ISSN 2354-9114 (online), ISSN 0024-9521 (print)
Indonesian Journal of GeographyVol 56, No 1 (2024): 24-32
DOI: 10.22146/ijg.77889 website: htps://jurnal.ugm.ac.id/ijg
©2024 Faculty of Geography UGM and The Indonesian Geographers Association

INDONESIAN JOURNAL OF GEOGRAPHY

RESEARCH ARTICLE

Use of Remote sensing and Geographic Information System for the Analysis of Urban Development: A Case Study of Banyumas Regency, Indonesia

Ermie Renita and Iswari Nur Hidayati
Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, Indonesia

Received: 2022-11-10
Revised: 2023-09-08
Accepted: 2024-04-16

Keywords: Land-use/land-cove;, urban development; multispectral classification; standard deviational ellipse

Correspondent email : ermie.renita@mail.ugm.ac.id

Abstract. The change in land-use/land-cover (LULC) is one of the physical factors in urban development and the rapid growth in population has necessitates the need for space, driven by high socio-economic activities. Banyumas is a regency that had experienced rapid population growth in the last two decades, establishing an activity and service center in the Barlingmascakeb region. This rapid population growth has led to massive changes in LULC. Therefore, this study aimed to observe the changes in LULC in 2000 and 2020 to determine the direction of urban development in Banyumas Regency within 20 years. Multispectral classification with a Maximum Likelihood algorithm was used to extract LULC information from Landsat images. The changes obtained by crosstab analysis on the multispectral classification results were used as a reference to observe the direction of urban development. This procedure used four quadrants according to the cardinal directions and Standard Deviational Ellipse (SDE). The result showed that LULC in the forest class experienced the highest change of 142,584.3 km², accounting for 48%. Based on the increase in built-up land over 20 years, the direction of urban development according to the cardinal directions showed that the most dominant increase was in quadrant II (Southeast), which is 56.44% or 21.95 km². It was concluded that the direction of urban development was oriented toward the southeast.

©2024 by the authors. Licensee Indonesian Journal of Geography, Indonesia.
This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution(CC BY NC) licensehttps://creativecommons.org/licenses/by-nc/4.0/.

1. Introduction

The change in land-use/land-cover (LULC) is a complex process caused by natural and human activities (Hadeel, Jabbar, & Chen, 2009). Some of the factors responsible for LULC change include population growth and socio-economic dynamics (Jokar Arsanjani, Helbich, & de Noronha Vaz, 2013). These factors are closely related to human activity due to the need for space, serving as the center of activity. According to (Bhatta, 2009), population growth and socio-economic activities have a direct relationship with urban development. Furthermore, (Desmet & Henderson, 2015) stated that most increases in the number and size of urban populations are caused by economic growth and development. Hoselitz in (*Polous (1982) Urban Growth Theories and Patterns of Iraq*, n.d.), population growth in urban and industrial centres is inevitable as a result of economic development, through industrialisation, mining or commercialisation, and development in agriculture.

Consistent with the statement of (Branch, 1995) in (Pigawati, Yuliastuti, & Mardiansjah, 2017), physical urban development is evident through the growth and increase of population density, as well as widespread development of built-up land to support social and economic activities. The continuous development of the city increases pressure due to the higher space demand for the benefit of socio-economic activities. However, due to the increasingly limited availability of land in urban areas, several individuals resorted to sacrificing non-developed land to address these spatial demands. As stated by (Halleux, Marcinczak, & van der Krabben, 2012), urban development has led to significant changes in LULC.

Banyumas is one of the regencies in the southwest part of Central Java Province, located in a strategic area. It is one of the intersection of cross-regional transportation, namely West Java to Yogyakarta and Cilacap Regency to Semarang City. This strategic location makes Banyumas Regency a center for activities and services in Banjarnegara, Purbalingga, Banyumas, Cilacap, and Kebumen, known as Barlingmascakeb Area. In addition, there is a transportation facility in the form of a large class A station belonging to PT KAI, namely Purwokerto Station, which supports access to land routes. Banyumas Regency is geographically located on the southern slope of Mount Slamet and the valley of Serayu River. This condition makes the Regency an area with abundant and wealthy resources. Some of the factors driving this region to continuous development include easy accessibility and abundant resources. This is evident in the events of the last two decades, where the growth that occurred has accelerated with population growth and continues to increase yearly.

The population of Banyumas Regency in 2000 was 1,485,745 (Kabupaten Banyumas Dalam Angka 2000, n.d.) and 1,553,902 in 2010 (Kabupaten Banyumas Dalam Angka 2011, n.d.). Meanwhile, in 2020, the figure increased to 1,776,918, as reported by (Kabupaten Banyumas Dalam Angka 2021, n.d.). An increase of 68,157 was recorded in ten years, from 2000 to 2010. However, compared to the increase of 223,016 from

2010 until 2020, the second decade tripled that of the first. Therefore, Banyumas Regency was predicted to experience continuous growth and development, both physically and socio-economically.

Remote sensing and GIS technologies for urban development are commonly used recently. This method extracts spatial information about the type of LULC and enables the detection of changes within a given area in a time series. The data is instrumental in informing urban planning and development activities (Ewing & Pendall, n.d.). Additionally, the images facilitate the observation of growth patterns in urban area (Yunus, 2005). (Bhatta, 2009), analyzed urban development patterns in Kolkata, India, by comparing and modeling temporal information, such as built-up land, number of households and workers, developable area, number of workers, and population. (Sabet Sarvestani, Ibrahim, & Kanaroglou, 2011) analyzed urban development in Shiraz, Iran, by examining land use changes from 1976 to 2005. (Wang, Gong, Wang, Deng, & Cao, 2021), analyzed urban development using a built-up land map based on several high-resolution satellite data. Based on many studies conducted globally, the use of remote sensing and GIS has proven reliable for extracting information on the spatial and temporal dynamics of urban development for planning and monitoring activities (Masek et al., 2000; Ramadan et al., 2004; Kaya & Curran, 2006; El Garouani, Mulla, El Garouani, & Knight, 2017; Ali et al., 2018; Woldesemayat & Genovese, 2021).

