Indonesian Journal of Geography Information Science

Journal homepage: https://ejournal.upi.edu/index.php/IJGIS/index

The Impact of Built-Up Land Increase on Green Open Space in Kawasan Bandung Utara

Muhammad Saiful Ruuhulhaq [1], Hilal Syahbana [2], Rafi'i Diva Sephana[3]*

[1]Amcolabora Institute, Indonesia
[2,3]Geo Impact, Indonesia
*Correspondence: E-mail: msaiful@amcolabora.or.id

ABSTRACT

Based on Peraturan Daerah (Perda) Provinsi Jawa Barat No. 2 Tahun 2016 tentang Pedoman Pengendalian Kawasan Bandung Utara sebagai Kawasan Strategis Provinsi, KBU serves critical functions in water and soil conservation, necessitating environmentally sustainable management. However, rapid urbanization and increased built-up land have threatened its ecological functions. The expansion of built-up land in KBU has significantly contributed to reducing green open space (GOS). This study analyzes the impact of built-up land expansion on changes in GOS area in KBU from 1990 to 2024. The methodology includes multi-temporal satellite imagery analysis and Geographic Information Systems (GIS) to map built-up land expansion and identify its effects on GOS. The data were analyzed using simple linear regression to examine the relationship between built-up land area and GOS reduction, supported by field accuracy tests. The results show that built-up land area increased more than fivefold over 33 years, from 2,555.55 hectares in 1990 to 13,063.56 hectares in 2023. Conversely, GOS declined from 35,607.97 hectares to 25,099.96 hectares, with the highest reduction occurring between 2010 and 2015. Regression analysis confirms the significant impact of built-up land expansion on GOS reduction. Sustainable spatial planning and enforcement of development control policies are crucial to protecting KBU's ecosystems.

ARTICLE INFO

Article History:
Submitted/Received 09 Des 2024
First Revised 14 Jan 2025
Accepted 19 Jun 2025
First Available Online 25 Nov 2025
Publication Date 30 Nov 2025

Keyword:
Kawasan Bandung Utara,
Built-up Land Expansion,
Green Open Space.

1. INTRODUCTION

Green Open Space (GOS) is a vital component of sustainable urban development, providing ecological, aesthetic, and social benefits for urban populations. In urban contexts, GOS plays a crucial role in maintaining environmental balance, providing habitats for biodiversity, and acting as carbon sinks that contribute to reducing greenhouse gas emissions (Herzele & Wiedemann, 2003). Moreover, GOS can help regulate local temperatures by mitigating the urban heat island effect and offering recreational spaces for urban communities (Bowler et al., 2010). Thus, adequate GOS in urban areas is essential for maintaining environmental quality and public health.

Kawasan Bandung Utara (KBU) is a strategic region in West Java Province, primarily functioning as a conservation area and an ecosystem service provider for surrounding regions. According to the West Java Regional Regulation No. 2 of 2016, KBU is designated as a Provincial Strategic Area to preserve ecological balance and sustain water resources through green space conservation (BAPPEDA, 2016). KBU plays a critical role in supplying water to Greater Bandung and maintaining water management balance through the forests and green spaces within it.

The rapid urbanization around KBU over the past few decades has led to increased land conversion, primarily for residential, commercial, and supporting infrastructure development. This phenomenon not only threatens the existence of GOS but also risks disrupting the ecological functions of the area, considering that KBU is a crucial water catchment zone (Susanto et al., 2021). Uncontrolled urbanization in this region has various negative environmental impacts, such as declining water quality, increased erosion risk, and microclimate changes in and around KBU (Widyastuti et al., 2019).

The reduction of GOS in KBU due to built-up land expansion is a critical issue. In urban areas, GOS loss directly impacts the loss of ecosystem functions, including rainwater absorption, carbon emissions reduction, and biodiversity loss (Tzoulas et al., 2007). In KBU, this reduction may affect water management balance and increase the risk of hydrometeorological disasters, such as floods and landslides, especially during the rainy season (Hakim et al., 2020). Furthermore, reduced GOS affects air quality in urban areas due to the decline in vegetation, which acts as a natural pollutant filter (Setiawan & Amalia, 2021).

