OPEN ACCESS
Journal Homepage:http://ejournal2.undip.ac.id/index.php/jwl

JURNAL WILAYAH DAN LINGKUNGAN
P-ISSN: 2338-1604 dan E-ISSN: 2407-8751
Volume 13 Nomor 3, Desember 2025, 61-71
https://doi.org/10.14710/jwl.13.3.61-71

Urban Sprawl and Its Impacts on Land Cover Change in the Outskirts of the Surabaya Metropolitan Area

Cut Sari Natasya Rahmadani[1]
Department of Landscape Architecture, Faculty of Agriculture, IPB University

Alinda Fitriany Malik Zain
Department of Landscape Architecture, Faculty of Agriculture, IPB University

Galuh Syahbana Indraprahasta
Research Center of Population, National Research and Innovation Agency (BRIN)

Received : 11 December 2024
Accepted : 4 December 2025
Available Online : 31 December 2025

Abstract: Development and economic growth in Indonesia have experienced rapid progress, followed by urbanization marked by the expansion of urban areas towards the outskirts, and have triggered urban expansion and land cover changes, especially on the outskirts of Surabaya City, and continue to expand to the Gerbangkertosusila area, which can indicate a decrease in Green Open Space (GOS). Given the important role of green open space in the sustainability of metropolitan areas, this study has three objectives. First, to analyze the impact of urban sprawl on GOS with spatial dynamics of land cover changes using Land Use Cover Changes (LUCC) analysis using ArcGIS software. Second, to identify spatial patterns of urban sprawl, and third, to calculate the index sprawl value to determine areas with urban sprawl impacts. The results of our study show that GOS has decreased in 25 years by 9.32%, and built-up area has increased by 8.27% of the total area of Gerbangkertosusila. The patterns of urban expansion that occur are Leap Frog Development, Ribbon Development, and Post-suburbia. The highest area expansion index value is in Sidoarjo at 4.74 and the lowest in Bangkalan at -7.62. The expansion of this area is marked by the development of settlements, industrial areas, and transportation routes, which result in the conversion of green open spaces into Built-up areas. Based on the analysis used in the Gerbangkertosusila area, the concept of Urban Growth Boundaries (UGB) is necessary; this concept effectively addresses urban expansion by establishing urban development permit policies.

Keywords: Green Open Space, Metropolitan Area, Spatial Analysis, Urban Sprawl Index

Introduction

Economic progress in developing countries such as Indonesia will continue to carry out gradual and planned development that creates economic stability (Efendi & Aimon, 2024). Rapid urbanization has followed this socioeconomic progress, turning a number of Indonesian cities into metropolitan areas (Pravitasari et al., 2020). Metropolitan areas are formed from several administrative areas that are adjacent and functionally integrated.

[1] Corresponding Author:
Email: cutsaricut@apps.ipb.ac.id

How to Cite
Asifah, Y., Alimuddin, I., & Idham, A. (2025). STRATEGI PENGURANGAN RISIKO BENCANA BANJIR PADA DAS KIRASA, KABUPATEN BULUKUMBA. *Jurnal Wilayah dan Lingkungan, 13*(3), 1-16. https://doi.org/10.14710/jwl.13.3.1-16

Within them, there are core areas as the main activity centers and peripheral areas that act as drivers and supporters of dynamics in the city center due to growth within them (McGee, 2007). This development has an impact on physical changes in the city, and if this continues, it will result in urban sprawl (Ramachandra et al., 2013). Urban sprawl is uncontrolled, unplanned, and uncoordinated growth in urban areas, planners cannot visualize growth in the planning, and decision-making processes to make it (Hidajat & Ridwan, 2018; Sudhira & Ramachandra, 2007; Tommy Firman & Fikri Zul Fahmi, 2017).

In East Java Province, there is the second largest metropolitan area in Indonesia, namely the Gerbangkertosusila area, which is the center of the economy in the fields of trade, services, and industry, and is part of the National Strategic Area (Sudarsono, 2015). Gresik, Bangkalan, Mojokerto, Mojokerto (City), Surabaya (City), Sidoarjo, and Lamongan are all part of the Gerbangkertosusila area, with Surabaya City serving as its hub. Although Surabaya City's population grew steadily between 1990 and 2010, it did so at a slower rate than the surrounding areas. The suburbs are growing faster (Table 1), which may indicate that there is still an expansion of economic activities outside the administrative boundaries of the city of Surabaya (Katherina & Indraprahasta, 2019).

