International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 07 | July 2024 www.irjet.net p-ISSN: 2395-0072

Application of the NDBI Method For Determining of Built-Up Land (A Case Study For Surabaya City, Indonesia)

Wayan Suparta[1,*], Hill Gendoet Hartono[2]

[1]*Department of Electrical Engineering, Institut Teknologi Nasional Yogyakarta, Jalan Babarsari, Caturtunggal, Depok, Sleman, Yogyakarta 55281, Indonesia*
[2]*Study Program of Magister of Geological Engineering, Institut Teknologi Nasional Yogyakarta, Jalan Babarsari, Caturtunggal, Depok, Sleman, Yogyakarta 55281, Indonesia*

Abstract - To determine the built-up areas within a region or city for land use planning, map interpretation is one of the effective techniques. This paper utilizes the Normalized Difference Built-Up Index (NDBI) method for built-up city in Surabaya, Indonesia as a case study. Analyzing NDBI parameters from Landsat optical data reveals that Surabaya City saw a 21% increase in built-up land from 2002 to 2022. These findings highlight significant urban development in the city during this period and offer valuable insights for future spatial planning and land use policy formulation.

Keywords: NDBI, Built up land, Urbanization, Surabaya City

1. INTRODUCTION

In terms of its potential utilization, physical environmental factors that influence land use include soil condition, climate, geological relief, topography, hydrology, and vegetation. Nearly every year, the population increases, leading to a rise in built-up land and a decrease in non-built-up land. According to Sajow et al. [1], built-up land includes residential areas, commercial goods and services, social facilities, and public facilities, while non-built-up land encompasses green open spaces (GOS) such as plantations and rice fields, and non-green open spaces (NGOS) such as open land and fields. Lillesand and Kiefer [2] define land use as related to human activities on a plot of land, whereas land cover is more about the physical manifestation of objects covering the land, regardless of human activities associated with those objects.

Urban land cover tends to change drastically within a short period due to urbanization. These changes are ideally monitored and detected using remote sensing imagery because such images are relatively current and provide thematic views. Remote sensing materials such as aerial photographs and satellite imagery are typically converted into useful information. To identify the built-up areas of a region or city, maps can be interpreted. Various image processing methods can be used to create maps of built-up land, such as Maximum Likelihood Classification (MLC), Normalized Difference Built-Up Index (NDBI), and others. This paper discusses the image processing method of NDBI. NDBI is one of the image processing methods aimed at identifying and analyzing built-up and non-built-up land in a region or city. The NDBI index highlights urban or built-up areas where there is usually higher reflectance in the Shortwave Infrared (SWIR) region compared to the Near-Infrared (NIR) region. SWIR is typically defined as light with a wavelength range of 0.9 – 1.7 μm [3].

The NDBI has advantages in identifying built-up areas because it utilizes the unique reflectance properties of building materials compared to vegetation and soil [3]. Using NDBI in land change analysis enables quicker and more efficient detection of urban expansion [4]. Combining NDBI with other indices like NDVI can improve the accuracy of land use classification [5]. Research shows that NDBI has a strong correlation with population density and economic activity in urban areas [6]. The NDBI method is highly effective in identifying changes in built-up land in tropical regions that frequently undergo rapid development [7] and it is also a low-cost but robust.

2. RESEARCH METHODS

2.1 Study Area

The study area for analyzing changes in built-up is in Surabaya City located in East Java of Indonesia, geographically located between 7°9′- 7°21′ South Latitude and 112° 36′ – 112° 54′ East Longitude. Surabaya was chosen as the study area due to its rapid infrastructure development linked to efforts to increase local revenue. According to the Central Statistics Agency (BPS), Surabaya is the second largest city in Indonesia after Jakarta, both in terms of area and population, with a population reaching 2,893,698 people. This density is driven by rapid urbanization, fast economic growth, and its role as a hub for trade and industry in East Java, Indonesia. Figure 1 shows the Surabaya City map with a free vector (https://www.vecteezy.com/free-vector/surabaya-map).