This study integrates remote sensing technology with geographic information systems to examine the direction of urban development in Banyumas Regency over 20 years. Remote sensing methods extract information on LULC and change through multispectral classification. Meanwhile, GIS was used to study and visualize the direction of development.

2. Methods

Study Area

Banyumas Regency is located in the southwest of Central Java Province, as shown in Figure 1. Astronomically, this regency is located between 7° 15' 05” to 7° 37' 10” South Latitude and 108° 39' 17” to 109° 27' 15” East Longitude, which is an area in the southern hemisphere of the equator. The area of Banyumas Regency is 1,327.59 km² or 132,759 Ha and has a topography in the form of lowlands and mountains with a dominance of >45% spread in the central and southern parts.

Data Collection

Three different data obtained from numerous sources were used in this study. The data include a medium-resolution remote sensing image, and a digital topographical map of Banyumas Regency from Rupabumi Indonesia (RBI) in 1:25,000 scale, with the population statistics in 2000 and 2020. Furthermore, the remote sensing images used are Landsat 8 OLI image recorded in 2020 and Landsat 5 TM image in 2000 retrieved from the Google Earth Engine platform. Both images are Landsat Image Collection 2 Level-2, enduring radiometric correction to the surface reflectance and geometric levels. The two images were used to extract LULC through multispectral classification with a maximum likelihood algorithm. A digital map of Banyumas Regency from Rupa Bumi Indonesia (RBI) on a 1:25.000 scale was necessary to obtain information on administration borders, roads, and rivers.

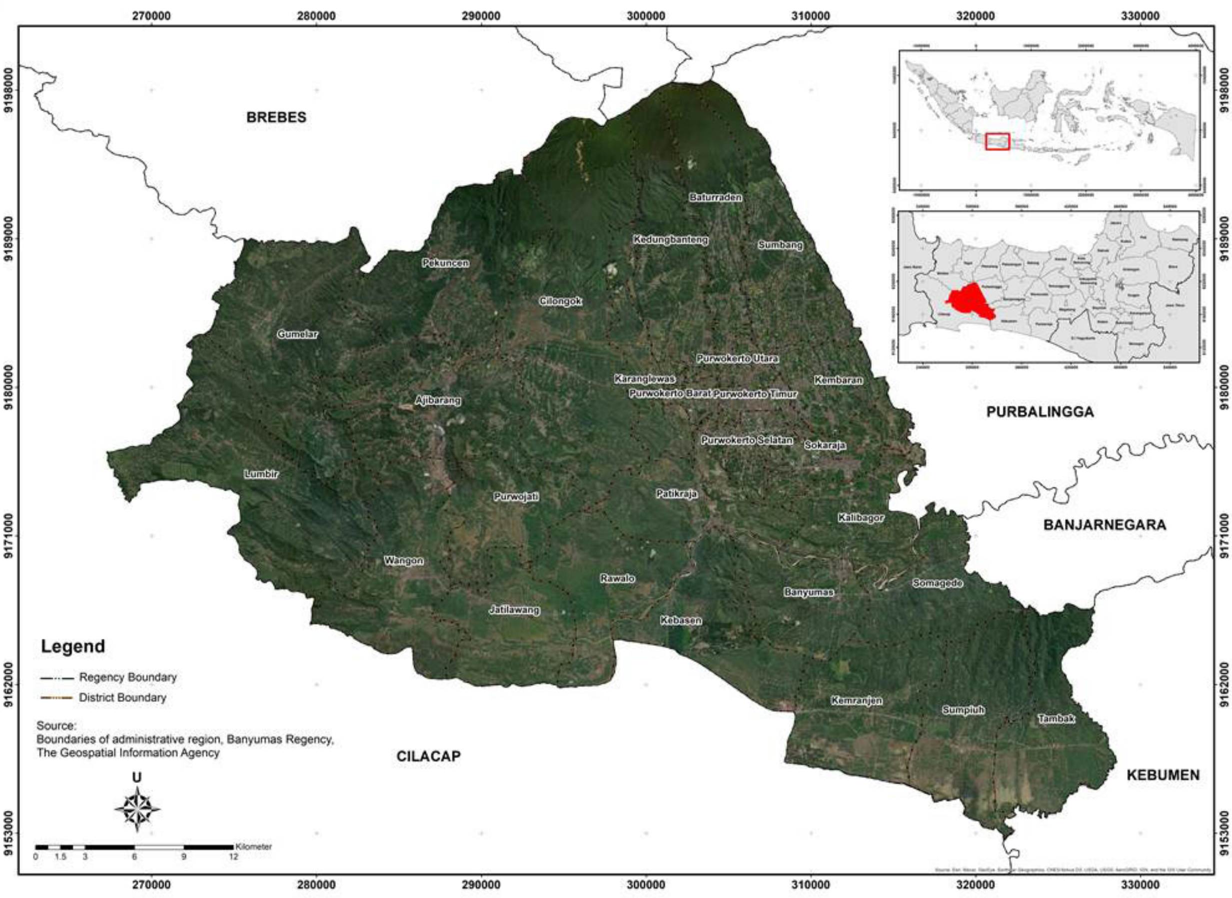

Figure 1. Study Area

Classification

Classification of LULC refers to the USGS (United States Geological Survey) system proposed by James R. Anderson. LULC information extraction was carried out through multispectral classification with the Maximum Likelihood algorithm on Landsat 5 TM imagery in 2000 and Landsat 8 OLI imagery in 2020. Based on the data source used, Landsat imagery with medium resolution and a map output scale of 1:100,000, classification system used was level II. However, this study used only 7 LULC classes with modifications designed to the conditions, as shown in Table 1.

LULC Changes Detection

LULC change was extracted from the results of the 2000 and 2020 classifications. The analysis was carried out by overlaying using time series through crosstabs in Terrset software and the results were used as a reference to observe the direction of urban development.