Table 1. Population 1995, 2000, 2015 and 2020

Location	1995	2000	2015	2020
Gresik	843.676	957.048	1.256.313	1.311.215
Bangkalan	776.058	762.046	954.305	1.060.377
Mojokerto	796.697	880.855	1.080.389	1.119.209
Mojokerto (City)	95.979	108.045	125.706	132.434
Sidoarjo	1.101.369	1.266.776	2.117.279	2.082.801
Lamongan	1.163.689	1.200.103	1.187.795	1.344.165
Total	4.777.468	5.174.873	6.721.787	7.050.201

Source: Central Statistics Agency of East Java Province (1995, 2000, 2015 and 2020)

This phenomenon impacts the acceleration of urban development outside the suburbs (Prakasa & Istijanto, 2017), as well as physical changes in the city, and if this continues, it will result in urban sprawl and changes in land cover. Overall, the main characteristics of urban sprawl are low-density development (Jiang et al., 2007), growth along main roads (Wu et al., 2015), dispersed growth (Yue et al., 2016), dependence on motor vehicles (Jain & Pallagst, 2015), poor quality of life (Romano et al., 2017), and poor environment (Aithal et al., 2012). Moreover, housing, and high land prices in urban areas make city people prefer to live in suburban areas (Wagistina et al., 2017).

These factors have an impact on the loss of agricultural land, disruption of natural ecosystems, and the aesthetics of Green Open Space (GOS). GOS in urban areas creates a healthy and comfortable environment, which is important. The benefits of urban GOS are generated from ecological benefits for the balance of the built and artificial environment, namely in environmental sustainability (Setiawati, 2012). GOS, as a natural space, is a significant part of a city with solutions to various environmental problems (Putri & Zain, 2010).

The suburban area's spatial planning will continue to evolve as a source of urban space because of the significance of green open space in the Gerbangkertosusila area's sustainable development. A study on the tendency of land conversion and its influence on green open space in the Gerbangkertosusila area due to urban sprawl is required in light of this phenomena. Therefore, this study has three objectives, namely first, analyzing the impact of urban sprawl on Green Open Space (GOS) with the spatial dynamics of land cover changes using Land Use Cover Changes (LUCC) analysis using ArcGIS software. This method is considered accurate, general, and effective in change detection for urban area expansion mapping (Lu et al., 2004). Second, identifying the spatial pattern of urban sprawl over a period of 25 years and third, calculating the index sprawl value over a period of 25 years to determine the areas with the highest and lowest urban sprawl impacts in the Gerbangkertosusila area.

Research Method

Location and Time of Research

This study covers several areas within the selected satellite cities within the Gerbangkertosusila area (Figure 1): Gresik, Bangkalan, Mojokerto, Mojokerto City, Sidoarjo, and Lamongan. Spatial modeling was used to determine land cover changes in the Gerbangkertosusila area, identifying patterns of sprawl and index values. We obtained satellite imagery data from the United States Geological Survey (USGS) for 1995, 2000, 2015, and 2020. The year 1995 was chosen as the baseline period for mapping land cover conditions before the inauguration of the Gerbangkertosusila area and prior to the intensification of regional development. The year 2000 marked the initial phase of accelerated urbanization and land cover change patterns. 2015 marked the beginning of large-scale infrastructure development. 2020 marked a further phase of urbanization, with increasingly rapid land use intensification.

Source: Author's Analysis, 2024

Figure 1. Study area in the Gerbangkertosusila area, East Java Province

Land Use Cover Change (LUCC) Analysis

Land Cover Change Analysis (LUCC) was conducted by comparing Landsat satellite imagery data from 1995, 2000, 2015, and 2020 using ArcGIS software. The data used in this analysis were maps from the East Java Regional Housing and Settlement Agency. Figure 2 illustrates the Land Cover Change analysis procedure, which includes color composition, image cropping, geometric correction, and Maximum Likelihood Classification (MLC) to classify land cover. The MLC determines the probability of each LULC class for each cell based on its attribute values. A cell is assigned to the class with the highest probability, which is also known as the maximum likelihood class (Duda et al., 2000). This technique relies on comparing the spectral signatures of the target pixels to those of specific classes, using probability and a cost function. MLC is a widely used method for LULC classification when a supervised approach is selected. We selected this method because it is efficient, easy to implement, and typically performs well, particularly when the number of classes is small and there is less spectral variation among the pixels.

