

THE IMPACT OF URBAN SPRAWL ON SOCIOECONOMIC DYNAMICS: A COMPREHENSIVE APPROACH UTILIZING REMOTE SENSING AND GIS TOOLS

Dewayany Sutrisno*¹, Hari Prayogi² and Prabu Kresna Putra³

^{1,2,3} National Research and Innovation Agency

Jalan Raya Jakarta Bogor KM 46 Cibinong 16911

Email: dewayany@brin.go.id, hari038@brin.go.id, prab003@brin.go.id

⁴Technique Faculty, Pakuan University

Jl. Pakuan, Tegallega, Bogor 16143

Email: jantthyhidayat@unpak.ac.id

KEYWORDS: urban sprawl, socioeconomic impact, remote sensing, GIS

ABSTRACT: Urban sprawl, characterized by the rapid and unplanned expansion of urban areas, has become a significant global phenomenon that influences various aspects of society and the economy. This study aims to examine the spatial extent and patterns of urban sprawl in a specific region in Banten instead of Jakarta, such as Tangerang City and South Tangerang city, which are satellite cities of Jakarta. Multidate med-resolution satellite, nighttime light images, and ancillary data were used to identify urban expansion by using a change detection method and socioeconomic analysis using statistical data shedding light on both positive and negative consequences of such growth. The findings of this study are expected to provide an understanding of the relationship between urban sprawl and its consequences, which can guide the formulation of sustainable urban development strategies and ensure a more equitable and resilient future for urban dwellers.

1. INTRODUCTION

1.1 Background

Urban sprawl, characterized by the uncontrolled expansion of housing, commercial infrastructure, and transportation networks across extensive tracts of land in urban regions, often without due consideration for urban planning (Fouberg, 2012), has become a significant global phenomenon that influences various aspects of society and the economy. This condition can occur in peri-urban areas adjacent to the center of economics and services, such as Jakarta, the capital city of Indonesia. In accordance with population growth and the increasing difficulties and expenses associated with land in metropolitan regions, peri-urban areas undergo a transformation from rural settings into emerging urban environments. These areas may also evolve into new economic hubs, which is sometimes referred to as urban sprawl.

Jakarta's expansion can be observed in the proliferation of numerous satellite cities in the adjacent provinces of Banten and West Java. Hence, the primary objective of this study is to examine urban development trends in the immediate vicinity of Jakarta, specifically Tangerang and South Tangerang cities in the province of Banten. Additionally, it seeks to analyze the various direct and indirect consequences of urban development in these areas, particularly in relation to infrastructure and socioeconomic development. This study utilized medium-resolution satellite images to conduct change detection analysis and other spatial and ancillary data, allowing for a comprehensive examination of the progression of this urban phenomenon during a specified timeframe.

1.2 Study Area

Tangerang and South Tangerang cities are located in the province of Banten, which is geographically adjacent to Jakarta Province on its eastern side and Tangerang Regency on its western side (see Figure 1).

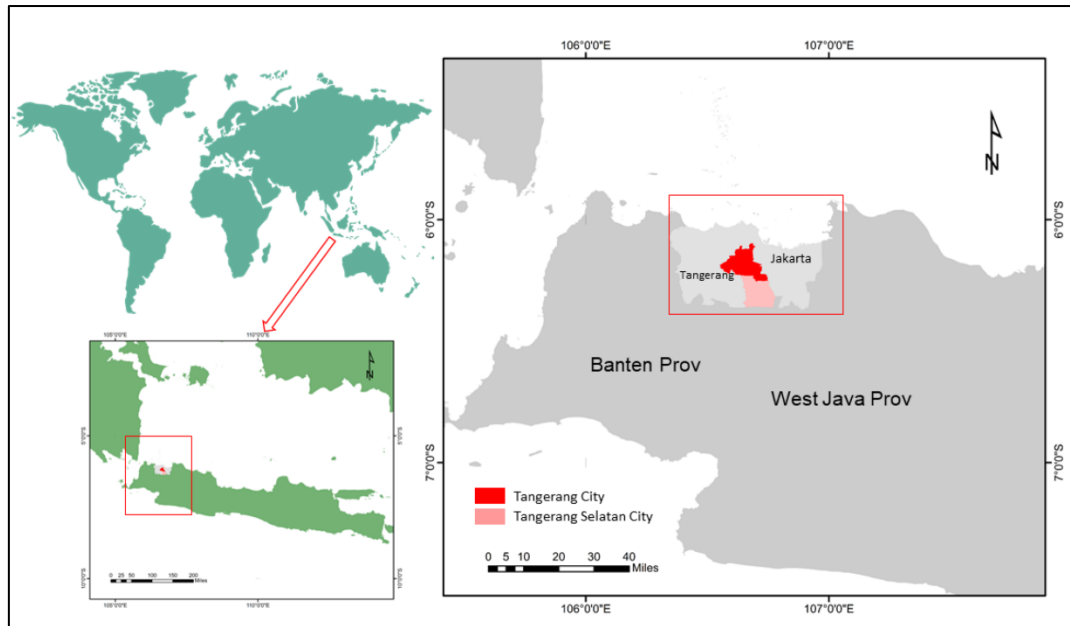


Figure 1. Study area, Tangerang and South Tangerang cities. Both of the cities, including the cities of Bogor, Depok and Bekasi area are included in a particular metropolitan area called "Jabodetabek".