Fig. 1: The map of Surabaya City, East Java of Indonesia (courtesy by https://www.vecteezy.com)

Since Surabaya City serves as a critical hub for trade, industry, and economic growth, their geological characteristics significantly influence its rapid urbanization and economic development. Based on the Surabaya City Government [8] report, the coastal plain comprises alluvial deposits, which are fertile and support agricultural activities, contributing to the city's food supply and secondary economic activities. The Brantas River and its tributaries as well as Tanjung Perak Port play a crucial role in the city's water supply, irrigation, flood control, and supporting international trade. These river systems are vital for maintaining the urban ecosystem and supporting agricultural and industrial demands. The region benefits from volcanic ash deposits from nearby volcanoes, enhancing soil fertility, which supports intensive agriculture. This agricultural productivity underpins the city's economy by providing raw materials for food processing industries. The presence of various minerals in the surrounding areas supports industries such as construction and manufacturing.

Hence, it is interesting to visualize or map the built-up land of Surabaya City as a case study with data in 2002 and 2022 by utilizing the NDBI method. The population of Surabaya in 2002 was approximately 2,489,800, and by 2022 it had increased to 2,887,223, indicating a 15.96% increase over 20 years, or an annual growth rate of 0.23%. The rapid population growth presents a significant challenge in urban planning, aiming to increase productivity, maintain green, healthy, safe, and sustainable cities [9].

2.2 NDBI Calculation, Atmospheric Correction, and Processing

The NDBI is calculated using satellite imagery, typically from sensors like Landsat, Sentinel-2, or other multispectral satellites. These sensors capture data in various spectral bands, including the near-infrared (NIR) and shortwave infrared (SWIR). The NDBI is computed using the formula [4]:

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} \quad (1)$$

where SWIR is the reflectance in the shortwave infrared band and NIR is the reflectance in the near-infrared band. Built-up areas tend to have higher reflectance in the SWIR band compared to the NIR band, resulting in higher NDBI values. Note that the NDBI on this Landsat 8 image uses SWIR and NIR channels, merging band five and band 6.

The next step involves performing atmospheric correction using the relative atmospheric correction method [10]. Several atmospheric correction methods can be employed, such as Dark Object Subtraction (DOS), Covariance Matrix Method (CMM), Multi-Band Regression technique (MBR), and Radiometric Control Area method (RCA), depending on the pixel image issues encountered. The DOS method is commonly used, assuming that some atmospheric effects, such as scattering, can be removed by identifying the darkest pixels in an image and subtracting their values from all other pixels. In this atmospheric correction, pixel values are used as correction values due to atmospheric disturbances during image capture. The lowest pixel values in the visible and NIR regions approximate atmospheric path radiance. Equation (2) shows the algorithm used for atmospheric correction [11].

$$DOS_j = Mean_j - 2\,STD_j \quad (2)$$

where DOS_j is represented path radiance or the influence of atmospheric effects from dark target of *j*, $Mean_j$ is the mean reflectance value of the selected dark target pixels from band *j*, and STD_j is the standard deviation of the reflectance values of the selected dark target pixels from band *j* [12].

When the computation of NDBI is obtained, Figure 2 illustrates the process of using the NDBI for land use analysis with remote sensing data from LandSat, including steps such as data collection, image processing, and accuracy assessment [13]. The flowchart in Figure 2 depicts the process which begins with defining the study area and timeframe, followed by data collection and processing. The main steps involve image acquisition, corrections (radiometric, geometric, atmospheric), feature extraction, index calculation, and image classification. The focus is on detecting built-up land through thresholding and segmentation. Once the NDBI is obtained, accuracy assessment through validation and metrics is conducted.

The results are then visualized using maps, followed by analysis and interpretation, which include spatial and trend analysis. Finally, the process concludes with reporting and recommendations.