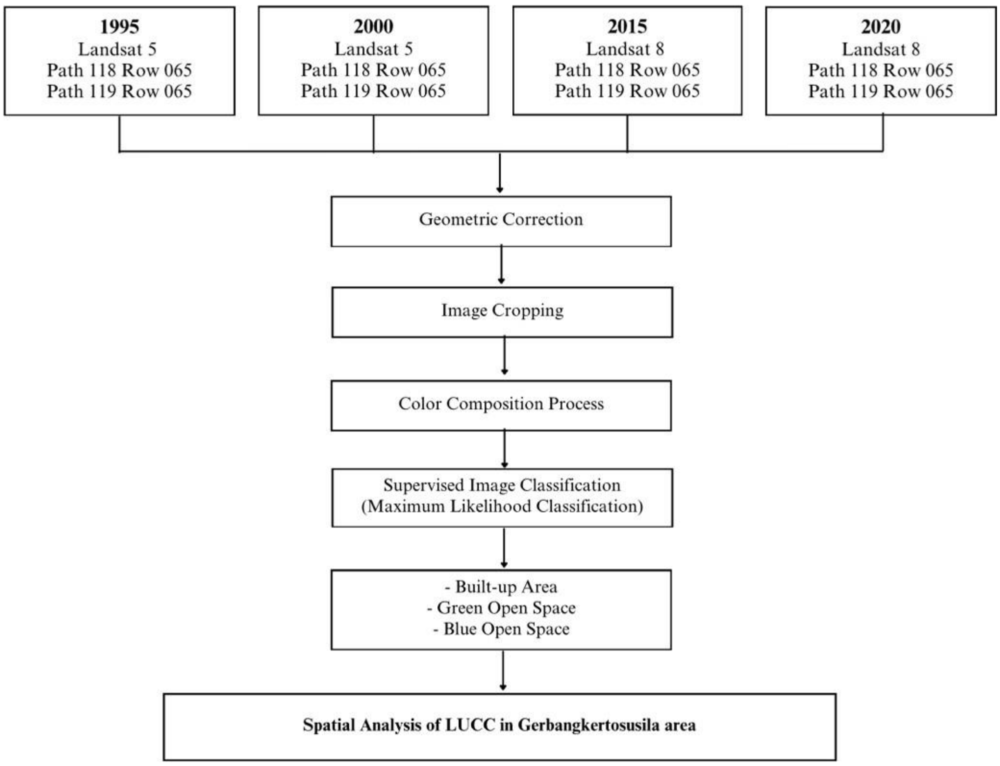
Table 2. Classification of land cover

Types of Land Cover	Description
Built-up area	Residential, industrial, road network, open land
Green open space	Farmland, forests, parks
Blue open space	Rivers, wetlands, lakes

Source: (SNI 7645:2010 on Land Cover Classification, National Standardization Agency)

This test assesses the degree of agreement between the classification results and field conditions, with an accuracy level of at least 80%. Based on the 2010 National Standardization Agency categorization (Table 2), this study used three types of land cover: Built-up Areas, Green Open Spaces, and Blue Open Spaces.

The final stage is accuracy testing using the Kappa Coefficient test in ArcGIS with Google Satellite as the basemap reference. Kappa coefficients and pertinent accuracy figures such as producer accuracy, user accuracy, and overall accuracy were determined. There were 65 validation samples utilized for each of the years 1995 and 2000, and 45 samples for each of the years 2015 and 2020. A stratified random sampling approach was used to spatially distribute the samples, with the LULC categories serving as the strata. Stratified random sampling, which is frequently employed in a variety of probability sampling scenarios, guarantees that each cell within each strata has an equal chance of being assessed. The majority of the ground truth data was derived from high-resolution Google Earth Pro, which were used to zoom in on the sample sites for each year under study.



Source: Author's Analysis, 2024

Figure 2. Flow chart of land cover analysis

Identification of Sprawl Patterns and Index Values

Following the acquisition of the LUCC study data for 25 years, an urban sprawl pattern was analyzed to ascertain whether the trend was concentrated in the Gerbangkertosusila area or spread evenly. Furthermore, the urban sprawl index value is calculated, which indicates the reduction in open space, the scale of land used for urban development, and the size of the pressure of regional development (Hidajat, 2004). By comparing the percentage of metropolitan area growth with the rate of population growth, the urban sprawl index value analysis is calculated. The following is the formula for the urban sprawl index:

$$\text{Indeks Sprawl} = \frac{\%\ \text{Urban area growth}}{\%\ \text{Population growth}}$$