The city of Tangerang, Banten, Indonesia, attained formal city status on February 28, 1993, following the issuance of Indonesian governmental decree No. 2/1993. Preceding this, the area in question functioned as a sub-region inside the administrative boundaries of the Tangerang Regency. Tangerang City is situated in a lowland area. The northern part of Tangerang City has an average elevation of 10 m above sea level, whereas the southern part has an elevation of 30 m above sea level. Tangerang City is intersected by the Cisadane River, which is recognized as one of the most significant rivers in Western Java. The river in question holds significant importance for the identity of Tangerang City. The headwaters of this river are located on Mount Salak and Mount Pangrango, Bogor, West Java. In 1995, when Tangerang City was still a district in Tangerang Regency, Soekarno-Hatta International Airport was officially launched in this area. Furthermore, a toll road was constructed to provide exclusive access to the airport. Subsequently, this toll road was expanded to facilitate connectivity between Java and Sumatra, ultimately reaching Merak Port.

South Tangerang City (Tangsel), located in Banten, Indonesia, attained official city status on November 26, 2008, following the issuance of Decree No. 51/2008 by the Indonesian government. Previously, it was part of the Tangerang Regency. The majority of the South Tangerang City region consists of low-lying areas characterized by a generally flat topography, featuring an average land slope of 0-3%. The elevation within this area varies between 0 and 25 m above the sea level. Similar to the city of Tangerang, this city is crossed by the Cisadane River, Angke River, and Pesanggrahan River, serving as the administrative boundaries of the city to the west. When South Tangerang City was a district in Tangerang Regency, Bumi Serpong Damai (BSD) development took place in 1984. The primary objective of this city was to establish a meticulously designed and self-sufficient urban center equipped with comprehensive amenities and infrastructure. Subsequently, BSD underwent substantial expansion and emerged as a prominent urban center within the Jabodetabek region. This growth has propelled BSD to become one of the largest metropolitan centers in the aforementioned region, a trend that persists to the present day.

2. Method

2.1 Data

To observe the city's development, this study utilized Landsat 5 MSS imagery acquired on July 31st 1998, Landsat Oli 8 imagery acquired on May 11th 2021, Landsat Oli 8 imagery acquired on July 28th 2023; and nighttime light imagery SVDNB-npp acquired on August 31st 2023. Other Ancillary data are Rupabumi (topographic) maps of Indonesian administrative boundaries, and statistical data from the Central Statistics Agency of the Republic of Indonesia (Statistic Indonesia a,b, 2023), encompassing several aspects, such as population statistics, transportation infrastructure details, and the Gross Regional Domestic Product (GRDP).

2.2 Urban change analysis

The analysis of urban development employs the Urban Built-Up Index (UBI) and image differencing method, allowing for the identification of patterns in a city's growth, particularly in relation to the development of existing economic centers. The analysis process can be summarized as follows:

$$UBI = \frac{SWIR+RED}{2*NIR} \quad (1)$$

$$Im_{def} = UBI_{2021} - UBI_{1998} \quad (2)$$

Where UBI is the urban built-up index, SWIR = shortwave infrared band, RED= red band, NIR= near-infrared band

Both images have previously been radiometrically corrected using the FLAASH method and have also undergone atmospheric correction.

Furthermore, the patterns and trends of urban development can be studied from the analysis results of the Urban Built-up Index (UBI), nighttime light index from the SVDNB-npp imagery recorded in 2023, and random forest machine learning algorithm on the GEE platform. The two remaining methods are employed to examine the urban development of the metropolis by utilizing nighttime light and land cover classification, both in the 2023 imageries as inputs, to demonstrate the existing conditions of the cities.

For the random forest machine learning algorithm, the input consisted of one to seven canals or bands from Landsat 8 OLI 2023, which had undergone pan sharpening, and then analyzed using three indices, namely NDVI, NDBI, and NDWI (Lillesand et al. 2004; Ashok et al. 2021). The formula as follow;

$$NDVI = \frac{B_{red} - B_{NIR}}{B_{red} + B_{NIR}} \quad (3)$$

$$NDBI = \frac{B_{SWIR} - B_{NIR}}{B_{SWIR} + B_{NIR}} \quad (4)$$

$$NDWI = \frac{B_{NIR} - B_{SWIR}}{B_{NIR} + B_{SWIR}} \quad (5)$$

The NDVI, NDBI, and NDWI were subjected to pixel rescaling at a resolution of 30 m. The acquired bands and indices were utilized as inputs for land cover classification by employing the random forest machine learning procedure.