Although previous studies have identified the impacts of urbanization on GOS reduction in urban areas, research on land conversion patterns and their ecological implications, particularly in conservation areas like KBU, remains limited (Prasetyo & Lestari, 2020; Susanto et al., 2021). Some studies have discussed the importance of GOS in maintaining ecosystem balance and preventing hydrometeorological disasters. However, comprehensive studies on land cover changes from multi-temporal and multi-spatial perspectives in KBU, especially using satellite imagery analysis and Geographic Information Systems (GIS), are still scarce (Dewi et al., 2022; Tzoulas et al., 2007).

West Java Regional Regulation No. 2 of 2016 designates KBU as a strategic area that must be protected. However, few studies evaluate the effectiveness of this regulation in controlling built-up land expansion in KBU and its impact on GOS sustainability. Therefore, this study aims to conduct an in-depth analysis of the impact of built-up land expansion on changes in GOS area and distribution in KBU from 1990 to 2023. This research is expected to provide new insights for policymakers to formulate more effective and sustainable spatial planning strategies in KBU.

By producing data-driven recommendations, this study is expected to enhance public and governmental understanding of the importance of ecosystem sustainability in KBU. Through collaborative efforts among government entities, academia, and the community, GOS

DOI: http://dx.doi.org/10.xxxxx/ijost.vXiX
p- ISSN xxxx-xxxx e- ISSN xxxx-xxxx

preservation in KBU can be achieved to support sustainable urban development in the future (Suharto et al., 2023).

2. METHODS

2.1. Location and Data

This research was conducted in Kawasan Bandung Utara (KBU), West Java. KBU encompasses four administrative regions: Cimahi City, Bandung City, Bandung Regency, and West Bandung Regency. Geographically, KBU is situated in the northern part of Greater Bandung, with an average elevation of 750 meters above sea level. It is bounded by Mount Burangrang in the west, Mount Tangkuban Perahu in the center, and Mount Manglayang in the east.

Various tools and materials were employed to support the analysis of land use and green open space changes in KBU. QGIS software was used for spatial data analysis, particularly for processing and visualizing land cover changes using Geographic Information Systems (GIS). Microsoft Office facilitated data processing, documentation, and report preparation. Multi-temporal satellite imagery from Landsat 4, 5, 7, 8, and 9 was the primary data source for analyzing land cover changes, specifically to detect built-up land expansion and GOS changes from 1990 to 2023.