The Direction of Urban Development

The direction of urban development was identified based on the increase in built-up land that occurred from 2000 to 2020. According to the cardinal directions (Nugroho & Rahardjo, n.d.), the first analysis divided the Banyumas Regency area into four quadrants, namely I (Northeast), II (Southeast), III (Southwest), and IV (Northwest) at the city center point. The second analysis was conducted using the Standard Deviational Ellipse (SDE) (Jian et al., 2016; Rizwan, Wan, & Gwiazdzinski, 2020; Li & Cao, n.d.), which considered the determination of the city center point, long axis, and short axis. Each of these analyses was processed in ArcGIS software.

3. Result and Discussion

Classification of LULC

Classification scheme of LULC refers to the system proposed by James. R. Anderson with modification. The result showed that the most significant change was in the decline of forest area from 908,582 pixels to 750,158 pixels. In the results of multispectral classification, isolated pixels are often found among the homogenous. Therefore, post-classification was necessary to accomplish the most accurate classification result. This process used a filtering method to generalize isolated pixels to homogenous. The filtering method is a majority filter with a moving window size of 3 x 3. The result of the majority filter showed a more precise and unified visual for each classification. This result generalized LULC with small areas into the more dominant classes. The visualization results of LULC classification in 2000 and 2020 results are shown as a map in Figures 2 and 3.

Table 1. Classes of LULC

Class	Description
Forest Land	Forest areas with green trees all year round; forest areas with trees as a resource for logs (plantation forest)
Mixed cropland/plantation area	Crops as resources for food production; fruit-producing trees for commercial purposes; seedling plants
Agricultural land and pastures	Harvested agricultural land (rice, corn, cassava, tubers, beans, unused agricultural land) and pastures
Residential area	Residential buildings from high to low-density
Commercial, services, and industrial area	Central business area; shopping area; expansion of commercial lanes along major highways; office buildings; educational, religious, health, and military facilities
Open land/other urban area	Golf course; field; burial lands; city park; mining area; and ex-mining area
River/other water area	Big rivers, streams, creeks, lakes, and reservoirs

Source: (Anderson, Hardy, Roach, & Witmer, n.d.)

Table 2. Number of Pixels in Each Class Image

Class Classification	Landsat 5 TM 2000 (px)	Landsat 8 OLI 2020 (px)
Forest Land	908,582	750,158
Mixed Cropland/Plantation Area	142,264	137,557
Agricultural Area and Pastures	346,125	467,661
Residential Area	133,933	169,965
Commercial, Services, and Industrial Areas	8,749	16,682
Open Land/Other Urban Area	12,847	11,422
River/Other Water Area	12,182	14,071