Results and Discussions

Land Use Cover Change (LUCC) Analysis

Based on the Land Use Cover Changes (LUCC) analysis in Figure 3, we found that the Gerbangkertosusila area in 25 years shows changes in land cover classification. Accuracy testing was conducted using the Kappa coefficients analysis method in the ArcGIS application with Google Satellite as a base map. The land cover data accuracy test results for the Gerbangkertosusila area were 90.74% in 1995, 92.59% in 2000, 94.55% in 2015, and 96.29% in 2020. From 1995 to 2020, the Built-up Area in the Gerbangkertosusila area in Table 3 expanded by 8.27% of the total area, from 27425.34 ha (4.73%) in 1995 to 79480 ha (13.71%) in 2020. The impact of the expansion of the city of Surabaya on built-up space can be seen in the areas with the highest values in Sidoarjo at 42.95%, Mojokerto City at 37.86 and Gresik at 7.11%.

From our study, we found that the increase in Built-up Space in Sidorajo and Gresik has spread to Green Open Space, which has experienced a significant population expansion compared to the surrounding areas and is physically adjacent to Surabaya City (Hapsari & Aulia, 2019), and there is urbanization pressure from Surabaya City towards Sidoarjo and Gresik. Factors in Mojokerto City occurred due to the construction of the Mojokerto toll road towards Surabaya City, which has a length of 36.27 km (Putra & Salim, 2022), and has become a destination for developers in industrial and residential areas, which fundamentally changes the accessibility which makes Open Space increasingly increase.

Table 3. Land cover of built-up in Gerbangkertosusial area

Location	Area (%)				Change of Area (%)			
	1995	2000	2015	2020	1995-2000	2000-2015	2015-2020	1995-2020
Gresik	5,76	8,13	11,63	12,86	2,38	3,50	1,23	7,11
Bangkalan	0,57	1,46	2,87	4,91	0,89	1,41	2,04	4,34
Mojokerto	6,23	6,95	9,22	10,73	0,72	2,27	1,51	4,50
Mojokerto (City)	29,72	37,89	62,97	67,57	8,18	24,08	5,60	37,86
Sidoarjo	10,15	18,01	37,90	53,11	7,86	19,89	15,20	42,95
Lamongan	3,86	4,15	4,38	5,57	0,28	0,23	1,19	1,70
Gerbangkertosusila	4,73	6,57	10,51	13,71	1,83	3,95	3,20	8,98

Source: Author's Analysis, 2024

Table 4. Land cover of green open space in Gerbangkertosusial area

Location	Area (%)				Change of Area (%)			
	1995	2000	2015	2020	1995-2000	2000-2015	2015-2020	1995-2020
Gresik	72,73	77,48	70,45	65,19	4,75	-7,03	-5,26	-7,54
Bangkalan	96,56	96,23	94,56	92,12	-0,33	-1,67	-2,43	-4,44
Mojokerto	93,03	91,67	90,35	84,84	-1,36	-1,32	-5,51	-8,19
Mojokerto (City)	59,97	60,15	36,41	25,67	0,18	-23,74	-10,74	-34,30
Sidoarjo	62,56	60,70	44,15	27,41	-1,86	-16,55	-16,74	-35,15
Lamongan	88,29	85,25	88,88	84,59	-3,05	-3,63	-4,28	-3,70
Gerbangkertosusila	84,88	84,27	81,38	73,56	-0,61	-2,89	-5,82	-9,32

