Article Journal of Asian Geography, 2024, Volume 3 (Issue 2), 70-75.
https://doi.org/10.36777/jag2024.3.2.7

The Impact of Population Growth on Open Area in the Coastal Area of Makassar City

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Received: 13 Jul 2024, Revised: 25 Aug 2024; Accepted: 20 Sep 2024; Published 24 Sep 2024

Abstract: Makassar City, as the capital of South Sulawesi Province, has advantages over other cities. Its status as an educational center in eastern Indonesia attracts people seeking education and employment. As a coastal area, Makassar City provides various eco-services with environmental, economic, and social value, which is a primary factor driving urbanization. The movement of people from villages to cities encourages rapid population growth and development, resulting in the conversion of open areas into built-up areas. Changes in land use and land cover are driven by human activities to meet various needs, such as housing, industry, and infrastructure. Monitoring land use changes can be achieved through satellite imagery, and this study utilizes data from 1997, 2002, and 2017. The aim of this study is to analyze changes in land use, particularly the transformation of open areas into built-up areas. The analysis technique employed is spatial analysis. Landsat data, including satellite imagery from L5_TM for 1997, L7_ETM for 2002, and L8_OLI for 2017, serve as primary data for classifying open areas and built-up areas. The results of the analysis indicate that the built-up area increased by 3.23% from 1997 to 2002, and by 10.94% from 2002 to 2017. Conversely, open areas experienced a decrease of 14.17% from 1997 to 2017. This change highlights the growing built-up area and its impact on the reduction of open areas. The data on these changes will provide valuable input for the government and the community as a basis for decision-making regarding environmental management and planning in the future.

Keyword: Population growth; Open area; Built-up area; Urbanization; Coastal area.

1.0 Introduction

Makassar City is the capital of South Sulawesi Province, covering an area of 175.77 square kilometers, which includes 15 sub-districts and 153 wards. The population growth rate increased by 1.40% from 2014 to 2016 (BPS, 2017). The population is defined as all individuals who occupy a specific area for six months or more, or those who occupy a particular area for less than six months but intend to settle there (Suryanto et al., 2023). As one of the largest cities in Indonesia, Makassar attracts people seeking a place to live and work. Key factors driving migration to Makassar include the need for employment, education, and family connections. As a coastal area, Makassar City provides a variety of ecosystem services with environmental, economic, and social value, further encouraging population growth and rapid development. Changes from open areas to built-up areas due to human activities can be monitored through satellite imagery. The development of remote sensing technology provides useful tools for exploring the relationship between population growth and land development (Zang et al., 2023).

The migration of people from villages to cities is referred to as urbanization. The pace of urbanization has accelerated faster than ever in human history. It is estimated that by 2025, 65% of the world's population will reside in urban areas (Zhu & Ling, 2024; Bongaarts, 2009). Additionally, the World Bank estimates that more than 50% of the world's population currently lives in urban areas, with this number projected to increase by 1.5 times (600 million people) by 2045 (Ulloa-Espíndola et al., 2023; Hardiansyah et al., 2024; Arifin et al., 2023). Urbanization is a megatrend defining the 21st century; another study predicts that by 2050, the urban population will increase by 68%, predominantly in Africa and Asia (McLean et al., 2024). Factors influencing population growth include five demographic elements: death, birth, immigration, gender, and age (Taha & Motlak, 2023). Urbanization has led to the transformation of open areas, resulting in land-use changes and an increase in built-up areas (Tran et al., 2017).

Land is a vital natural resource for human life (Al-Taei et al., 2023). Due to its significance for economic activities, changes in land use and land cover associated with urbanization lead to reductions in open areas, agricultural land, and increased built-up areas (Ramadan & Hidayati, 2022). The expansion of built-up areas and the growth of urban populations yield significant benefits for development and stimulate economic growth (Pan et al., 2023). The expansion of urban areas is an inevitable result of urbanization and represents the most visible spatial characteristic of this process. With urbanization, economic activities are growing rapidly, attracting more people to cities and contributing to the swift growth of urban populations (Wang et al., 2023). Land cover changes, driven by human needs for housing, industry, agriculture, mining, and other infrastructure, are a major concern regarding sustainable economic growth in an area (Zope et al., 2016; Kadhim & Abbas, 2021; Zhang et al., 2014). Furthermore, continuous growth in building construction and urban development leads to reduced rainwater infiltration into the soil and an increase in surface temperatures.