Source: data processing

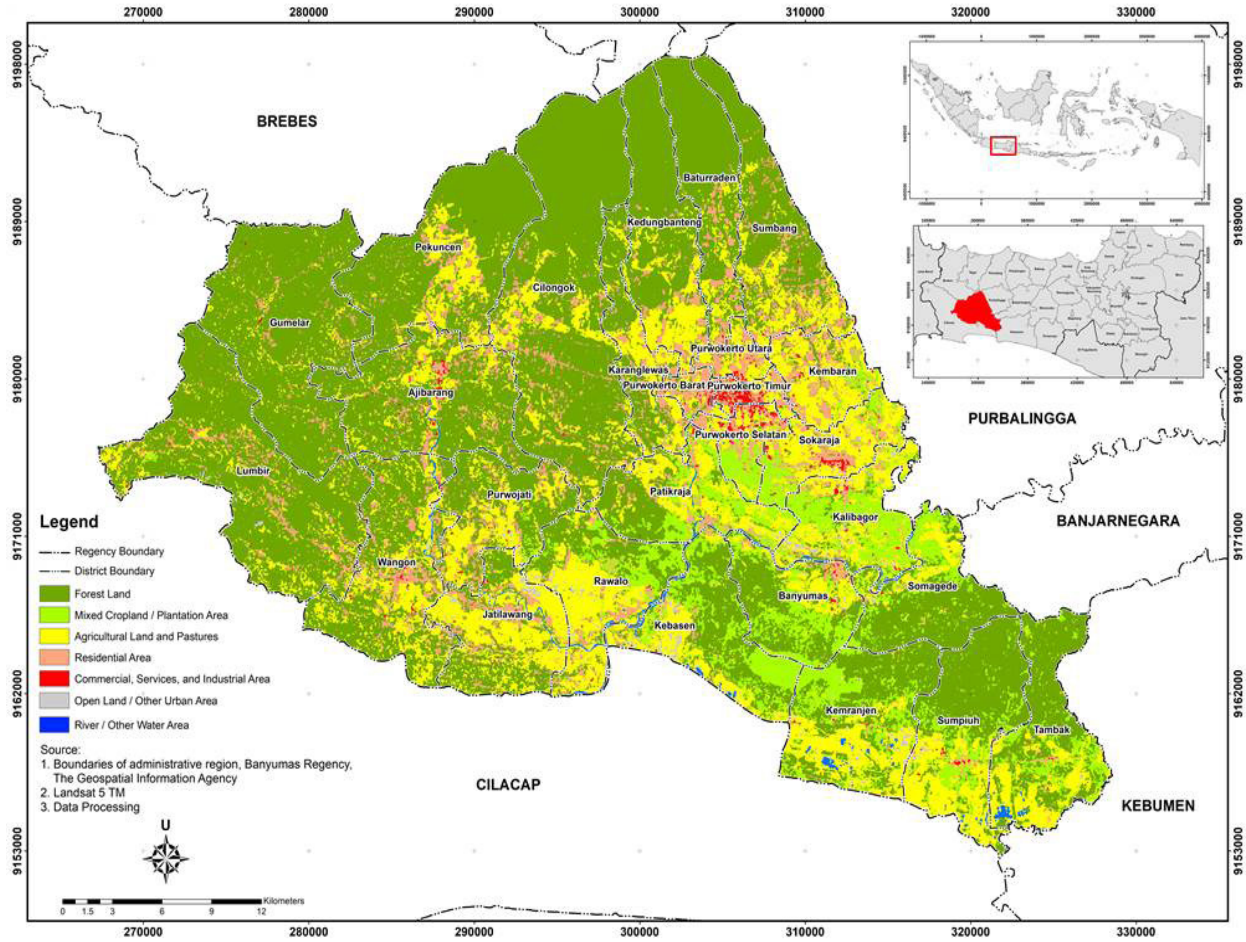

Figure 2. LULC in 2000

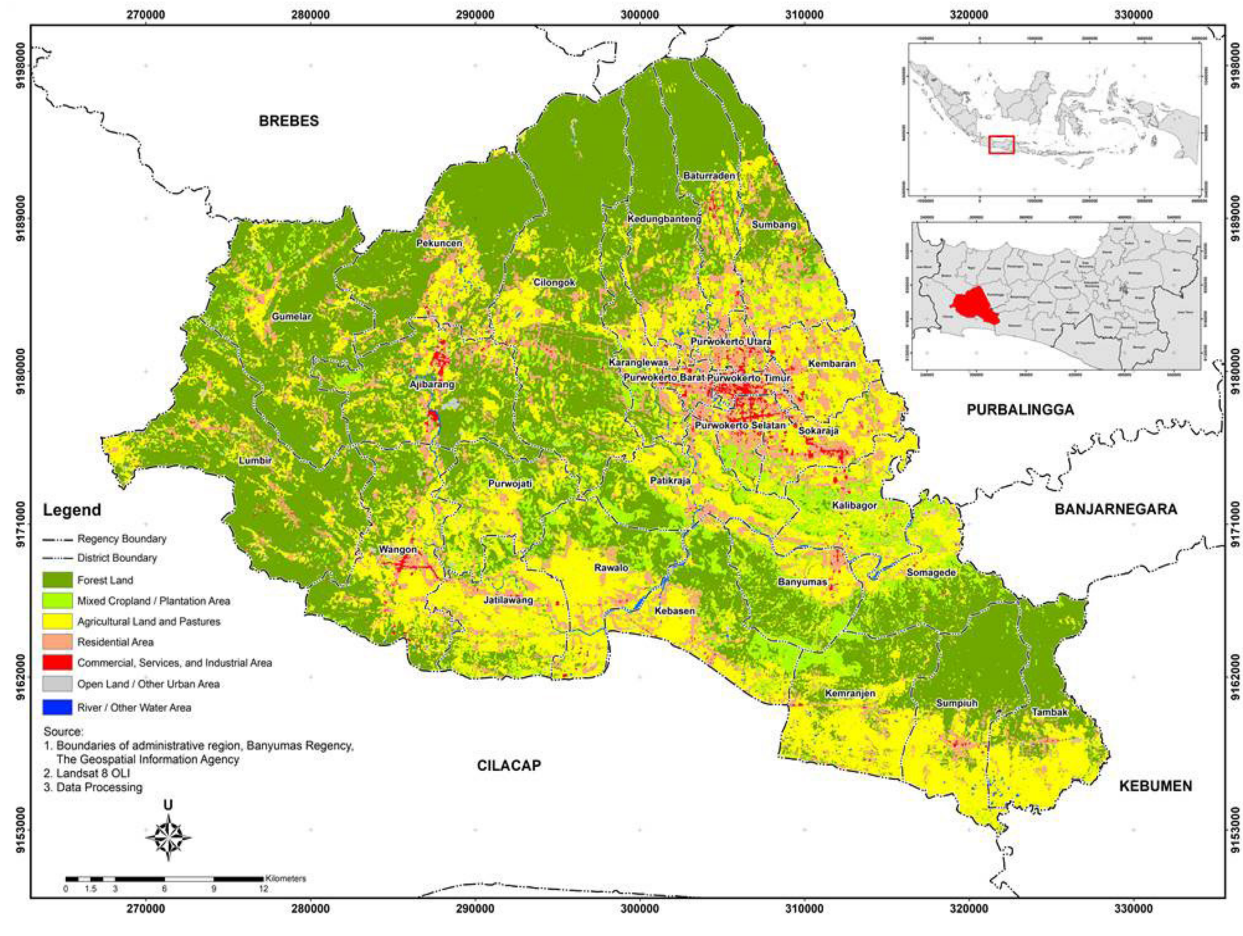

Figure 3. LULC in 2020

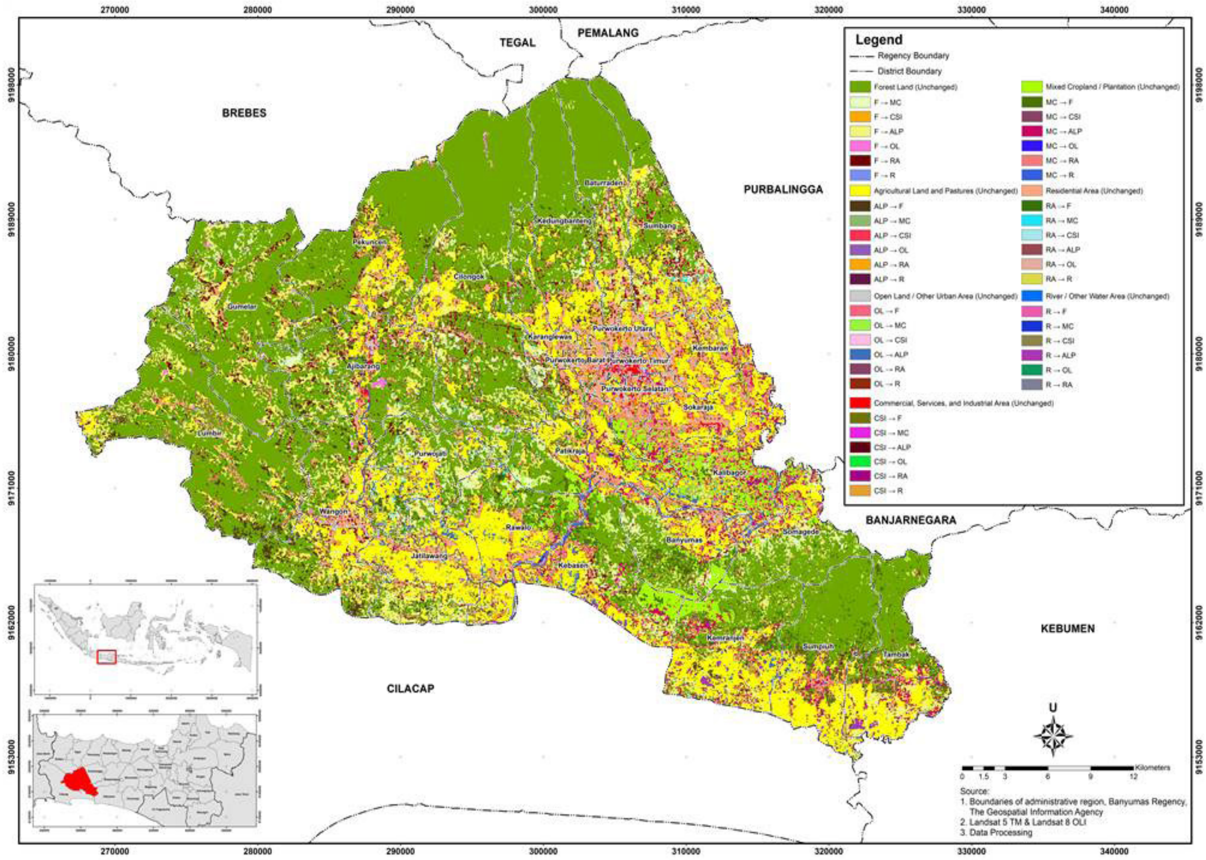

Figure 4. LULC change 2000 - 2020

Table 3. The Area of LULC Change in Banyumas Regency from 2000-2020

Class Classification	Area (km²)		Change (km²)	Percentage (%)
	2000	2020		
Forest Land	816,948	674,363.7	142,584.3	48
Mixed Cropland/Plantation Area	127,831.5	123,240.6	4,590.9	1.55
Agricultural Area and Pastures	311,172.3	418,412.7	107,240.4	36.10
Residential Area	120,468.6	152,931.6	32,463	10.93
Commercial, Services, and Industrial Areas	7,866	14,903.1	7,037.1	2.37
Open Land/Other Urban Area	11,556.9	10,206	1,350.9	0.45
River/Other Water Area	10,722.6	12,508.2	1,785.6	0.60

Source: Data processing

LULC Changes

Banyumas Regency had experienced a certain amount of LULC change from 2000 to 2020. LULC was analyzed through a comparison between several maps using change/time series in crosstab between 2000 and 2020. The result of this analysis is a map of LULC from 2000-2020 shown in Figure 4. and a matrix of changes, which was obtained from pixel-based cross-tabulation. Table 3 shows the result of processing the matrix of changes, which is the area of LULC change of each classification.

The highest class changes are forest as well as agricultural land and pastures, with an area of 142,584.3 km² and 107,240.4 km², respectively. This change occurred in the hilly valleys of Gumelar, Lumbir, Wangon, Jatilawang, and Ajibarang Districts. Furthermore, the changes in the class of agricultural land and pastures occurred on the slopes of Slamet Volcano, specifically in Pekuncen, Cilongok, Baturraden, and Sumbang Districts. This change is attributed to development of livestock breeding fields in Cilongok, Baturraden, and Sumbang Districts, requiring a pasture area for breeding sustainability. This change is followed by the residential class, with an area of 32,463 km². This change is due to the increase in population, which increased by 19.6% from 2000 to 2020 (Kabupaten Banyumas Dalam Angka 2000, n.d.; Kabupaten Banyumas Dalam Angka 2021, n.d.).

The Direction of Built-up Land Development from 2000-2020