Source: Author's Analysis, 2024

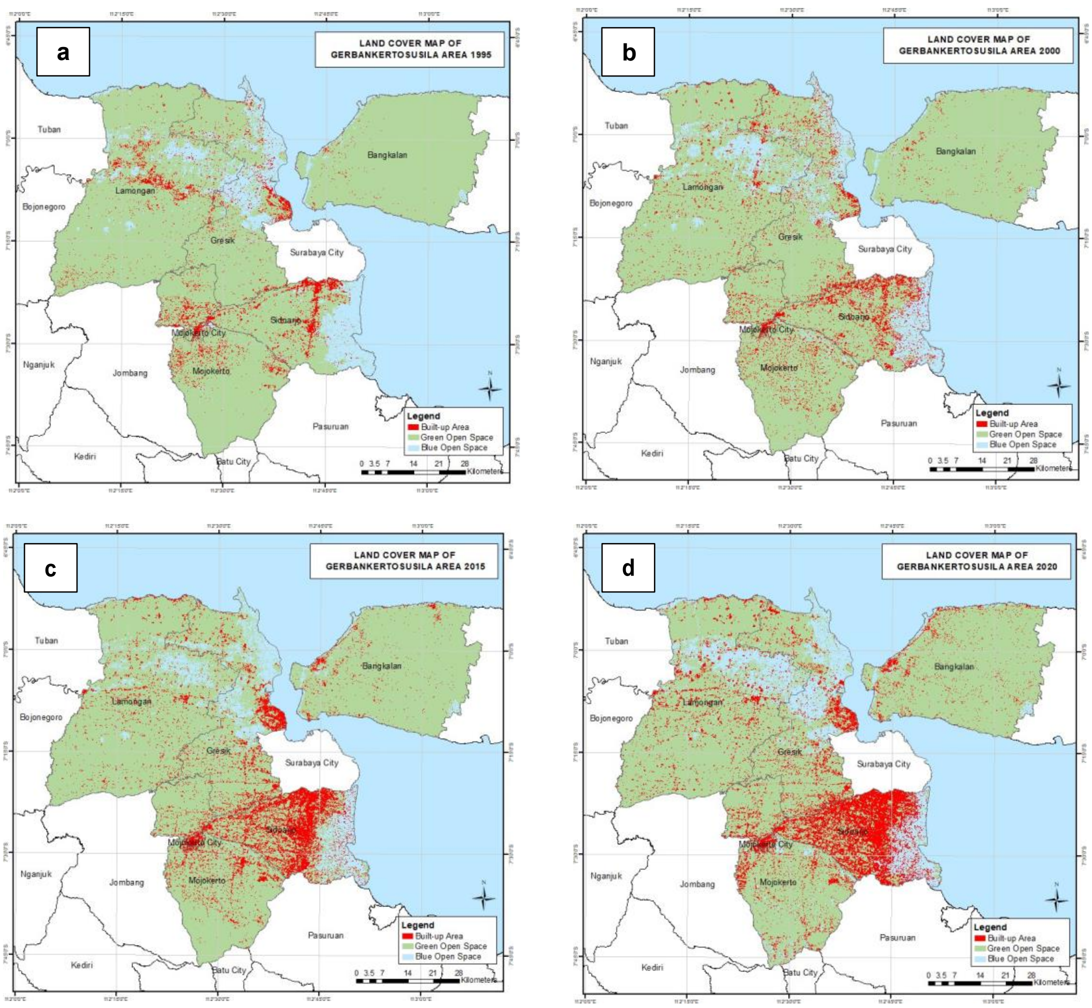
Table 5. Land cover of blue open space in Gerbangkertosusial area

Location	Area (%)				Change of Area (%)			
	1995	2000	2015	2020	1995-2000	2000-2015	2015-2020	1995-2020
Gresik	21,51	14,39	17,92	21,95	-7,12	3,53	4,03	0,44
Bangkalan	2,87	2,31	2,57	2,96	-0,55	0,26	0,39	0,10
Mojokerto	0,74	1,38	0,44	4,43	0,64	-0,95	3,99	3,69
Mojokerto (City)	10,32	1,95	1,62	6,76	-8,36	-0,33	5,14	-3,56
Sidoarjo	27,29	21,29	17,95	19,49	-5,99	-3,34	1,54	-7,80
Lamongan	7,84	10,61	6,74	9,84	2,76	3,87	3,10	1,99
Gerbangkertosusila	10,39	9,17	8,11	10,73	-1,22	1,89	0,85	1,34

Source: Author's Analysis, 2024

In Table 4, Green Open Space (GOS) has decreased by 9.32%. In 1995, it was 491901.94 ha (84.88%); in 2020, it was 437876.53 ha or 73.56%. The highest decrease was in Sidoarjo, at 35.15%, followed by Mojokerto City, at 34.30%, and Gresik, at 7.54%. This is because of the area's population growth rate and the number of people living there as a result of extensive home building over the past few decades. It is also because of the large number of people who choose to work in Surabaya City and choose to live on the outskirts of Surabaya City so that there is a new residential development center, the availability of adequate transportation and infrastructure, low land values that change the shape of the landscape, and the factor of reduced GOS, that directly harms environmental sustainability. The loss of green open space reduces water catchment areas (increasing the risk of flooding), reduces air quality (loss of pollutant absorbers).

The percentage of Blue Open Space is shown in Table 5, from 1995 to 2020 the lowest decline occurred in Sidoarjo at -7.80%, Mojokerto City at -3.56% and Gresik at 0.44%. This occurs in these areas due to climate change which causes fluctuations in weather and soil quality, reducing productivity and land carrying capacity which has an impact on the decline in blue open space. The loss of Blue Open Space reduces their natural pollutant filtering function. When these lands are converted, the quality of surface and groundwater deteriorates, threatening the availability of clean water a key pillar of sustainability. The decline in Blue Open Space increases the vulnerability of coastal areas (especially Sidoarjo and Gresik) to future climate disasters, which is contrary to the goal of Urban Sustainability to build resilient cities.