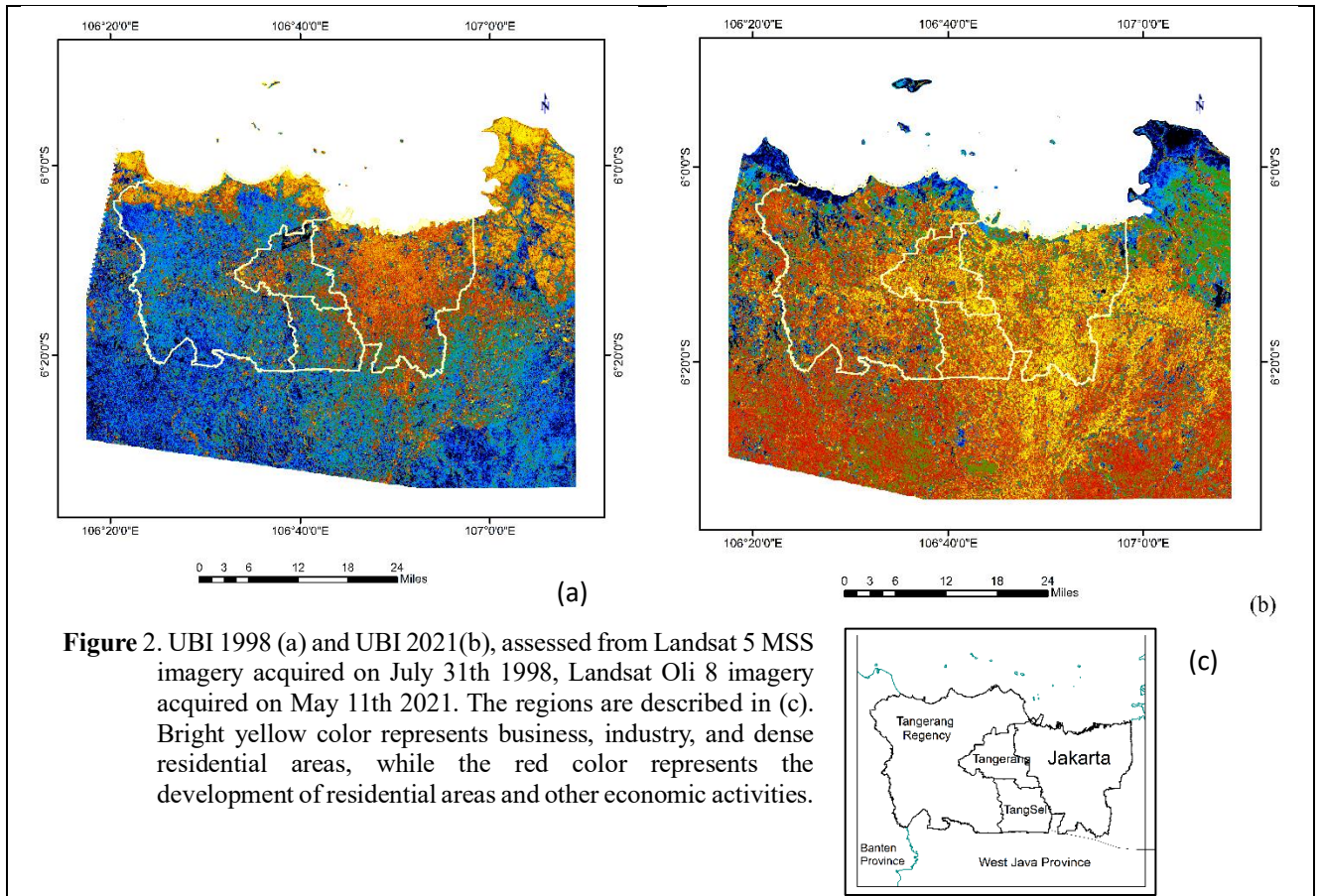
2.3 Social Economic Analysis

A comprehensive analysis of urban growth involves the utilization of statistical data, consisting of population, road infrastructure, and Gross Regional Domestic Product (GRDP). This analysis adopted a qualitative descriptive approach based on the statistical data acquired. Additionally, the utilization of statistical data analysis can be correlated with the projection of urban growth by leveraging the outcomes derived from remote sensing data.

3. RESULT AND DISCUSSION

3.1 Urban Development

The results of the UBI analysis for 1998 and 2021 are shown in Figure 2, while the changes are shown in Figure 3.



A comparison of the results of the UBI analysis in 1998 and 2021 clearly shows significant development in both Tangerang and South Tangerang (Tangsel) cities. Economic and business activities have rapidly grown in these two satellite cities. This change can be clearly seen in Figure 3, which demonstrates the transformation of the urban landscape from 1998 to 2021. Figure 3 illustrates the results of image differencing (1998 and 2021), revealing exclusively the areas that have undergone changes. Observable transformations can be discerned, such as the change from non-residential to residential/business centers or the conversion of residential areas into commercial centers.

