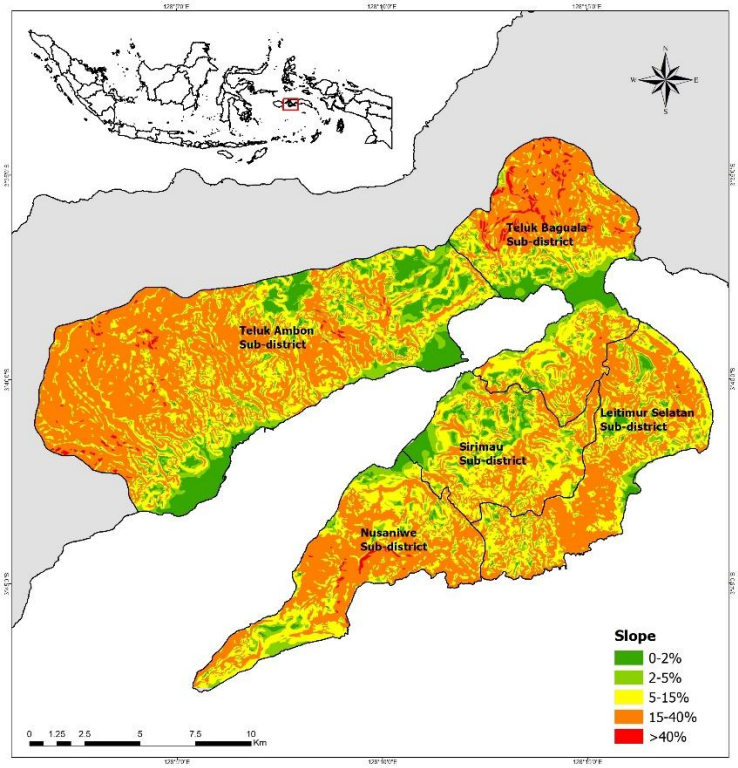

Figure 2. Slope Map of Ambon City

*3.2. **Morphology of Ambon City***

Morphology is the study of the shape, structure, and physical characteristics of an object or environment, including land, buildings, and road networks. In the urban context, morphology includes the analysis of land use, building layout, and network patterns that interact with each other in an area. Understanding morphology is important for effective and sustainable spatial planning, as well as for identifying potential and limitations in regional development (Sari et al., 2021). The results of the morphological analysis of Ambon City indicate that the Plains area has an area of 6,116.17 ha, Ramps area of 4,800.60 ha, Moderate Hills has an area of 8,741.96 ha, Mountains / real hills area of 11,782.32 ha, and Very steep mountains / hills has an area of 1,122.46 ha. This morphological analysis is important for spatial planning and natural resource management in Ambon City, assisting in determining the most suitable locations for development as well as identifying areas that need to be protected from overdevelopment. The spatial morphology of Ambon City can be seen in Figure 3.

*3.3. **Land Use of Ambon City in 2024***

Land use planning is a process of planning and regulating land use in an area that aims to achieve a balance between various land functions, such as settlement, agriculture, industry, and open space. This process includes the division of areas for specific functions, so as to optimize land use benefits and maintain environmental sustainability. Land use in this study is classified into two classes, namely developed and undeveloped land. The results of the analysis show that built-up land in Ambon City in 2024 is 4,439.25 ha and non-built-up land is 28,133.90 ha.