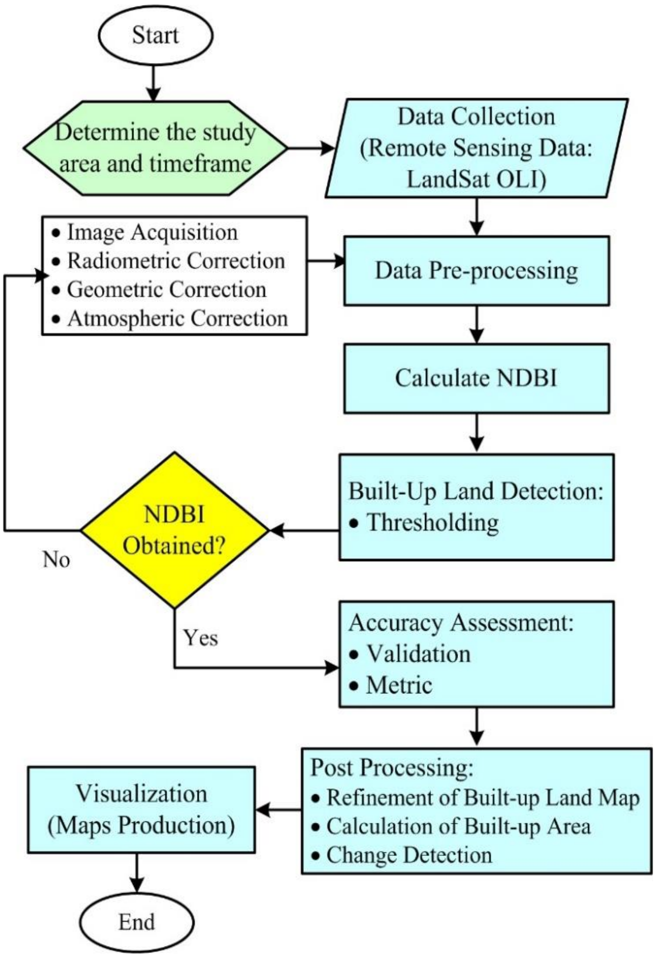

Fig. 2: The flowchart of how NDBI work in the research area

3. RESULTS AND DISCUSSION

3.1 NDBI Transformation

Figure 3 shows the NDBI transformation result in Surabaya City. The image clearly demonstrates the spatial distribution of built-up areas in Surabaya, with a concentration of urban development in the central region, namely the northern part of South Surabaya City and more scattered or less dense built-up areas towards the outskirts.

a). *Red Areas*: These indicate high NDBI values, suggesting dense built-up or urban areas. In this figure, the central part with the most intense red likely represents the city center or highly urbanized regions of Surabaya.

b). *Yellow/Orange Areas*: These areas have moderate NDBI values, indicating less dense or semi-urban built-up areas.

c). *Blue/Green Areas*: These regions have low or negative NDBI values, representing non-built-up areas such as vegetation, water bodies, or open land.