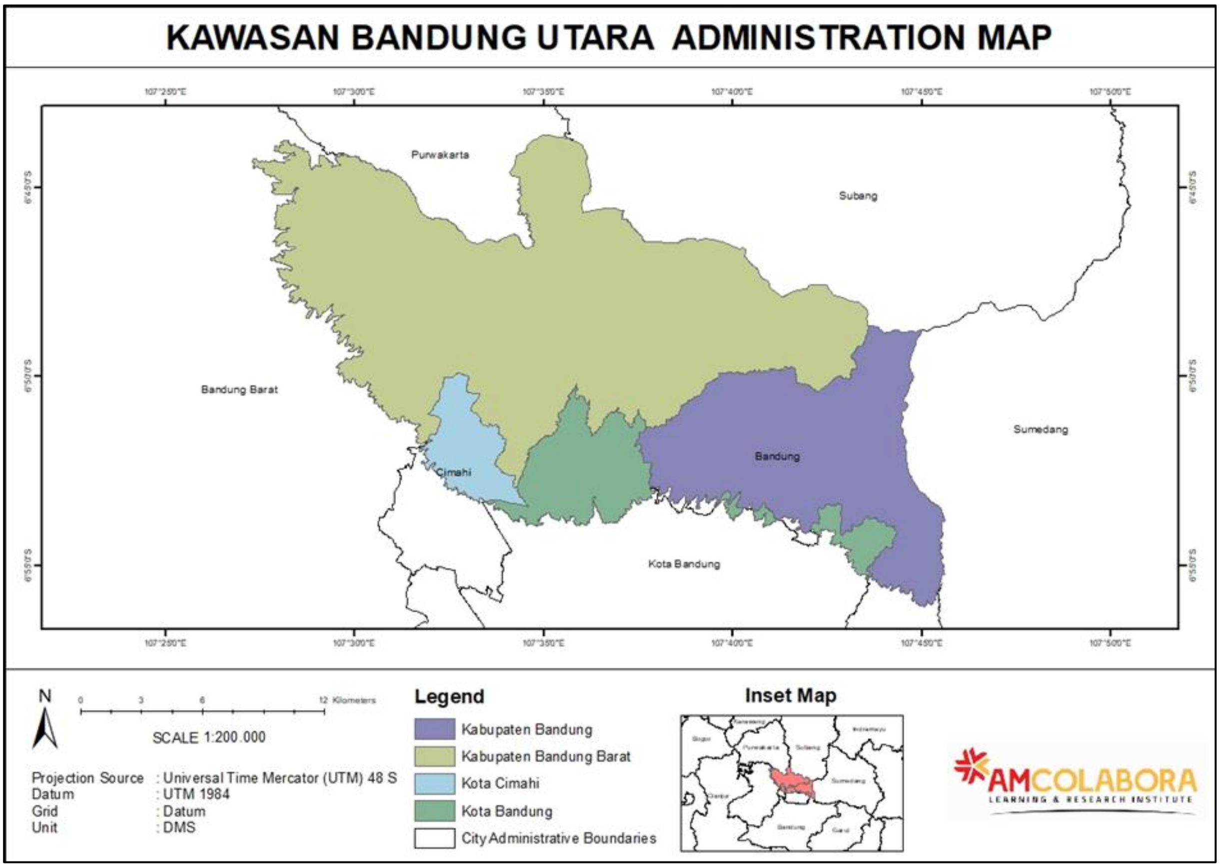

Figure 1. Administrative Boundaries Kawasan Bandung Utara

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2.2 Normalized Difference Built-Up Index (NDBI)

This study utilized the Normalized Difference Built-Up Index (NDBI) to detect and map built-up land. NDBI is based on the comparison of reflectance values in the near-infrared (NIR) and shortwave infrared (SWIR) bands, which are highly sensitive to man-made materials, such as built-up land. Landsat imagery with appropriate spatial resolution was the primary data source. Using NDBI calculations, built-up land distribution maps were generated and analyzed spatially and temporally.

The NDBI formula is as follows:

$$NDBI = (SWIR - NIR) / (SWIR + NIR) \quad (1)$$

Where:

SWIR = Shortwave Infrared Reflectance

NIR = Near-Infrared Reflectance

2.3 Normalized Difference Vegetation Index (NDVI)

This study employed the Normalized Difference Vegetation Index (NDVI) to detect green open spaces (GOS). Landsat satellite imagery with a spatial resolution of 30 meters was utilized for the analysis.

The NDVI formula is as follows:

$$NDVI = (NIR - RED) / (NIR + RED) \quad (2)$$

Where:

NIR = Reflectance in the Near-Infrared band

RED = Reflectance in the Red band

2.4 Data Analysis

The analysis employed a quantitative approach to examine the impact of changes in built-up land area on GOS area (Li & Zhou, 2019; Setiawan, 2020). Simple linear regression was used, where the dependent variable was GOS area, and the independent variable was built-up land area. The study utilized secondary data comprising built-up land and GOS areas over specific time periods (Ridwan et al., 2018). The regression coefficients indicated the direction and strength of the relationship between built-up land expansion and GOS reduction.