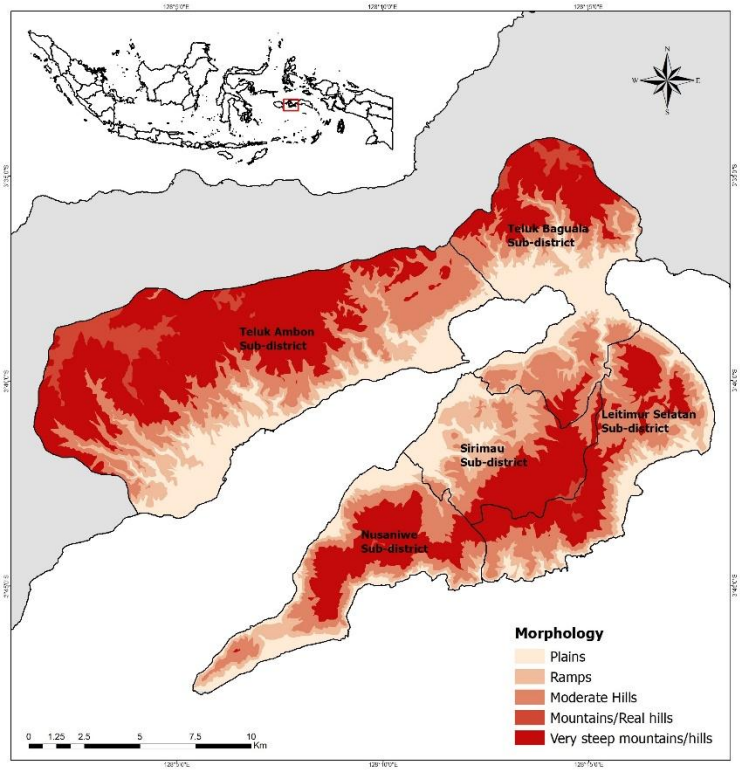

Figure 2. Morphological Map of Ambon City

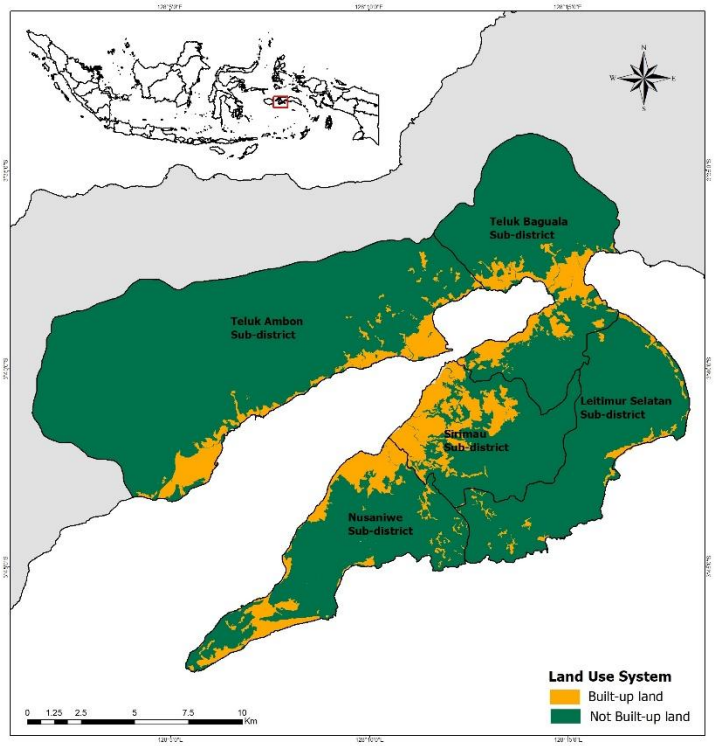

Figure 3. Land Use Map of Ambon City

3.4. Land Capability Unit Morphology of Ambon City

Morphological Land Capability Units (LCU) are an analysis used to identify and classify landforms in an area, and determine their potential and limitations for various uses (Kautsar et al., 2020). This analysis is important in spatial planning and natural resource management, as it helps to understand how morphological characteristics can influence sustainable land use (Ahmada, 2023). The Morphological Land Capability Unit of Ambon City was obtained from the overlay of morphology and slope. The morphological land capability unit of Ambon City is divided into five classes, namely High covering 3,128.21 ha or 9.99%, Simply covering 7,337.18 ha or 23.43%, Medium covering 13,462.45 ha or 42.99%, Less covering 7,337.18 ha or 23.43% and Low covering 47.14 ha or 0.15%. Spatially, the morphological land capability units of Ambon City can be seen in Figure 4.