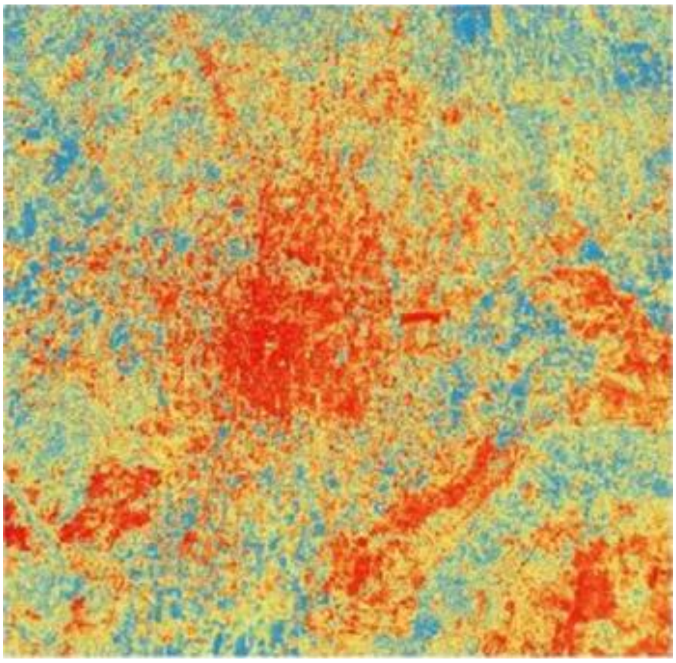

Fig. 3: NDBI transformation results

3.2 Built-Up and Non Built-Up Areas Analysis

Figure 4 shows the map represents the built-up and non-built-up areas of Surabaya City in 2002, with data projected using the UTM system and a geographic grid based on the WGS84 datum. The map uses color coding to distinguish between built-up areas (red) and non-built-up areas (gray). To perform a quantitative analysis, we need to measure the area covered by built-up and non-built-up regions and analyze their spatial distribution.

a). Built-Up Areas

- The total area of Surabaya City in 2002 is approximately 350.54 km^2.
- Built-up area coverage: According to the map, the built-up area (marked in red) appears to cover a significant portion of the city's total area. Based on GIS tools, the built-up areas cover approximately 56% of the city's total area, and then the built-up area is about 213.36 km^2.
- The built-up areas are predominantly concentrated in the central and northern parts of Surabaya. This distribution indicates a high level of urbanization in

these regions, likely corresponding to the city's commercial, residential, and industrial zones. The central concentration suggests a dense urban core, typical of metropolitan development patterns.

b). Non-built-Up Areas

- The non-built-up areas are mainly located in the western, southern, and peripheral regions of the city. These areas may consist of agricultural land, open spaces, and less developed regions, reflecting lower population density and urban infrastructure.

- The limited non-built-up areas within the urban core suggest a scarcity of green spaces, which are crucial for environmental sustainability, urban cooling, and residents' quality of life.

- The high concentration of built-up areas can contribute to the urban heat island effect, where urban regions experience higher temperatures than their rural surroundings due to human activities and built environments.

The map clearly shows the extent of urban sprawl in Surabaya as of 2002. The significant presence of built-up areas highlights the city's rapid urbanization, a common trend in many Southeast Asian cities. The urban expansion appears to follow the main transportation routes, indicating the influence of infrastructure development on urban growth.

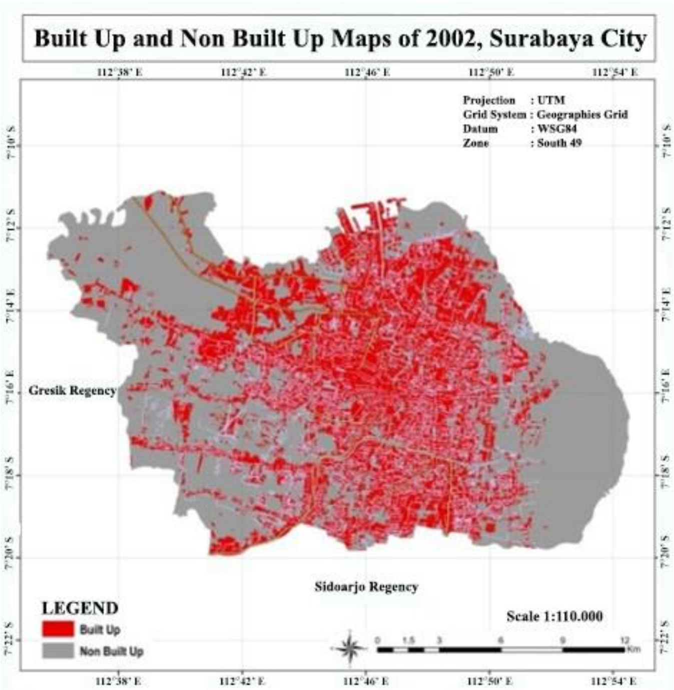

Fig. 4: Map of built-up and non-built-up of Surabaya City in 2002 generated by RBI Kota Surabaya