Development direction of built-up land in Banyumas Regency was identified using four quadrants based on cardinal direction and SDE. The quadrants were centered on the point of the city, which is located in the city square. Furthermore, the built-up land in 2000 and 2020 was calculated to obtain the number of changed areas, and the direction of the dominant development was obtained. This direction can fall into quadrant I (northeast), II (southeast), III (southwest), or IV (northwest). The division of four quadrants based on the cardinal direction regarding the change of built-up land is shown in Figure 5. Table 4 shows the calculation table of built-up land area in 2000 and 2020, as well as the change. The results show that the highest change of built-up land from 2000 to 2020 occurred in quadrant II, stretching to the southeast with an extension area of 21.95 km². This extension occurred due to some factors that caused a land change in quadrant II. In addition, land change was influenced by the characteristics of the location in which it occurs. The factors causing land change include the close distance from the area of the city center, easy accessibility, adequate public facilities, and access to the main transportation route that connects regions. For example, Figure 6 shows the presence of public facilities, such as health, recreational areas, transportation, and main routes that connect Banyumas Regency with other regions. This includes the primary arterial road that runs along Tambak, Sumpiuh, and Kemranjen Districts, and the collector road in Sokaraja District, which are also in quadrant II. Major transportation routes impact land change, where many shops and settlements are close to the road.

The following process was used to observe the direction of built-up land development using SDE. The analysis showed that the trends of central tendency, dispersion, and the directional trend of LULC change. Furthermore, the result of the SDE analysis was in the form of ellipse that shows the directional trend of built-up land development (Figure 7). According to ellipse formed, the change in built-up land only occurred evenly across Banyumas Regency, but concentrated in the east and south parts, thereby forming an oval ellipse. The result of this study showed a significant difference between the range of the minor and major axes because the change points of the built-up land were not concentrated near urban center. However, it formed a directional trend of built-up land