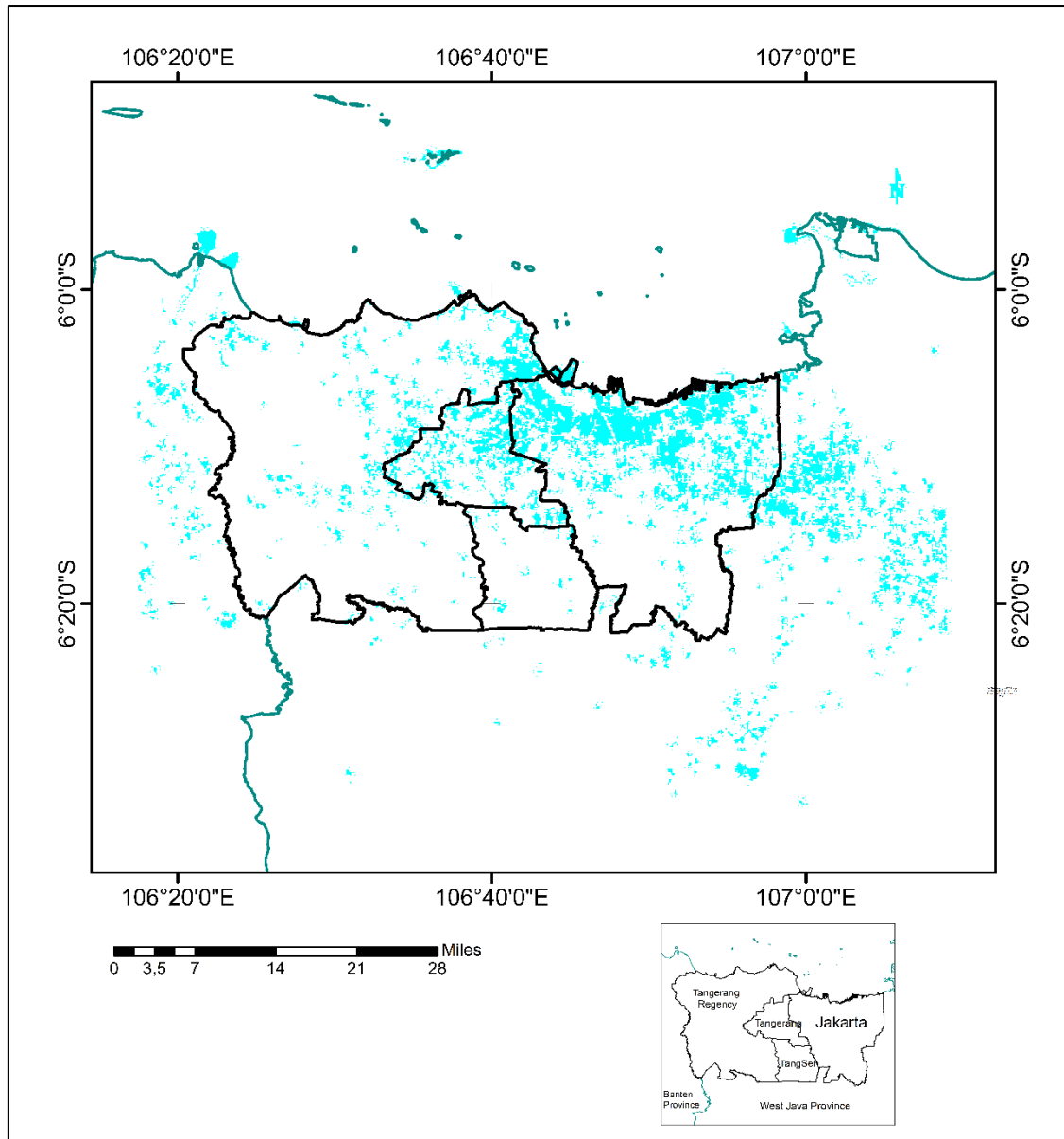


Figure 3. Change detection of urban area from 1998 to 2021, showing the changes area of Tangerang, South Tangerang cities and their expansion to Tangerang Regency.

The analysis in Figure 3 also reveals substantial urban growth in Tangerang, indicating a development trend beyond its administrative boundaries. The urban expansion of Tangerang City tended to expand in the direction of the adjacent Tangerang Regency. Meanwhile, South Tangerang City (Tangsel), a relatively new urban area, demonstrates a propensity towards internal development. The development trends of both cities can also be observed in Figure 4, which is based on the nighttime lights. As mentioned earlier, the development of BSD within South Tangerang City is still ongoing, with significant emphasis on maintaining a large green area. Therefore, the transformation into a commercial area may seem to have not changed much.