With the same analysis as Figure 4, the built-up area in 2022 from Figure 5 is estimated around 68% or 259,08 km^2. This means that during 20 years there has been an increase of around 45.72 km^2 or 21.43%. The majority of Surabaya City appears to be built-up and spread across the city, with a higher concentration towards the central and western parts. While for Non-built-up areas are relatively sparse and scattered throughout the city. These areas are more prominent on the outskirts, especially towards the northern and eastern regions. The central and western parts of the city show dense urban development, reflecting the city's expansion and population concentration in these areas. This widespread development might require comprehensive planning to ensure balanced growth and avoid overburdening certain areas.

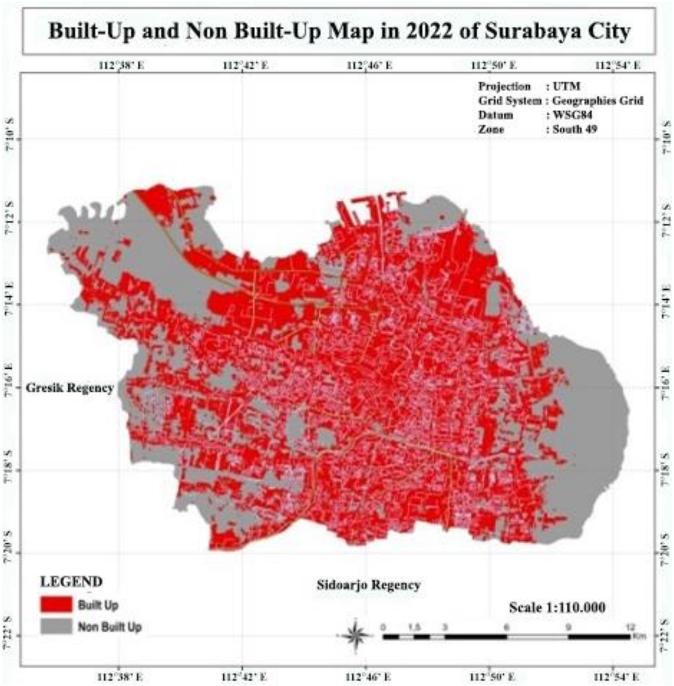

Fig. 5: Map of built-up and non-built-up of Surabaya City in 2022 generated by RBI Kota Surabaya

4. CONCLUSIONS

The NDBI method was successfully used to estimate the built-up area of Surabaya City, which spans approximately 350.54 km^2. Over a 20-year period, the built-up area increased from around 213 km^2 in 2002 to 259 km^2 in 2022, representing a 21% growth. This substantial increase highlights rapid urbanization and underscores the need for sustainable urban planning to manage the city's development. For future research, the NDBI method can be compared with other methods such as NDVI, Normal Difference Water Index (NDWI), modification of land use/land cover (LULC), or other remote sensing techniques for more accurate results and interpretation.

ACKNOWLEDGEMENT

The author would like to thank you goes to Ms. Anjani Maisyarani Putri of Undergraduate student of Urban and Regional Planning Study Program, Institut Teknologi Nasional Yogyakarta, Indonesia for satellite data collection that was used in this work.

REFERENCES

[1] C. V. M. Sajow, R. Palamba, and J. A. Ruru, "Land Use and Land Cover Changes and Their Impacts on Flood Events in Manado City," *Journal of Environmental and Earth Sciences*, vol. 6, no. 2, pp. 147-159, 2016.

[2] T. M. Lillesand and R. W. Kiefer, *Remote Sensing and Image Interpretation*, 3rd ed., New York: John Wiley & Sons, 1993.

[3] Q. Zhang and K. C. Seto, "Mapping urbanization dynamics at regional and global scales using multi-temporal DMSP/OLS nighttime lights data," *Remote Sensing of Environment*, vol. 115, no. 9, pp. 2320-2329, 2011.