2.5 Field Accuracy Testing

To evaluate the accuracy of satellite-based classification of built-up land and GOS, field accuracy tests were conducted (Congalton & Green, 2009; Foody, 2002). Sampling points representing all land cover classes were randomly selected, with the number of samples adjusted to the study area's size and land cover diversity (Stehman, 1997). Each sample point was verified on-site to identify the actual land cover type. The field data were then compared with the classification results using a confusion matrix to calculate overall accuracy, producer's accuracy, and user's accuracy (Olofsson et al., 2014).

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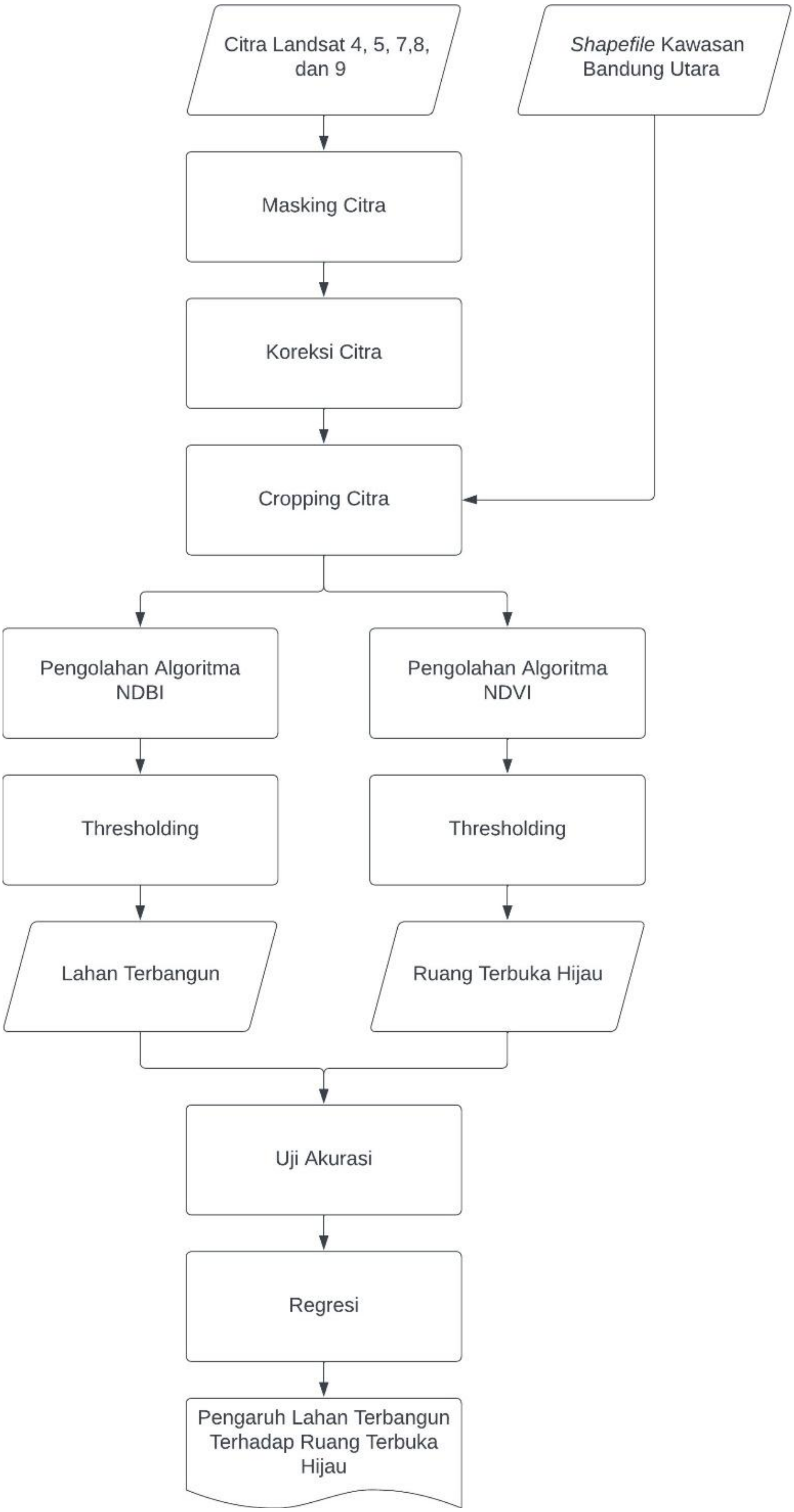