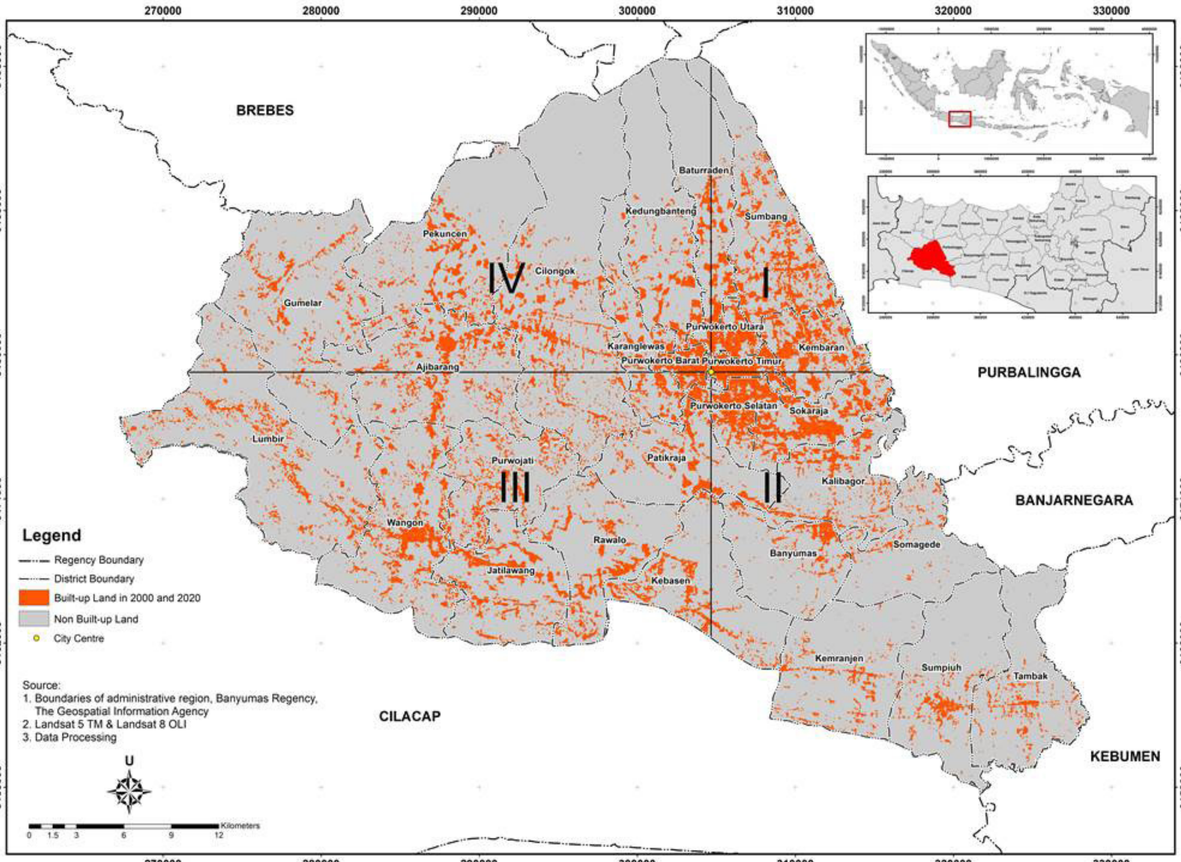

Figure 5. Map of built-up land development Using Four Quadrants

Table 4. Area of Built-up Land Extensions from 2000-2020 Based on Quadrant Direction

Quadrant Division	Area of Built-up Land (km²)		
	2000	2020	Change
I	22.81	29.57	6.76
II	23.92	45.87	21.95
III	48.79	50.41	1.62
IV	31.01	39.57	8.56
Total	126.53	165.42	38.89