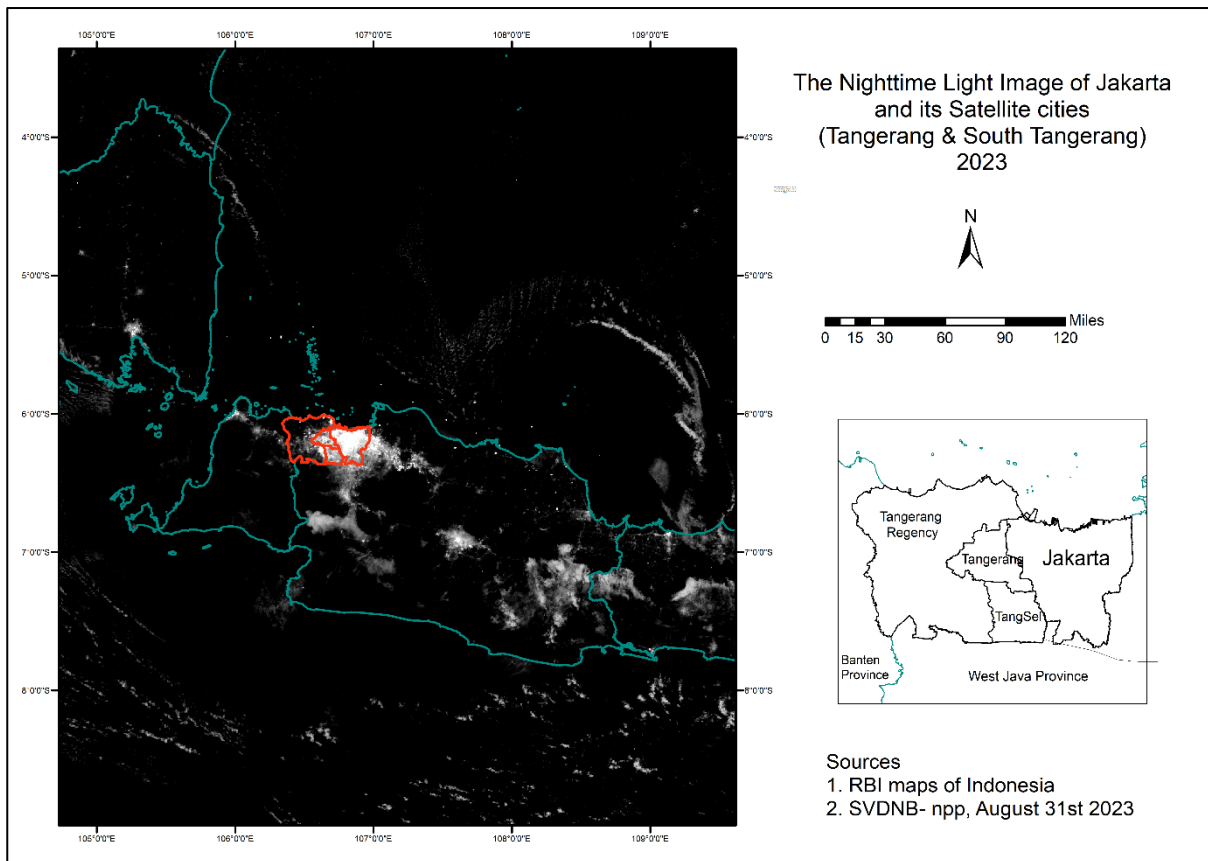


Figure 4. Nighttime light of the Banten, Java and Jakarta Provinces, focus in Jakarta, Tangerang and South Tangerang cities, showing the existing condition of urban areas of the two studied cities which tend to expand to the vicinity of Tangerang Regency

According to the analysis of nighttime light imagery, which utilizes nighttime light data acquired on August 31st, 2023, it can be observed that the expansion of both satellite urban areas exhibits a tendency to progress towards the Tangerang Regency. The rapid development of Tangerang is undeniably related to the central government's infrastructure development. The presence of Sukarno-Hatta International Airport and all associated infrastructure as access points to the airport in this area has stimulated the growth of industries, commercials, and residential areas in its vicinity. This economic influx has an impact on population growth, leading to a need for land for housing and various activities.

Existing land cover conditions in the study area were classified into three classes: vegetation, built-up areas, and water bodies (Figure 5). These features indicate a noticeable pattern of urban growth that is gradually extending from Tangerang and South Tangerang cities towards the Tangerang Regency. Examination of the Urban Built-up Index (Figure 3) enables the identification of changes in multiple information images, particularly in residential and commercial areas. Nevertheless, it may not offer detailed insights into the various categories of change, as illustrated in the Land Cover data (Figure 5). However, the utilization of nighttime light data (Figure 4) and UBI (Figure 3) can aid in differentiating between commercial and non-commercial regions by assessing the level of illumination and indices. To gain a more comprehensive understanding of the changes previously examined in Figure 3, it would be beneficial to acquire more precise data in the future. This contributes to a more refined assessment of the current state of these changes.