[4] Y. Zha, J. Gao, and S. Ni, "Use of normalized difference built-up index in automatically mapping urban areas from TM imagery," *International Journal of Remote Sensing*, vol. 24, no. 3, pp. 583-594, 2003.

[5] H. Xu, "Extraction of urban built-up land features from Landsat imagery using a thematic-oriented index combination technique," *Photogrammetric Engineering & Remote Sensing*, vol. 73, no. 12, pp. 1381-1391, 2007.

[6] C. He, Z. Liu, J. Tian, and Q. Ma, "Urban expansion dynamics and natural habitat loss in China: A multiscale landscape perspective," *Global Change Biology*, vol. 16, no. 9, pp. 2886-2902, 2010.

[7] J. Chen, P. Gong, C. He, R. Pu, and P. Shi, "Land-use/land-cover change detection using improved change-vector analysis," *Photogrammetric Engineering & Remote Sensing*, vol. 69, no. 4, pp. 369-379, 2003.

[8] Surabaya City Government, *Surabaya in Figures 2019*, Surabaya: Badan Pusat Statistik (BPS) Kota Surabaya, 2019. Available: Surabaya in Figures 2019.

[9] United Nations, *World Urbanization Prospects: The 2018 Revision*, New York: United Nations, 2019. Available: https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf.

[10] P. S. Chavez, "An improved dark-object subtraction technique for atmospheric scattering correction of multispectral data," *Remote Sensing of Environment*, vol. 24, no. 3, pp. 459-479, 1988.

[11] P. Wicaksono and M. Hafizt, "Comparison of atmospheric correction methods for multi-temporal satellite images over land," *International Journal of Remote Sensing*, vol. 39, no. 6, pp. 1-15, 2018. doi: 10.1049/iet-ipr.2017.0295.

[12] C. Song, C. E. Woodcock, K. C. Seto, M. P. Lenney, and S. A. Macomber, "Classification and change detection using Landsat TM data: When and how to correct atmospheric effects?" *Remote Sensing of Environment*, vol. 75, no. 2, pp. 230-244, 2001.

[13] C. He, P. Shi, D. Xie, and Y. Zhao, "Improving the normalized difference built-up index to map urban built-up areas using optical remote sensing data," *International Journal of Remote Sensing*, vol. 31, no. 24, pp. 7011-7024, 2010.

BIOGRAPHIES

	**Wayan Suparta,** is a principal lecturer at the Institut Teknologi Nasional Yogyakarta (2022-Now) and the professional title of Engineer (Ir.) in Electrical Engineering was obtained from the Indonesian Institute of Technology (ITI) of South Tangerang City in 2024. He received the degree of Doctor of Philosophy (Ph.D.) in Electrical, Electronic and Systems Engineering from The National University of Malaysia (UKM), Bangi, Selangor in 2008. He was lecturer of Electronics Engineering of Legenda College Group, Malaysia. A Post-Doctoral Fellow (2007-2008), Senior Lecturer (2008-2012) and Associate Professor (2012-2017) in UKM. He teaches communication engineering, digital signal processing, instrumentation and control, robotics and industrial automation, machine learning, advanced softcomputing, etc. His research focused on GPS/GNSS technology, communication systems (remote sensing), smart systems, and UAV/drones.
	**Hill Gendoet Hartono** earned a bachelor's degree in Geological Engineering from the National Technology College of Yogyakarta in 1993. He received a master's degree from the Bandung Institute of Technology specializing in volcanic geology in 2000. He received a doctorate in geology on ancient volcanoes from Padjajaran University in Bandung in 2010. He is a permanent lecturer at the Institut Teknologi Nasional Yogyakarta (ITNY), Indonesia (since 1993). He teaches volcanic petrology, volcanology, volcanic stratigraphy. His research is volcanic petrology and determining the center of ancient volcanic eruptions.