Source: data processing

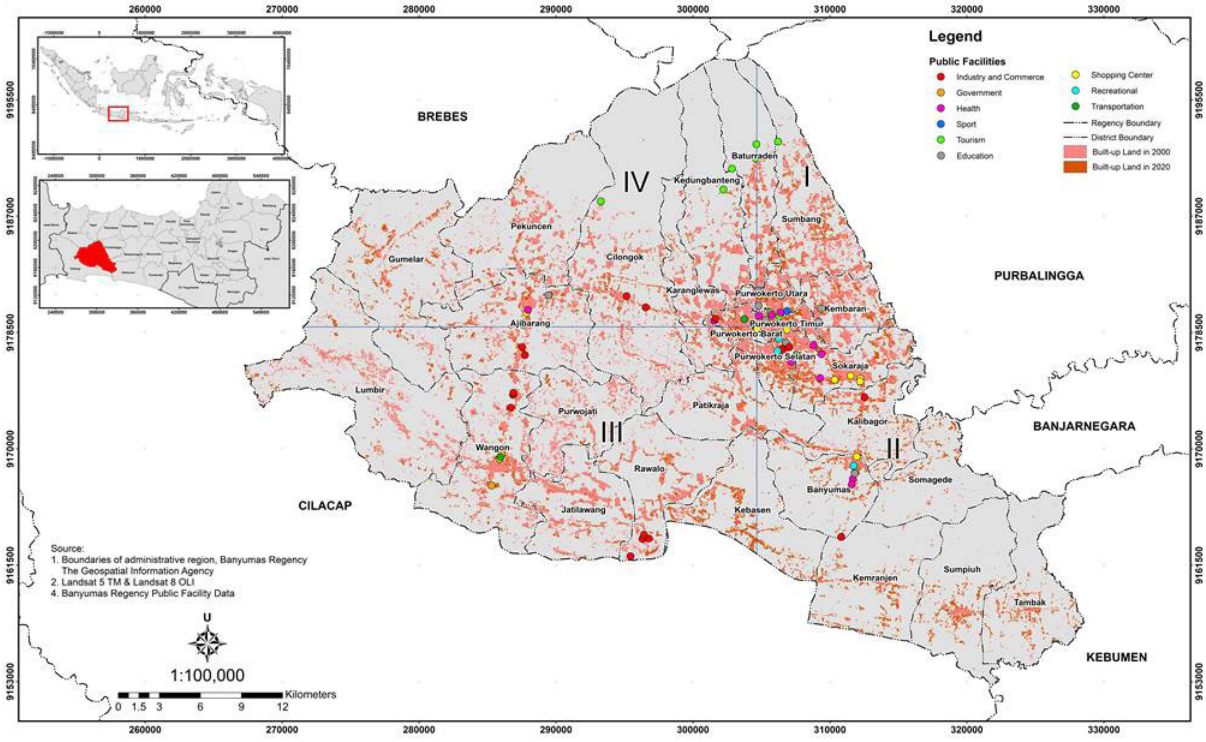

Figure 6. Public Facility in Banyumas Regency

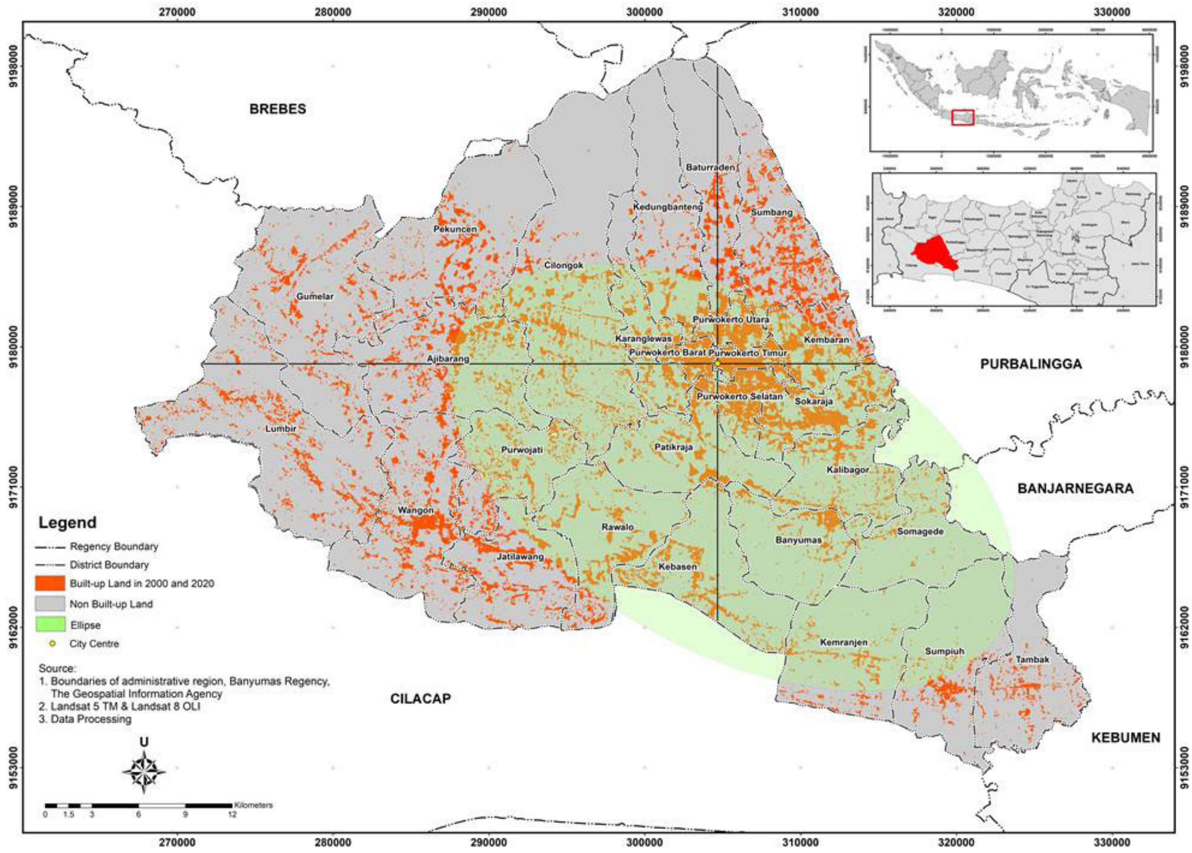

Figure 7. Map of built-up land development Using SDE

development oriented towards the southeast. Suppose ellipse is shown with the built-up land map of 2000-2020, then the number of extensions will be relatively high, specifically in West Purwokerto, South Purwokerto, Sokaraja, Kebasen, Kemranjen, and Sumpiuh Districts. The directional trend of land development in Banyumas Regency, oriented towards the southeast was associated with several factors that trigger land change. The districts of West and South Purwokerto were directly adjacent to the city center in East Purwokerto District. The only train station in Purwokerto, which is one of the major routes connecting cities both within and outside the province, was located in West Purwokerto District. Therefore, development of built-up land around facilitate the growth of places for services and shops as well as living areas. In South Purwokerto District, there are some recreational locations, such as Rajawali Cinema, Bulupitu Terminal, offices, shopping centers, and small shops.

The results of both analyses using quadrants according to the cardinal directions and SDE showed that land development in Banyumas Regency from 2000-2020 tended towards the southeast, included in quadrant II. The area of the districts covered in quadrant II includes South Purwokerto, Sokaraja, Kalibagor, Banyumas, Kemranjen, Sumpiuh, Tambak, parts of Kebasen, and Patikraja. The factors influencing land change in the elliptical area were similar to those described in the quadrant method, with complete transportation facilities and amenities. Socio-economic activities cannot be separated from population growth, showing that the changes in LULC, such as the significant increase in built-up land, will continue to be interrelated with population and socio-economic aspects as a driving factor in development of the city. Remote sensing and GIS showed that information on LULC played a significant role in urban development, specifically in the planning and management of a city.

4. Conclusion

In conclusion, urban development in Banyumas Regency was caused by increased public facilities, both for educational purposes and economic affairs, such as shops and commercial activity. This development occurred in response to the increase in population with the high activity frequency. Therefore, the demands for space to accommodate the physical facilities to conduct the activity were also higher. Remote sensing and geographic information systems were successfully used to conduct mapping, both partially and temporally in the study of urban development. Physically, urban development was observed by changing non-built into built-up lands. In 20 years, Banyumas Regency experienced a high extension of built-up and a decrease in non-built lands. According to the four quadrants, which are based on cardinal direction and the SDE, urban development in Banyumas Regency was directed towards the southeast.

Urban development was a very dynamic matter, requiring appropriate monitoring of urban areas to achieve sustainable goals. This monitoring was intended as a basis for future planning regarding urban development by examining the changes that occurred from the past to the present. This showed that the trend or dynamics of urban development was an essential aspect of understanding urban growth.

Acknowledgement

The authors are grateful to Universitas Gadjah Mada for funding this study through the 2022 Final Project Recognition grant.