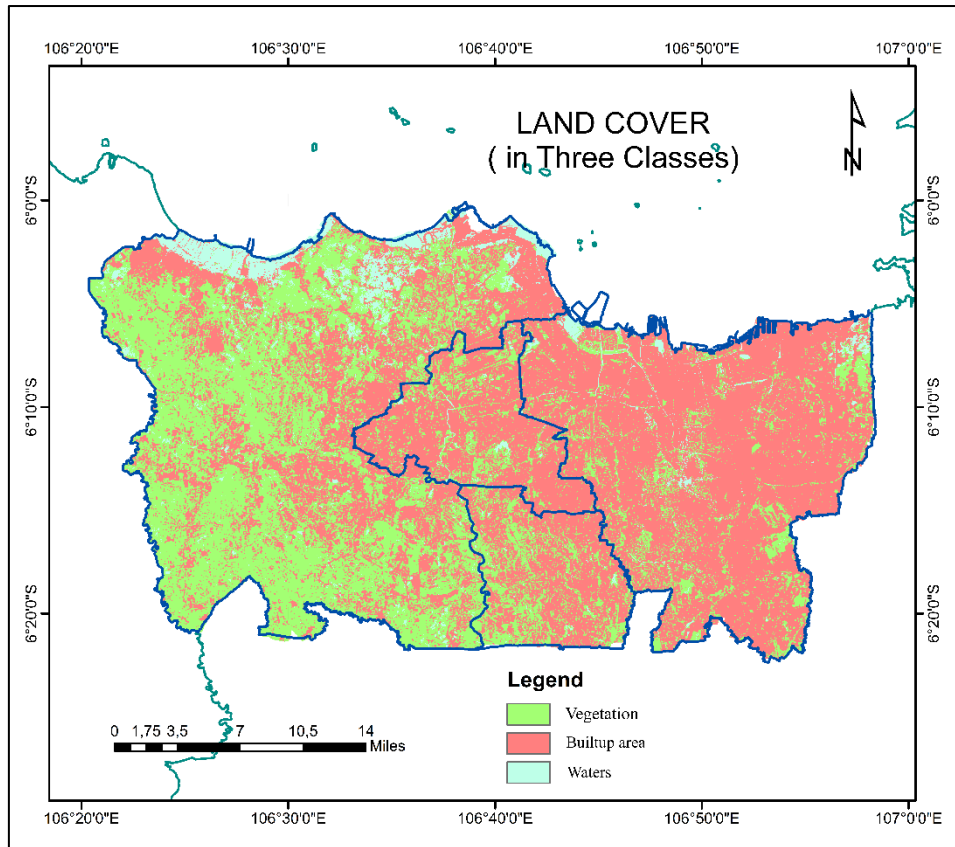


Figure 5. Land cover of study area in three classes, showing the existing condition of the city's expansion of Tangerang and south Tangerang into Tangerang regency

3.2 Social Economic Development

Figures 6, 7, and 8 present statistical data pertaining to growing populations, road development, and economic growth as measured by Gross Regional Domestic Product (GDP) (Statistic Indonesia a,b, 2023). In both cities, there was relatively modest population growth in 2022. The exact reason for the decline in population growth in 2020 cannot be definitively determined, but it may be related to the pandemic or other factors. Regarding road development, it appears that there will continue to be road development in Tangerang City until 2022, while there will be no road development in South Tangerang City during the same period. As for the impact of the pandemic on economic activity, it is evident that it led to a decrease in Gross Regional Domestic Product (PDRB) in 2020. The economic situation began to improve after the pandemic subsided. This is a common pattern seen in many regions worldwide, where the pandemic disrupted economic activities, and recovery took some time.

The development of roads and vital infrastructure, such as ports and airports, is key to the growth of a city (Prayogi et al. 2023; Pratama et al. 2021). In the case of Tangerang and South Tangerang cities, the presence of the Sukarno Hatta International Airport and the development of toll roads connecting Jakarta to the capital of Banten Province have spurred economic and residential development in the surrounding areas. In the Tangerang City area, the central government continues to build national roads totaling 18,401 km in 2022, most likely to facilitate access to Sukarno Hatta International Airport and the Jakarta-Merak toll road that passes through this region. The provincial and city governments of Tangerang have continued to develop provincial and city roads connected to national roads. This situation has had an impact on socioeconomic growth, as reflected in the Gross Regional Domestic Product (PDRB) of Tangerang City. However, this economic growth experienced a correction in 2020-2021 due to the pandemic. The gap in Gross Regional Domestic Product (GRDP) between Tangerang City and South Tangerang City can be attributed to the impact of these both vital infrastructures, as depicted in Figures 7.

The rise in economic activity in Tangerang City has resulted in an increase in urban growth in Tangerang Regency. This phenomenon can be attributed to the rising need for land for both commercial and residential uses, as depicted in the UBI and nighttime light analysis (Figures 3 and 4). One of the factors contributing to the occurrence of urban sprawl in

nearby areas is relatively lower land prices in the nearby urban cities (Sinha, 2018), which may cause the expansion of the built-up area to Tangerang Regency,

Similar to Tangerang City, the economic landscape of South Tangerang City showed indications of recuperation in 2022 subsequent to the end of the pandemic (Figure 7). Nevertheless, the growth of the commercial sector is predominantly focused inside the city's administrative boundaries (see Figure 3), while the extension into Tangerang Regency is projected to commence by 2023 (see Figure 4, and 5). As stated before, the development of BSD inside South Tangerang City is among the cities newly planned by governments, but what sets it apart is the pricing segment it targets. This new city primarily caters to middle- and high-income individuals. Consequently, residents from the suburbs are compelled to relocate to areas around the new city that align with their economic status, leading to continued urban sprawl expansion around the new city (Rita, 2017)