Figure 2. Research Flowchart

DOI: http://dx.doi.org/10.xxxxx/ijost.vXiX
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3. RESULTS AND DISCUSSION

Several studies have analyzed the relationship between the increase in built-up area and the decrease in green open space (RTH) using regression analysis and field accuracy tests. Research by Zhang et al. (2020) analyzed the change of built-up land in urbanized areas in China using a linear regression approach. The results of this study show that the increase in built-up land has a significant impact on the decrease in green spaces, which has an impact on the balance of urban ecosystems and is the most visible indicator of environmental degradation in urban areas.

Another study by Rahman et al. (2021) used multi-temporal analysis of Landsat satellite images to identify land cover change patterns in Dhaka, Bangladesh. The study integrated spatial regression techniques with field accuracy tests to validate the land cover classification. The results show that the increase in built-up land has a strong negative correlation with the area of green space, which has gradually decreased over the past two decades, with field validation methods strengthening the accuracy of spatial classification results.

Research by Almutairi et al. (2022) used regression analysis to evaluate the effect of built-up land increase on urban ecosystem variables in Riyadh, Saudi Arabia. Almutairi et al. confirmed that urbanization resulted in a decrease in the area of green spaces, which had an impact on air quality and microtemperature.

3.1. Built-Up Land in Kawasan Bandung Utara

The data on changes in built-up land area in Kawasan Bandung Utara (KBU) show significant increases from 1990 to 2023. In 1990, the built-up area was recorded at 2,555.55 hectares, which grew to 13,063.56 hectares by 2023. This represents a substantial change in land use driven by rapid urbanization and economic activity growth in the region.

Table 1. Built-Up Land Area, 1990–2023

Year	Built-Up Land Area (ha)
1990	2.555,55
1995	3.524,33
2000	6.507,45
2005	7.191,45
2010	7.764,99
2015	12.257,45
2023	13.063,56

During the 33-year period, the two most significant increases occurred between 1995–2000 and 2010–2015. From 1995 to 2000, built-up land expanded by 2,983.12 hectares (84.67%), reflecting early urbanization spurred by new residential developments and supporting infrastructure. Similarly, from 2010 to 2015, built-up land increased by 4,492.46 hectares (57.84%), indicating large-scale infrastructure projects and urban expansion in the KBU conservation area. Conversely, the growth rate was slower between 2005–2010 (573.54 hectares, 7.98%) and 2015–2023 (806.11 hectares, 6.58%), suggesting partial implementation of development control measures.