The primary objective of this study is to estimate the changes and transformations of open areas into built-up areas over time. This research plays a crucial role in analyzing change scenarios in Makassar City, as the data on these changes will serve as valuable input for the government and the community in making informed decisions about environmental management and future planning.

2.0 Study Area

This research was conducted in Makassar City, South Sulawesi Province, Indonesia. Geographically, Makassar City is situated between 119°4'-119°32' E and 4°58'-5°14' S. The study area encompasses all wards located along the coastline of Makassar City. Indonesia is a vast archipelagic country, where most major cities are situated in coastal areas and are sustained by abundant marine resources. Consequently, coastal cities are sensitive to environmental changes due to their socio-ecological nature (Arifin et al., 2023). This sensitivity is particularly concerning, given that coastal areas are among the most densely populated regions globally, with an estimated 23% of the world's population living within 100 km of the coast (Munji et al., 2013). Rapid population growth, urban sprawl, increasing demand for waterfront properties, and coastal resort development have further detrimental effects on protective coastal ecosystems. Seasonal floods within coastal mangrove forests can adversely impact human livelihoods, disrupt ecological balance, and lead to environmental degradation. This presents an intriguing challenge for study, which is why researchers have chosen coastal areas as their focus. The map is shown in Figure 1.

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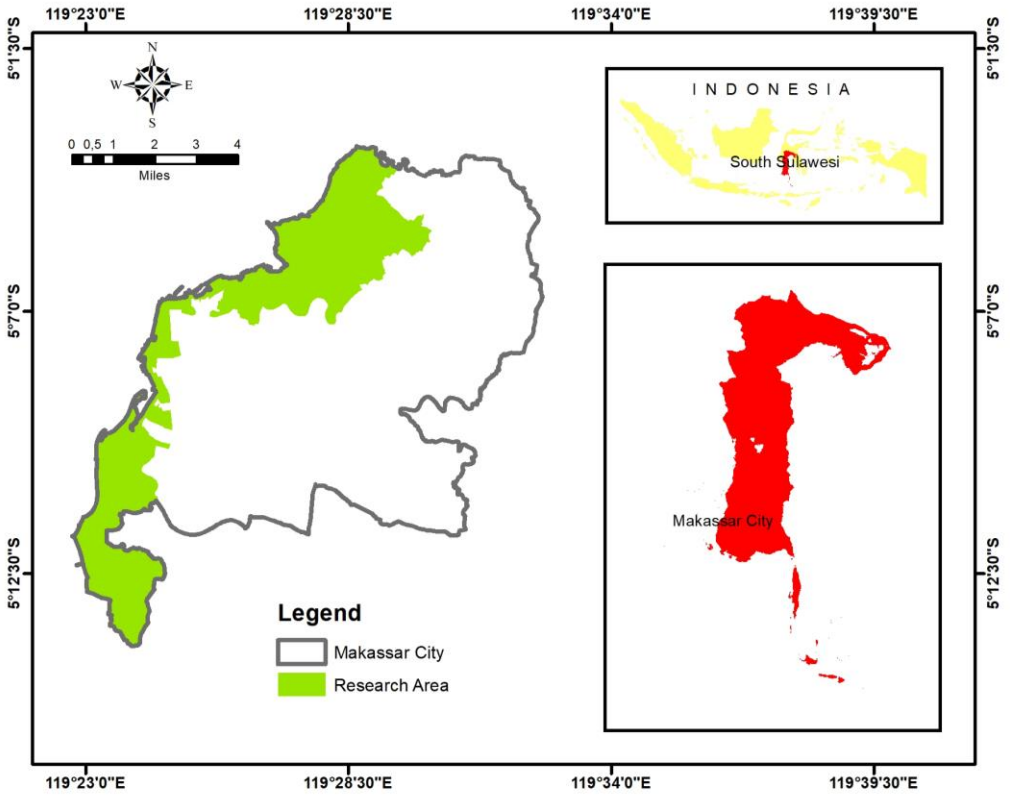