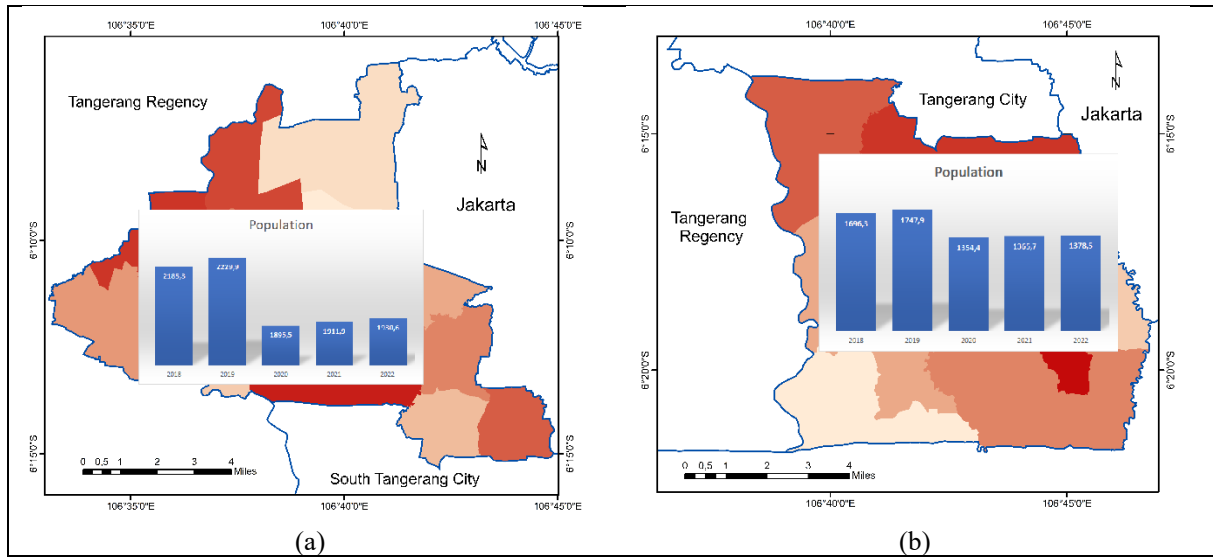


Figure 6. Statistic data of Population growth in Tangerang (a) and South Tangerang (b) cities, which illustrated the decrease during the pandemic and slight increase afterward

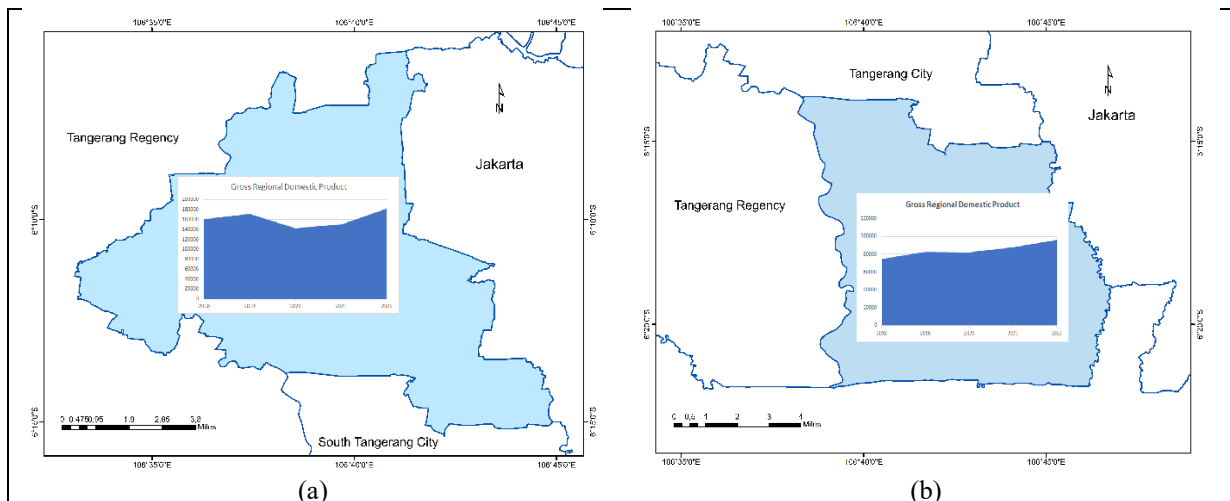


Figure 7. The Gross Regional domestic product of Tangerang (a) and South Tangerang (b) cities, which illustrated the decrease during the pandemic and gradually increase afterward