DOI: http://dx.doi.org/10.xxxxx/ijost.vXiX
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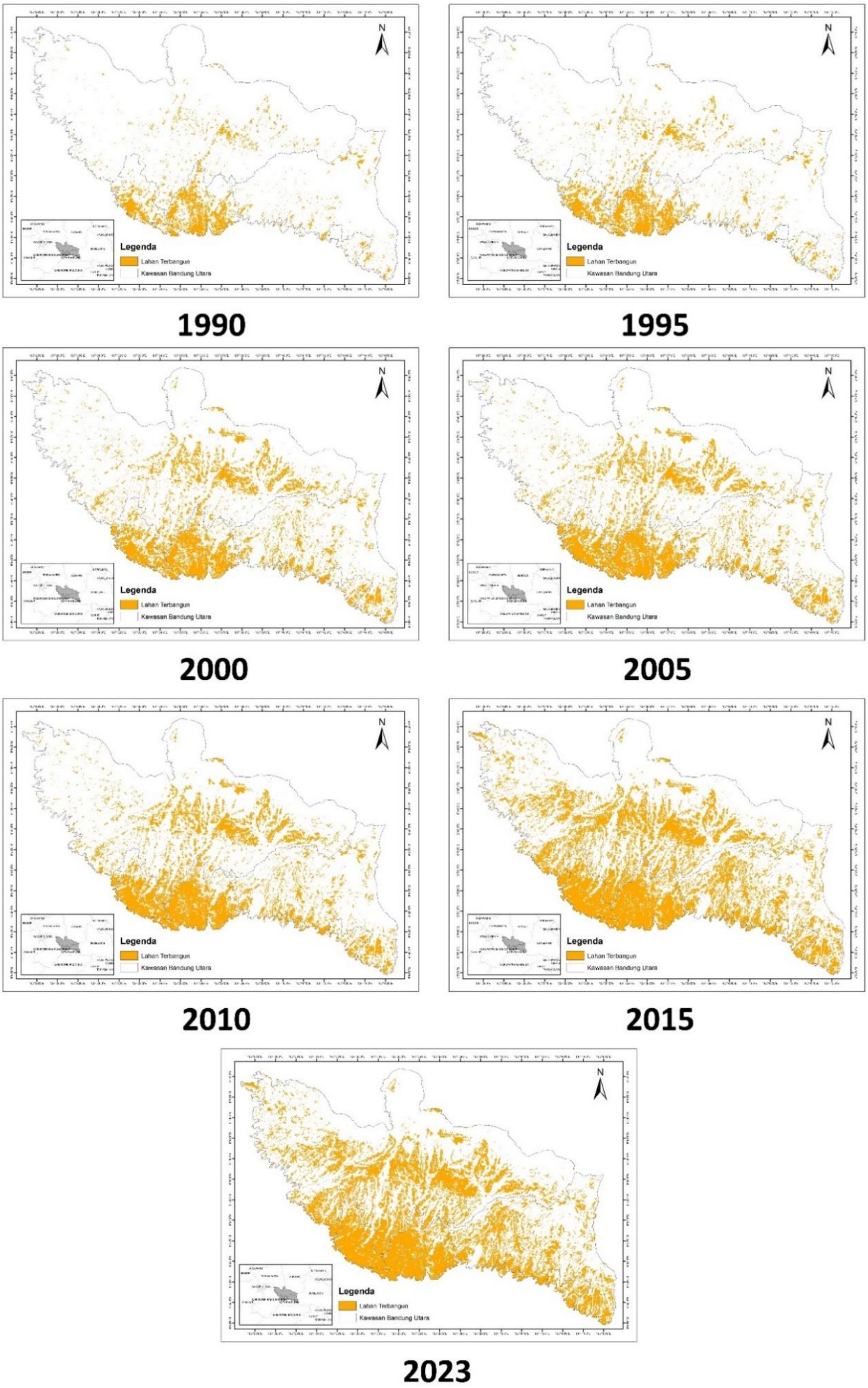

Figure 3. Built-Up Land Map of Kawasan Bandung Utara

DOI: http://dx.doi.org/10.xxxxx/ijost.vXiX
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The map illustrates the spatial distribution of built-up land in KBU from 1990 to 2023. The expansion is predominantly concentrated in the southern and central parts of KBU, near urban centers such as Bandung City. The rapid growth of built-up land reflects increasing urbanization pressure near urban cores.

3.2. Green Open Space in Kawasan Bandung Utara

The availability of Green Open Space (GOS) in KBU has significantly declined due to urbanization and built-up land expansion. As a strategic area with critical water and soil conservation functions, the presence of GOS in KBU is essential to maintaining ecosystem balance and preventing environmental degradation. The findings reveal that built-up areas for residential, commercial, and infrastructure purposes have replaced previously green areas.