Figure 1: Location of Makassar City and the Research Area

3.0 Materials and Methodology

3.1 Materials

The research data is sourced from remote sensing images taken in 1997, 2002, and 2017. The study utilized 30m resolution satellite data from Landsat L5 TM, L7 ETM, and Landsat 8 OLI. The images were obtained from the United States Geological Survey (USGS) through their Earth Explorer web portal (https://glovis.usgs.gov/) (Dahanayake et al., 2024; Baig et al., 2022). Information regarding the satellite data is presented in Table 1.

Table 1: Satellite imagery data

No.	Year of acquisition	Satelite	Path/row	Sensor	Resolution (m)	Source
1	1997	Landsat	114/64	L5_TM	30 x 30	USGS
2	2002	Landsat	114/64	L7_ETM	30 x 30	USGS
3	2017	Landsat	114/64	L8_OLI	30 x 30	USGS

3.2 Methodology

Remote sensing classification is an important method for obtaining land cover information. The process of identifying features in remote sensing images essentially involves transforming the identification problem into sample classification. The quality and representativeness of training samples directly impact the classification results of remote sensing image classifiers (Zhang et al., 2023).

In general, the initial training samples are acquired randomly based on the constraints of the ground reference map, with approximately 10% of the ground reference map selected as the training samples (Lv et al., 2019). The satellite images were classified using a supervised classification method with the Maximum Likelihood Classifier. The images were classified into two categories: open area and built-up area, using different band combinations. The analysis was carried out by creating training samples (Nganro et al., 2022; Dehkordi et al., 2022; Richards & Jia, 2006; Phinzi et al., 2023).

These training samples consist of groups of homogeneous pixels or regions of interest (ROIs) obtained from the class categories present in the image (Bhaskaran et al., 2010). Training sample selection is a critical component of most remote sensing classification methods (Yang et al., 2018).

To expand the selected annotated points for point-to-surface sampling, the following patterns are typically used: (1) point-centered outward expansion or linear pattern expansion based on pixels; (2) point-centered outward expansion with regular or irregular polygons; and (3) point-centered outward expansion with circles or ellipses. The combination of ROIs expanding with these three patterns is more effective. The patterns are shown in Figure 2, and the framework of spatial analysis is shown in Figure 3.

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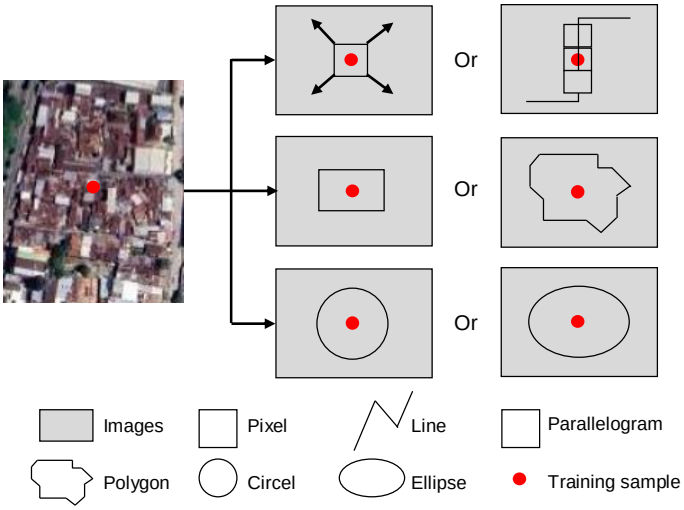