Source: Author's Analysis, 2024

Figure 3. Map of land cover change in the Gerbangkertosusila area: (a) 1995, (b) 2000, (c) 2015 period and (d) 2020 period.

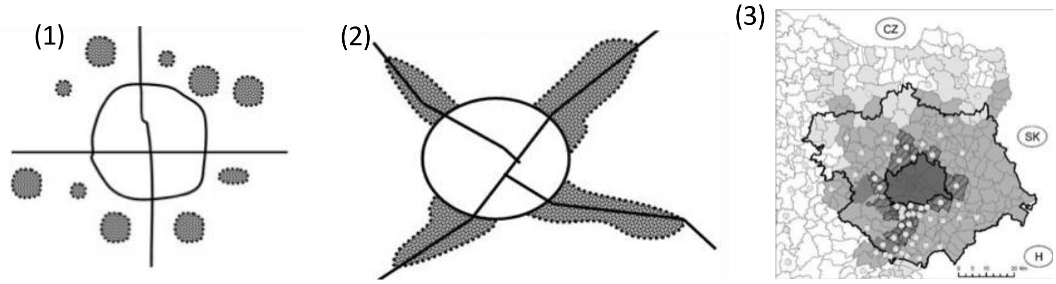
Pattern and value of the urban sprawl index

a. Urban sprawl pattern

Analysis of urban sprawl spatial patterns in the period 1995-2000 shows a leapfrog development pattern that occurred in Gerbangkertosusila (Figure 4 (1)). Leapfrog is the most detrimental, because it has no aesthetic value, is economically inefficient and unattractive (H. S. Yunus, 1994). This resulted in uneven provision of public facilities and inefficient development infrastructure because it was spread across separate points (H. Yunus, 2000). In contrast, Sidoarjo tended to follow a ribbon development pattern in the same period (Figure 4 (2)). Ribbon Development shows uneven urban sprawl on the outer side and the main city area. This sprawl occurs along transportation routes, especially from the city center which is radial. The main transportation route that connects Sidoarjo and Surabaya City tends to be followed by the linear growth of built-up areas.

The spatial pattern of urban sprawl from 2015 to 2020 in the study area shows a typical ribbon development pattern (Figure 4 (2)) as a result of the growth of populated areas along the major toll road corridors, including Porong-Gempol, Surabaya-Mojokerto, and

Surabaya-Gresik. In Sidoarjo, there is a transformation towards the post-suburbia phase (Figure 4 (3)). The post-suburbia is characterized by significant changes in land use and socio-economic structures, with a shift in land function from agriculture to more complex industrial and service areas and this is reinforced (Kling et al., 1995). Fishman's opinion (Fishman, 1987) about post-suburbia as a multifunctional activity center aligns with the conditions in Sidoarjo, which shows the growth of new economic activity centers outside the main urban area.



Source: Author's Analysis, 2024

Figure 4. Urban sprawl patterns 1) Leap frog development, 2) Ribbon development and 3) Post- suburbia in the Gerbangkertosusila Area

b. Distribution of Sprawl Index Values

To analyze the urban sprawl phenomenon in the Gerbangkertosusila area, we calculated the sprawl index by comparing urban area and population growth data from 1995-2020 (Table 6). From the sprawl index analysis results, Sidoarjo was identified as the area with the highest value in the Gerbangkertosusila area, indicated by the highest sprawl index value of 4.74. There is high development pressure on land for various community needs, such as housing and public facilities, as well as an increase in population that has significantly driven urban sprawl in Sidoarjo.

Table 6. Sprawl Indeks Value 1995-2020

Location	Sprawl Indeks Value
Gresik	-1,23
Bangkalan	-7,62
Mojokerto	-5,80
Mojokerto (City)	3,35
Sidoarjo	4,74
Lamongan	2,84

Source: Author's Analysis, 2024

Rapid economic growth often triggers uncontrolled urban expansion, where high demand for land drives the development of new industries and settlements. In contrast, Bangkalan shows a slower and more controlled sprawl index value, with a negative sprawl index value of -7.62. This indicates the presence of more expansive green open spaces and lower development pressure.