Table 2. Green Open Space Area, 1990–2023

Year	GOS Area (ha)
1990	35.607,97
1995	34.639,19
2000	31.656,07
2005	30.972,07
2010	30.398,53
2015	25.906,07
2023	25.099,96

Over the 33-year period, GOS in KBU decreased from 35,607.97 hectares in 1990 to 25,099.96 hectares in 2023. The sharpest decline occurred between 2010 and 2015, with a loss of 4,492 hectares, highlighting accelerated land conversion for residential and infrastructure development. Meanwhile, periods such as 1990–1995 and 2005–2010 saw relatively slower declines (968.78 hectares and 573.54 hectares, respectively), indicating fluctuating urbanization pressures over time.

The map illustrates the distribution of GOS in KBU from 1990 to 2023. Initially, GOS dominated the region, reflecting its role as a conservation and water catchment area. Over time, however, GOS areas became increasingly fragmented and reduced, particularly near urbanized zones and infrastructure corridors.

3.3. Regression Analysis

A simple linear regression analysis was conducted to evaluate the impact of built-up land expansion on GOS reduction in KBU. The results revealed a significant and negative correlation between these variables.

Table 3. Regression Statistics

Regression Statistics	
Multiple R	0,922174883
R Square	0,850406516
Adjusted R Square	0,820487819
Standard Error	2495,425363
Observations	7

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p- ISSN xxxx-xxxx e- ISSN xxxx-xxxx