Figure 2: Training sample extension models

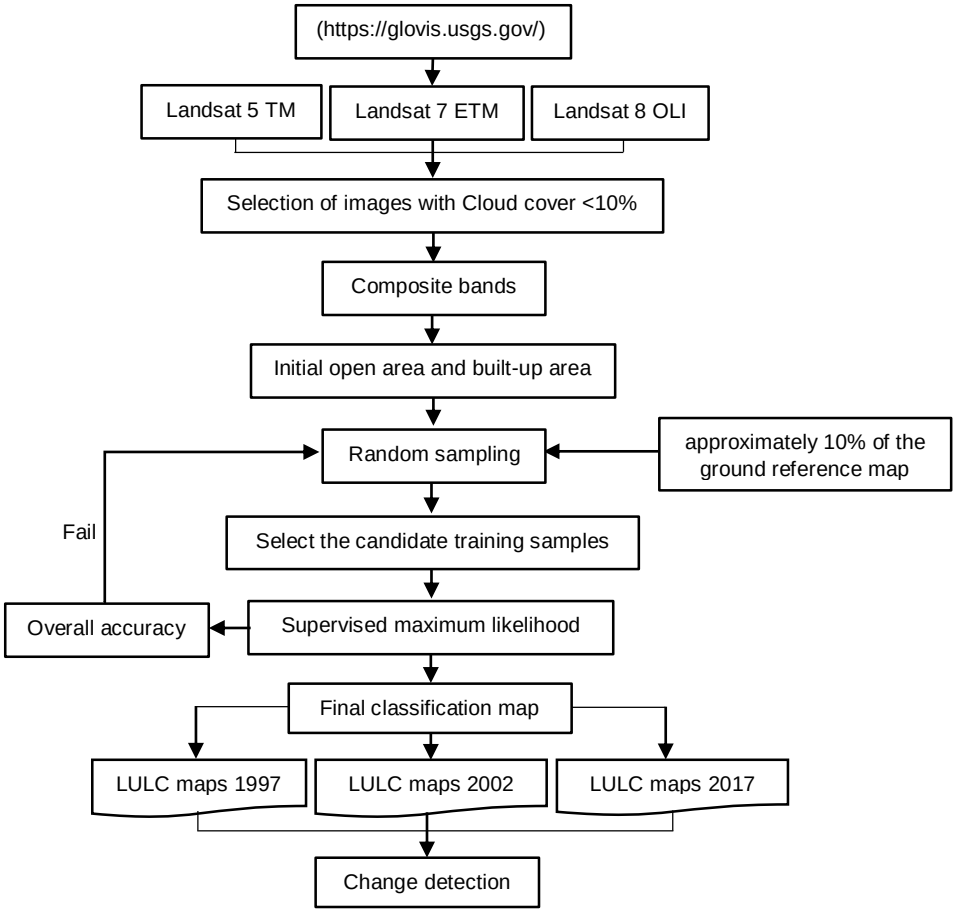

Figure 3: Framework of spatial analysis

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4.0 Results

The types of coastal land use in 1997, 2002, and 2017 are grouped into two classes: open area and built-up area. The maps of coastal land use were prepared from the results of supervised classification using the band combination. There is a correlation between the population growth of Makassar City and the change from open areas to built-up areas in the coastal area of Makassar City. The green color represents open areas, while the red color indicates built-up areas. The results of the analysis are shown in Figure 4. The results of the analysis of the change from open areas to built-up areas in 1997, 2002, and 2017 in the coastal area of Makassar City are shown in Table 2.