Conclusion

Green Open Space (GOS) in the Gerbangkertosusila area has significantly decreased by 9.32% due to land conversion for housing and infrastructure development brought on by the fast urbanization of the Surabaya City area, according to the study's findings from the Land Use and Cover Change (LUCC) analysis. The built-up area of the Gerbangkertosusila area has been growing for the past 25 years, accounting for 8.27% of the total area, particularly in Sidoarjo and Gresik, which are close to Surabaya City. This shows that converting GOS into Built-up areas will continue to be a significant challenge in regional management.

The Leapfrog and Ribbon development patterns, which led to inefficiency and were deemed the most harmful, were identified in the study of spatial patterns of urban sprawl from 1995 to 2000. The development of built-up regions also followed the primary transportation lines. From 2015 to 2020, the Gerbangkertosusila area showed a typical Leap Frog Development pattern and a post-suburban phase, marked by significant land use and socioeconomic structure changes. At the highest urban sprawl index value in Sidoarjo, the population is growing rapidly, thus driving the need for land. There is low development pressure at the lowest urban sprawl index value in Bangkalan, so urban growth is more controlled.

The study in Gerbangkertosusila area shows the need for spatial policy solutions in response to the pressure of urbanization from Surabaya City on GOS in the suburbs. In an effort to control urban sprawl, one concept that is considered effective is the Urban Growth Boundary (UGB). As stated by Ball (Ball et al., 2014), UGB works by setting clear boundaries regarding areas that are permitted and prohibited for urban development. The application of the UGB concept contributes to the preservation of green open spaces and agricultural land, minimizing negative impacts on the environment, improving people's standard of living, and encouraging efficiency in infrastructure development. Implementation of UGB is a key policy to achieve sustainability. UGB serves as a tool for green open space on a permanent basis, limiting the city's ecological footprint.

In the recommendations for managing GOS, the utilization of Built-up area vertically is proposed as a solution to overcome the limitations of agricultural land, forests, and other green open spaces that are essential for ecosystem balance. In order for the implementation of this strategy to provide optimal and effective results, support from regional planning policies is essential.

References

Aithal, B. H., TV, R., & Sanna, D. D. (2012). Insights to urban dynamics through landscape spatial pattern analysis. *International Journal of Applied Earth Observation and Geoinformation*, *18*, 329–343. https://doi.org/10.1016/j.jag.2012.03.005

Ball, M., Cigdem, M., Taylor, E., & Wood, G. (2014). Urban Growth Boundaries and their Impact on Land Prices. *Environment and Planning A: Economy and Space*, *46*(12), 3010–3026. https://doi.org/10.1068/a130110p

Duda, R. O., Hart, P. E., & Strork, D. G. (2000). *Pattern Classification, Second ed*. Interscience Publication.

Efendi, A., & Aimon, H. (2024). Analisis Pengaruh variabel Makroekonomi Terhadap Pertumbuhan Ekonomi di Indonesia. *Media Riset Ekonomi Pembangunan*, *1 (3)*, 391–400. https://medrep.ppj.unp.ac.id/index.php/MedREP/login

Fishman, R. (1987). *Bourgeois Utopias: The Rise and Fall Of Suburbia*. Basic Book.

Hapsari, A. D., & Aulia, B. U. (2019). Tipologi Wilayah Peri Urban Kabupaten Sidoarjo Berdasarkan Aspek Fisik, Sosial, dan Ekonomi. *Jurnal Teknik ITS*, *7*(2). https://doi.org/10.12962/j23373539.v7i2.34248

Hidajat, J. T. (2004). *Kajian Gejala Urban Sprawl di Tiga Koridor Utama Pinggiran Kota Wilayah JABOTABEK*.

Institut Pertanian Bogor.

Hidajat, J. T., & Ridwan, M. (2018). Assessment of the quality of public green open space (GOS) in the urban fringes in response to urban sprawl phenomenon (case study District of Tanah Sareal, Bogor City). *IOP Conference Series: Earth and Environmental Science*, *179*(1). https://doi.org/10.1088/1755-1315/179/1/012027

Jain, M., & Pallagst, K. (2015). Land Use Beyond Control. *DisP - The Planning Review*, *51*(3), 29–43. https://doi.org/10.1080/02513625.2015.1093349

Jiang, F., Liu, S., Yuan, H., & Zhang, Q. (2007). Measuring urban sprawl in Beijing with geo-spatial indices. *Journal of Geographical Sciences*, *17*(4), 469–478. https://doi.org/10.1007/s11442-007-0469-z

Katherina, L., & Indraprahasta, G. (2019). Urbanization pattern in Indonesia's secondary cities: Greater Surabaya and its path toward a megacity. *IOP Conference Series: Earth and Environmental Science*, *338*(1). https://doi.org/10.1088/1755-1315/338/1/012018

Kling, R., Olin, S. C., & Poster, M. (1995). The Emergence of Post-suburbia: An Introduction. In *Post- suburban California: The Transformation of Orange County since World War II* (Paperback edition). University of California Press.