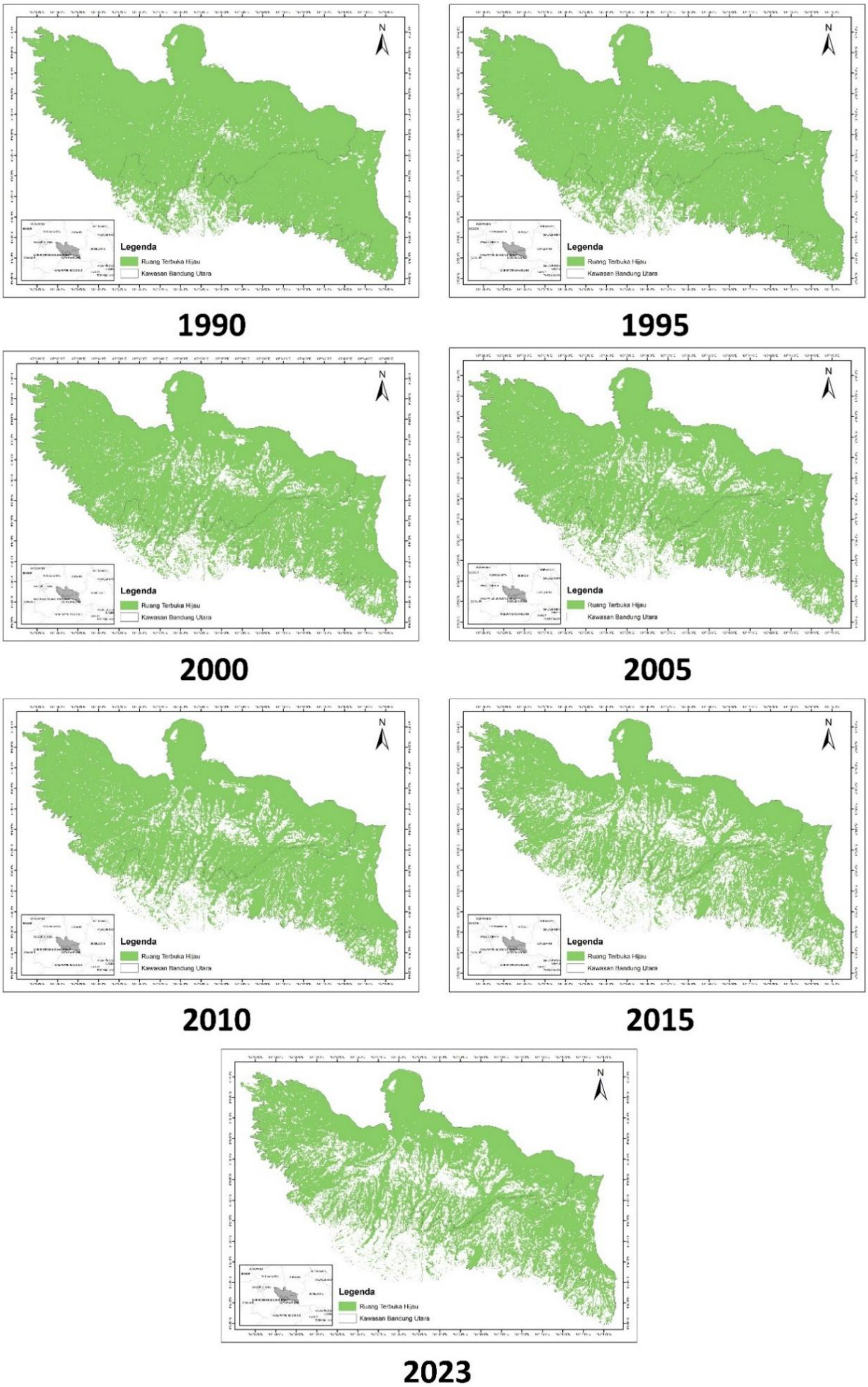

Figure 4. Green Open Space Map of Kawasan Bandung Utara

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p- ISSN xxxx-xxxx e- ISSN xxxx-xxxx

The correlation coefficient (R) of -0.922 indicates a strong negative relationship, implying that increases in built-up land are significantly associated with GOS reductions. The high R Square value (0.850) suggests that 85% of the variance in GOS area can be explained by changes in built-up land.

3.4. Field Accuracy Testing

To validate the classification results, a field accuracy test was conducted using a confusion matrix.

Table 4. Confusion Matrix

		Field Survey			**User Accuracy**
Interpretation Results	Classification	Built-Up Land	Green Open Space	Total	
	Built-Up Land	59	16	75	78,67
	Green Open Space	11	64	75	85,33
	Total	70	80	150	
	Producer's Accuracy	84,29	80,00		
	Overall Accuracy		82,00		

The overall accuracy was 82.00%, demonstrating reliable classification results, although some misclassifications occurred. For example, 16 pixels of built-up land were misclassified as GOS, and 11 pixels of GOS were misclassified as built-up land. These results highlight the need for more advanced classification methods to improve accuracy.

4. CONCLUSION

The findings underscore the critical impact of urbanization on GOS reduction in KBU. The period of rapid built-up land expansion coincides with significant GOS losses, highlighting the need for stricter enforcement of conservation policies. Without sustainable spatial planning and development control, the ecological functions of KBU are at risk, including water absorption, biodiversity preservation, and carbon sequestration. Collaborative efforts among policymakers, academics, and the community are essential to mitigate these environmental impacts and ensure the sustainability of KBU.

5. ACKNOWLEDGMENT

The authors extend their gratitude to the West Java Regional Development Planning Agency (BAPPEDA Jawa Barat) for providing access to data and relevant policy documents related to the North Bandung Area (KBU). We also thank the research teams from Amcolabora Institute and Geo Impact for their invaluable technical support during field data collection and spatial analysis.

Special thanks go to our colleagues and experts who provided insights and feedback that greatly enriched this research. This study was made possible through the collaborative efforts of government institutions, academic researchers, and local communities, whose shared commitment to environmental sustainability has been truly inspiring.

DOI: http://dx.doi.org/10.xxxxx/ijost.vXiX
p- ISSN xxxx-xxxx e- ISSN xxxx-xxxx

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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DOI: http://dx.doi.org/10.xxxxx/ijost.vXiX
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