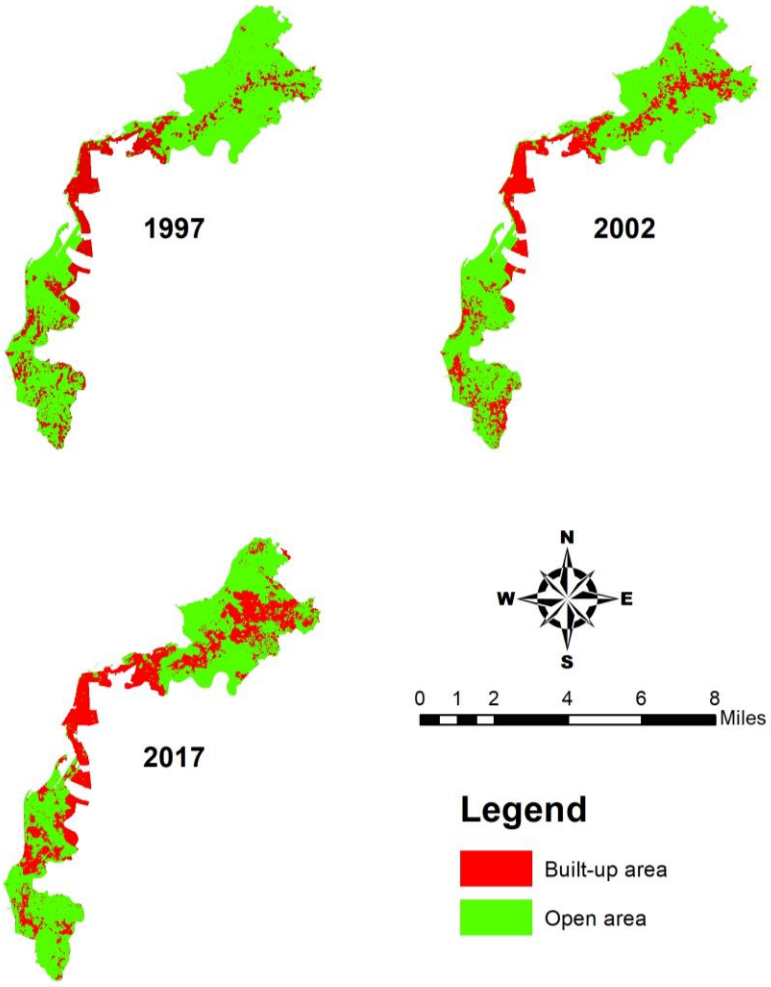

Figure 4. Land use change maps

Tabel 2: Land use changes

No.	Land use	Area (ha)			Percentage (%)			Land use change			
								1997-2002		2002-2017	
		1997	2002	2017	1997	2002	2017	Ha	%	Ha	%
1	Built-up area	1,021.12	1,170.99	1,677.78	22.05	25.28	36.22	+149.87	+3.23	+506,79	+10,94
2	Open area	3,610.56	3,460.69	2,953.90	77.95	74.72	63.78	-149.87	-3.23	-506,79	-10,94

5.0 Discussion

This study divides land classification into two categories: built-up areas and open areas. Classifications can be determined based on research needs, including water bodies, developed land, barren land, forests, agriculture, and wetlands (Baig et al., 2022). The land classification categories can also include water bodies, dense vegetation, other vegetation, settlements, and open areas (Dahanayake et al., 2024). In this study, land classes, as identified by Nganro et al. (2019), are divided into business areas, settlements, forests, agriculture, and water bodies. The determination of land class categories is guided by the researchers based on the objectives to be achieved. Human activities over the last three centuries have significantly transformed the Earth's environment (Ramankutty & Foley, 1999). Land use/land cover (LULC) change is one of the most important indicators for understanding the interactions between humans and the environment (Li et al., 2017). An increase in population leads to a rise in built-up areas and, consequently, an increase in population density. A report by the WHO places the optimal population density at 96 people per hectare.

6.0 Conclusions

The migration of people from rural to urban areas has led to rapid land use/land cover (LULC) changes to meet the population's needs, resulting in tremendous growth in urban areas in developing countries worldwide. Population growth and urbanization in Makassar City from 1997 to 2017 have led to the expansion of built-up areas and a reduction in open areas. The human demand for housing and urban infrastructure has resulted in land conversion in coastal areas, significantly transforming the Earth's environment. Based on maps and analysis data, it is evident that several areas have undergone significant changes. Therefore, in the future, attention must be paid to the community's needs for urban land, ensuring better community-land coordination to promote sustainable development. This study aims to provide a scientific reference for land use planning and urban development. The research data is limited to three series of Landsat images spanning 10 years. More data series are needed, covering longer time periods for more measurable results. For future research, it is essential to juxtapose population growth data with land use change analysis to confirm the trend of changes in each observation period.

Acknowledgement: Thank you to Hasanuddin University for the support in this research, especially to the dean of the graduate school and the head of the urban management study program. We would also like to express our gratitude to the reviewers for their comments and suggestions, which have greatly improved the quality of this article. I hope this research proves to be useful to both academics and the community.

Conflicts of Interest: The authors declare that there are no conflicts of interest regarding this research.

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