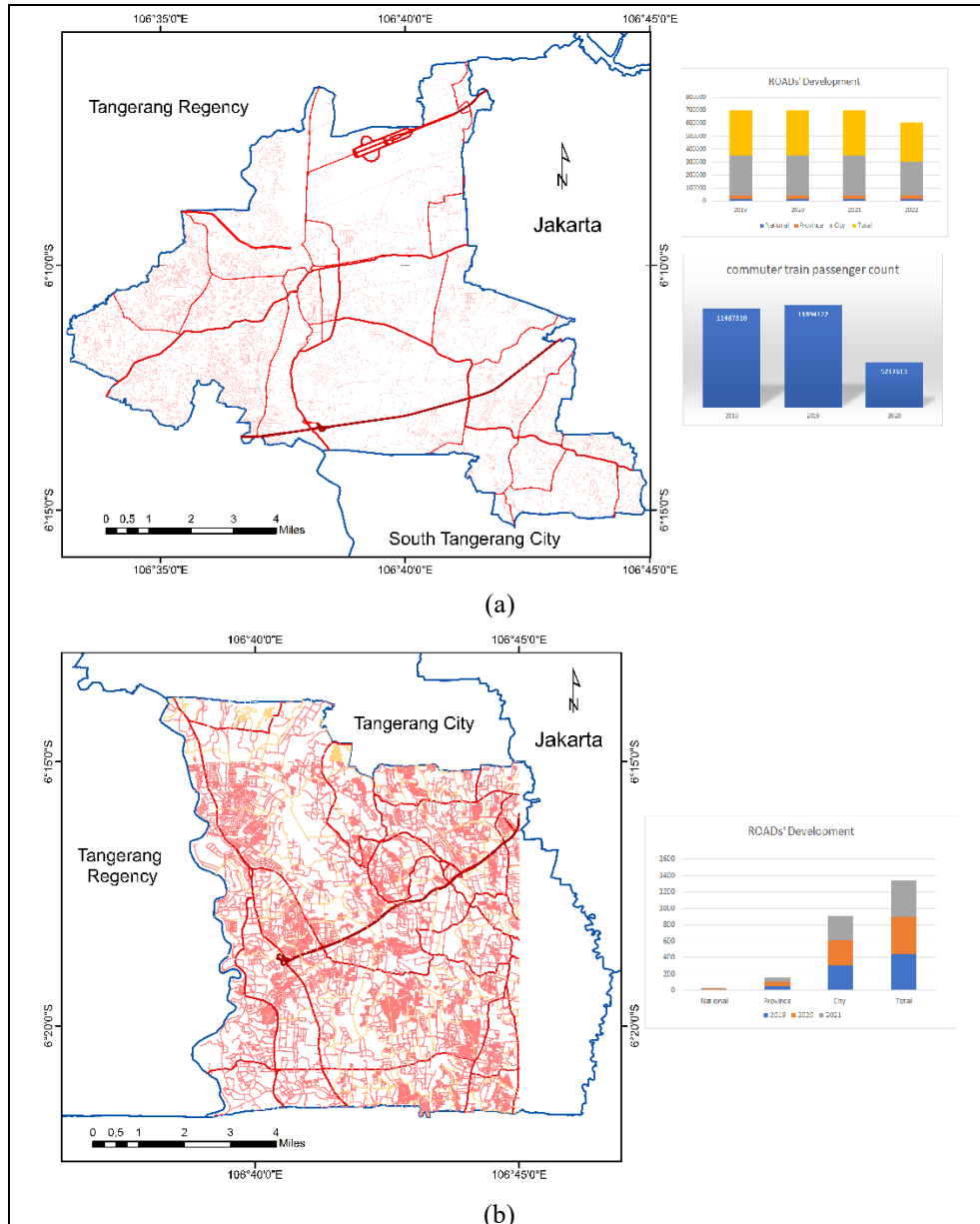


Figure 8. Road development in Tangerang (a) and South Tangerang (b) cities, which indicate the more develop in the Tangerang city and more stable in South Tangerang city

4. CONCLUSIONS

The utilization of medium-scale remote sensing data, specifically Landsat 8 OLI and Landsat 5, alongside Nighttime Light data derived from NPP multi-temporal nighttime light imagery, enables the classification, monitoring, and prediction of urban development trends. The simple urban built-up index (UBI) and image differencing methods can be used to analyze changes and patterns of urban sprawl. However, for a more convenient assessment of the type of urban development, whether it is evolving into commercial or residential areas, it can be visually determined through the brightness of nighttime light imagery or land cover classification. Nevertheless, the land cover classification used in this study does not focus on categorizing the type of urban development but rather on ensuring the patterns and trends of urban development using the most up-to-date imagery. In the future, the use of image classification and differencing is likely to assist in analyzing urban changes in greater detail.

Through the analysis of statistical data, it can also be observed that population growth, the development of public infrastructure and roads, and economic growth tend to increase with urban development and simultaneously serve as triggers for urban sprawl into surrounding areas. When statistical data and existing land use data are available, this information can be employed to assess the availability of land for both commercial and residential usage. This input is important for spatial monitoring and implementation because it facilitates the attainment of sustainable spatial planning through many inputs, such as urban development analysis. Hence, in-depth studies related to urban development projections based on remote sensing and other ancillary data are necessary in the future.

ACKNOWLEDGEMENT

We extend our gratitude to all the authors who have contributed to this writing. Dewayany Sutrisno and Hari Prayogi are the primary contributors to this article, while Prabu Kresna Putra and Janthy T. Hidayat are contributing members.

REFERENCES

- Ashok, A., H. P. Rani, and K. V. Jayakumar, 2021. *Monitoring of Dynamic Wetland Changes Using NDVI and NDWI Based Landsat Imagery*. Remote Sensing Applications: Society and Environment, 23, 100547. doi:10.1016/j.rsase.2021.100547
- Fouberg, E.H. 2012. Human geography: people, place, and culture. Murphy, Alexander B.; De Blij, Harm J. (10th ed.). Hoboken: Wiley. p. 560. ISBN 978-1118018699. OCLC 752286985
- Lillesand, T.M., R.W. Kiefer, and J.W. Chipman. 2004. Remote Sensing and Image Interpretation. 5th Edition, John Wiley & Sons Inc., New York.
- Prayogi, H., Setiadi, H., Supriatna, Dewayany. 2023. *Land cover change analysis in Majalengka Regency using the pan-sharpening method and random forest machine learning algorithm*. Jurnal Pendidikan Geografi:Kajian, Teori, dan Praktik dalam Bidang Pendidikan dan Ilmu Geografi, 28(2), 2023, 178-192. DOI: 10.17977/um017v28i22023p178-192
- Pratama, A.P., Yudhistira, M.H. and Koomen, E. 2021. *Highway expansion and urban sprawl in the Jakarta Metropolitan Area*. Land Use Policy, Vol 112: 105856. <https://doi.org/10.1016/j.landusepol.2021.105856>
- Rita, A.R.R. 2017. Pola Perkembangan Urban Sprawl Di Sekitar Kota Baru, Studi Kasus Bsd Tangerang Selatan. Thesis, magister teknik perencanaan Tarumanegara University.
- Sinha, S.K. 2018. Characteristics Of Urban Sprawl: A Cross-Cultural Analysis. Review Of Research, vol- 7 (11)
- Statistica Indonesia-a. 2023; Tangerang Municipality Figure 2023. BPS-Statistic Municipality of Tangerang
- Statistica Indonesia-b. 2023. South Tangerang Selatan Municipality Figure 2023. BPS-Statistic Municipality of South Tangerang