References

Ali, A., Khalid, A., Butt, M. A., Mehmood, R., Mahmood, S. A., Sami, J., - Azhar, M. (2018). Towards a Remote sensing and GIS-Based Method to Study Population and Urban Growth: A Case Study of Multan. *Advances in Remote sensing*, *07*(03), 245-258. https://doi.org/10.4236/ars.2018.73017

Anderson, J. R., Hardy, E. E., Roach, J. T., & Witmer, R. E. (n.d.). *A Land Use And Land Cover Classification System For Use With Remote Sensor Data.*

Bhatta, B. (2009). Analysis of urban growth pattern using remote sensing and GIS: A case study of Kolkata, India. *International Journal of Remote Sensing*, *30*(18), 4733–4746. https://doi.org/10.1080/01431160802651967

Branch, M. C. (1995). *Perencanaan Kota Komprehensif : Pengantar & Penjelasan* . Yogayakarta: Gadjah Mada University Press.

Desmet, K., & Henderson, J. V. (2015). The Geography of Development Within Countries. In *Handbook of Regional and Urban Economics* (Vol. 5, pp. 1457–1517). Elsevier B.V. https://doi.org/10.1016/B978-0-444-59531-7.00022-3

El Garouani, A., Mulla, D. J., El Garouani, S., & Knight, J. (2017). Analysis of urban growth and sprawl from remote sensing data: Case of Fez, Morocco. *International Journal of Sustainable Built Environment*, *6*(1), 160-169. https://doi.org/10.1016/j.ijsbe.2017.02.003

Ewing, R., & Pendall, R. (n.d.). *MEASURING SPRAWL AND ITS IMPACT Volume I.*

Hadeel, A. S., Jabbar, M. T., & Chen, X. (2009). Application of remote sensing and GIS to the study of land use/cover change and urbanization expansion in Basrah province, Southern Iraq. *Geo-Spatial Information Science*, *12*(2), 135-141. https://doi.org/10.1007/s11806-009-0244-7

Halleux, J. M., Marcinczak, S., & van der Krabben, E. (2012). The adaptive efficiency of land use planning is measured by the control of urban sprawl. The cases of the Netherlands, Belgium, and Poland. *Land Use Policy*, *29*(4), 887-898. https://doi.org/10.1016/j.landusepol.2012.01.008

Jian, P., Yanxu, L., Hong, S., Pan, X., Xiaoxu, H., & Yanglin, W. (2016). Using impervious surfaces to detect urban expansion in Beijing of China in the 2000s. *Chinese Geographical Science*, *26*(2), 229-243. https://doi.org/10.1007/s11769-016-0802-5

Jokar Arsanjani, J., Helbich, M., & de Noronha Vaz, E. (2013). Spatiotemporal simulation of urban growth patterns using agent-based modeling: The case of Tehran. *Cities*, *32*, 33-42. https://doi.org/10.1016/j.cities.2013.01.005

Kabupaten Banyumas Dalam Angka 2000. (n.d.).

Kabupaten Banyumas Dalam Angka 2011. (n.d.).

Kabupaten Banyumas Dalam Angka 2021. (n.d.).

Kaya, S., & Curran, P. J. (2006). Monitoring urban growth on the European side of the Istanbul metropolitan area: A case study. *International Journal of Applied Earth Observation and Geoinformation*, *8*(1), 18-25. https://doi.org/10.1016/j.jag.2005.05.002

Li, G., & Cao, H. (n.d.). *SPRINGER BRIEFS IN GEOGRAPHY Understanding Spatial-Temporal Patterns of the Ethnic Minority Mobility in China's Urbanization*. Retrieved from http://www.springer.com/series/10050

Masek, J. G., Lindsay, F. E., & Goward, S. N. (2000). Dynamics of urban growth in the Washington DC metropolitan area, 1973-1996, from Landsat observations. *International Journal of Remote Sensing*, *21*(18), 3473-3486. https://doi.org/10.1080/014311600750037507

Nugroho, S. P., & Rahardjo, N. (n.d.). *VISUALISASI ARAH PERKEMBANGAN PERMUKIMAN DI KOTA YOGYAKARTA DARI TAHUN 1987-2007.*

Pigawati, B., Yuliastuti, N., & Mardiansjah, F. H. (2017). PEMBATASAN PERKEMBANGAN PERMUKIMAN KAWASAN PINGGIRAN SEBAGAI UPAYA PENGENDALIAN PERKEMBANGAN KOTA SEMARANG. *TATALOKA*, *19*(4), 306. https://doi.org/10.14710/tataloka.19.4.306-319

Polous (1982) Urban Growth Theories and Patterns of Iraq. (n.d.).

Ramadan, E., Feng, X. Z., & Cheng, Z. (2004). Satellite remote sensing for urban growth assessment in Shaoxing City, Zhejiang Province. *Journal of Zhejiang University: Science*, *5*(9), 1095-1101. https://doi.org/10.1631/jzus.2004.1095

Rizwan, M., Wan, W., & Gwiazdzinski, L. (2020). Visualization, spatiotemporal patterns, and directional analysis of urban activities using geolocation data extracted from LBSN. *ISPRS International Journal of Geo-Information*, *9*(2). https://doi.org/10.3390/ijgi9020137

Sabet Sarvestani, M., Ibrahim, A. L., & Kanaroglou, P. (2011). Three decades of urban growth in the city of Shiraz, Iran: A remote sensing and geographic information systems application. *Cities*, *28*(4), 320-329. https://doi.org/10.1016/j.cities.2011.03.002

Wang, H., Gong, X., Wang, B., Deng, C., & Cao, Q. (2021). Urban development analysis using built-up area maps based on multiple high-resolution satellite data. *International Journal of Applied Earth Observation and Geoinformation*, *103*. https://doi.org/10.1016/j.jag.2021.102500

Woldesemayat, E. M., & Genovese, P. V. (2021). Monitoring urban expansion and urban green spaces change in Addis Ababa: Directional and zonal analysis integrated with landscape expansion index. *Forests*, *12*(4). https://doi.org/10.3390/f12040389

Yunus, H. S. (2005). *Manajemen Kota: Perspektif Spasial*. Pustaka Pelajar.