Lu, D., Mausel, P., Brondízio, E., & Moran, E. (2004). Change detection techniques. *International Journal of Remote Sensing*, *25*(12), 2365–2401. https://doi.org/10.1080/0143116031000139863

McGee, T. G. (2007). Metrofitting the Emerging Mega-Urban Regions of ASEAN: An Overview. In *The Mega-Urban Regions of Southeast Asia* (pp. 3–26). University of British Columbia Press. https://doi.org/10.59962/9780774854351-004

Prakasa, D. T., & Istijanto, S. (2017). Implementation of Spatial Hybrid Concept in Sustainable City Growth in Urban Sprawl Periphery Case Study: Border Area Surabaya with Sidoarjo Regency. *Asian Academic Society International Conference (AASIC)*.

Pravitasari, A. E., Rustiadi, E., Mulya, S. P., Widodo, C. E., Indraprahasta, G. S., Fuadina, L. N., Karyati, N. E., & Murtadho, A. (2020). Measuring urban and regional sustainability performance in Java: A comparison study between 6 Metropolitan Areas. *IOP Conference Series: Earth and Environmental Science*, *556*(1). https://doi.org/10.1088/1755-1315/556/1/012004

Putra, R. D. W., & Salim, W. (2022). Struktur Ruang Wilayah Gerbangkertosusila Berdasarkan Teori Pusat-Pinggiran: Sebuah Kajian. *TATALOKA*, *24*(3), 186–201. https://doi.org/10.14710/tataloka.24.3.186-201

Putri, P., & Zain, A. F. (2010). Analisis spasial dan temporal perubahan luas ruang terbuka hijau di Kota Bandung. *Jurnal Lanskap Indonesia*, *2*(2). https://doi.org/doi.org/10.29244/jli.2010.2.2.%25p

Ramachandra, T. V, Bharath Aithal, H., Vinay, S., Joshi, N. V, Kumar, U., & Rao, K. V. (2013). *Modelling Urban Revolution in Greater Bangalore, India*. http://ces.iisc.ernet.in/energy

Romano, B., Zullo, F., Fiorini, L., Marucci, A., & Ciabò, S. (2017). Land transformation of Italy due to half a century of urbanization. *Land Use Policy*, *67*, 387–400. https://doi.org/10.1016/j.landusepol.2017.06.006

Setiawati. (2012). *Analisis Ruang Terbuka Hijau dan Pengalihgunaannya di Kota Bogor*. Institut Pertanian Bogor

Sudarsono, A. (2015). *Analisis Potensi Ekonomi Sektoral dan Keterkaitan Ekonomi di Wilayah Gerbangkertosusila*. Universitas Airlangga.

Sudhira, H., & Ramachandra, T. (2007). Characterizing urban sprawl from remote sensing data and using landscape metrics. *Computer in Urban Planning and Urban Management*. http://www.clarklabs.org

Tommy Firman, & Fikri Zul Fahmi. (2017). The Privatization of Metropolitan Jakarta's (Jabodetabek) Urban Fringes: The Early Stages of "Post-Suburbanization" in Indonesia. *Journal of the American Planning Association*, *83*(1), 68–79. https://doi.org/https://doi.org/10.1080/01944363.2016.1249010

Wagistina, S., Suman, A., & Yanuwiadi, B. (2017). Urban Sprawl, Suburbanization, and Informal Sector in Westerner Suburb Area-Malang City-East Java. *Wacana*, *20*(2), 89–97.

Wu, W., Zhao, S., Zhu, C., & Jiang, J. (2015). A comparative study of urban expansion in Beijing, Tianjin and Shijiazhuang over the past three decades. *Landscape and Urban Planning*, *134*, 93–106. https://doi.org/10.1016/j.landurbplan.2014.10.010

Yue, W., Zhang, L., & Liu, Y. (2016). Measuring sprawl in large Chinese cities along the Yangtze River via combined single and multidimensional metrics. *Habitat International*, *57*, 43–52. https://doi.org/10.1016/j.habitatint.2016.06.009

Yunus, H. (2000). *Struktur Tata Ruang Kota*. Pustaka Pelajar.

Yunus, H. S. (1994). *Teori dan Model Struktur Keruangan Kota*. Fakultas Geografi. Universitas Gajah Mada.