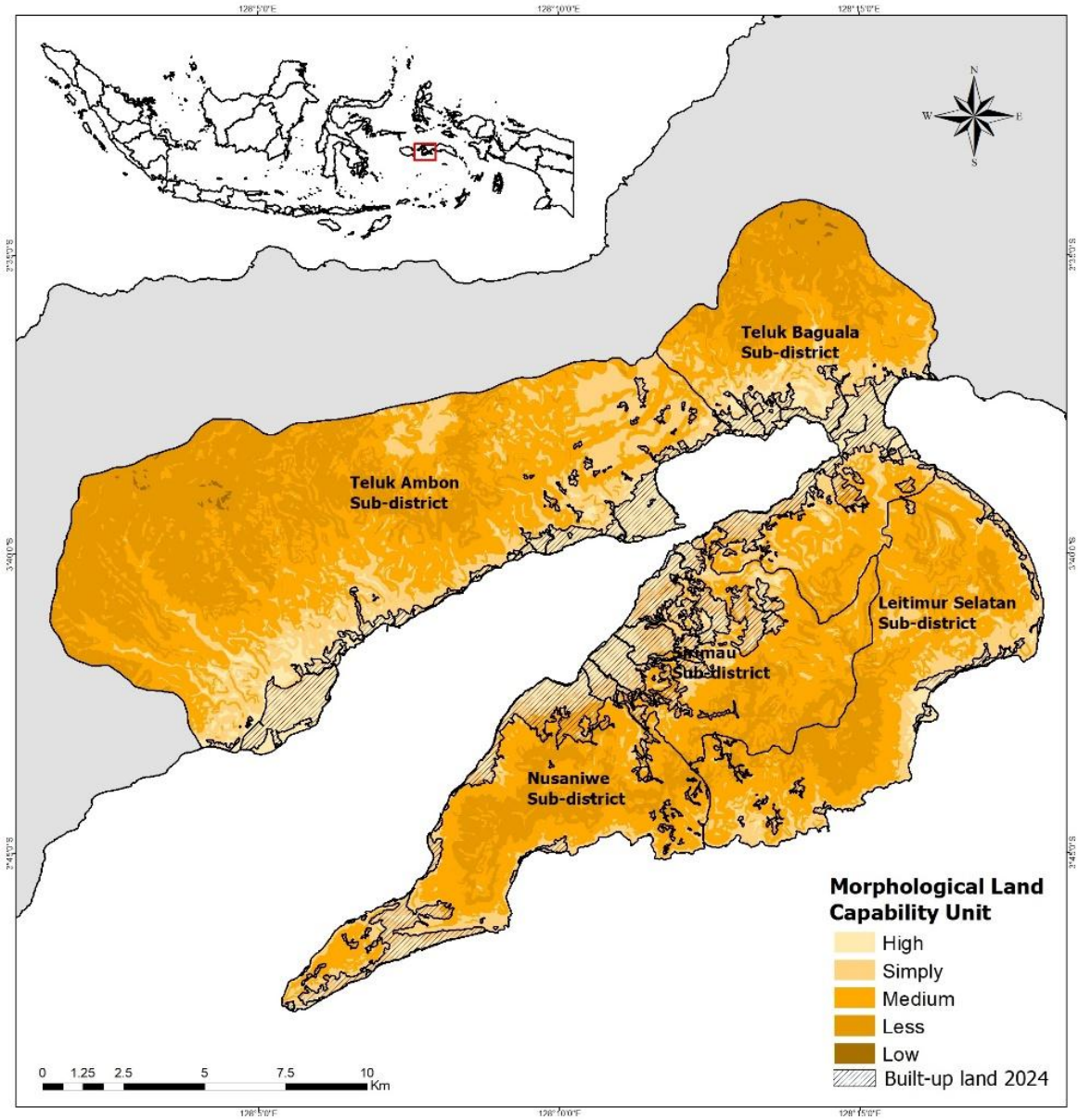

Figure 4. Morphological Land Capability Unit Map of Ambon City.

Table 2. Unit Class Land Capability Morphology (Ha) - Sub-district

Sub-district	Unit Class Land Capability Morphology (Ha)				
	High	Simply	Medium	Less	Low
Sirimau	478.74	1047.36	1600.32	576.05	-
Nusaniwe	326.07	1123.42	2167.14	1057.20	-
Teluk Ambon	1258.04	2676.98	4916.83	4479.78	29.50
Teluk Baguala	878.82	1347.77	2288.10	1347.77	17.65
Leitimur Selatan	186.55	1141.65	2490.06	932.73	-

Table 2 shows the area of the morphological land capability unit class in 5 sub-districts in Ambon City, with categories consisting of High, Simply, Medium, Less, and Low. Sirimau sub-district has the largest land area in the Medium category with 1,600.32 ha, while the High category has an area of 478.74 ha. Nusaniwe sub-district shows a significant area in the Simply category with 1,123.42 ha and Medium with 2,167.14 ha. Teluk Ambon sub-district has the largest total land area in all categories, especially in the Medium (4,916.83 ha) and Less (4,479.78 ha) categories. Meanwhile, Teluk Baguala and South Leitimur sub-districts also show notable variations in area within these categories, although there is no data for the Low category in Sirimau and South Leitimur. The built-up land of Ambon City in 2024 was then overlaid with the Morphological Land Capability Unit, settlements in the High Morphological Land Capability Unit had an area of 2,182.04 ha, the Medium class had an area of 507.85 ha, the Less class had an area of 14.56 ha and the Simply class had an area of 1732.52 ha.

Analysis of the development of built-up land in Ambon City based on morphological Land Capability Units (LCU) provides important benefits in more effective spatial planning (Sari et al., 2021). By identifying land potential and limitations, planners can determine the most suitable locations for infrastructure and settlement development (Irjadi et al., 2020). This analysis also helps in protecting areas vulnerable to natural disasters, thereby reducing the risk of environmental damage. In addition, the information generated supports the development of policies that are responsive to community needs and environmental conditions. Overall, this analysis contributes to sustainable development and improved quality of life in Ambon City.

4. CONCLUSION

The conclusion of this study shows that the analysis of built-up land development in Ambon City based on morphological Land Capability Units (LCU) is essential for sustainable spatial planning. The results of the analysis identify land potentials and limitations, allowing planners to determine the most suitable locations for infrastructure and residential development. By understanding morphological characteristics and environmental risks, land management strategies can be formulated to protect areas vulnerable to natural disasters. This research also emphasizes the importance of using GIS technology in supporting better decision-making that is responsive to community needs. Overall, the results of this research are expected to make a positive contribution to the sustainable development and improvement of the quality of life of the people in Ambon City.

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