Bulletin of Geology
e-ISSN 2580-0752
e-ISSN 2580 – 0752
Fakultas Ilmu dan Teknologi Kebumian
Institut Teknologi Bandung
www.buletingeologi.com

IDENTIFY THE PATTERN OF URBAN GROWTH IN BANDUNG CITY USING GEOSPATIAL ANALYSIS

Dwiputra Sam, Albertus Deliar, Anjar Dimara Sakti, Riantini Virtriana, Budhy Soeksmantono, Akhmad Riqqi, Andri Hernandi, Sella Lestari Nurmaulia

1. Department of Geodesy and Geomatics Engineering, Faculty of Earth Sciences and Technology, Bandung Institute of Technology, 10th Ganesha Street, Bandung, Indonesia
email: dwiputrasam@gmail.com

Abstract. Land-use changes essentially are a side-effect of the growth of a city, which is commonly caused by urban developments. The spreading of urban developments on undeveloped land near a city (Urban Sprawl) may lead to a lack of urban planning, a lack of proper laws that regulate urban planning, and many other issues. To mitigate urban sprawl, the current study aims to determine the pattern of Bandung City's growth. The study focuses on the urban developments, that may have caused urban sprawl. The usage of time-series spatial data in an urban development analysis is typically used as the backbone of the study. Therefore, a 30 year dataset (1988-2018) is used to determine the pattern. The mean spatial method has been used to evaluate the dataset in Bandung City and the districts around the city. The method resulted in a pattern of movement resulting into the southwestern part of the city. Two points are also used to act as a pivot to determine the direction of the city's growth. The geometrical center of the study area and Gedung Sate were chosen as the pivot points. The direction of Bandung City's growth based on the two pivot points resulted in the Southwest direction.

1. INTRODUCTION

A city can be defined as a permanent and densely settled place with defined boundaries whose members work primarily on non-agricultural tasks (Caves, 2004). The growth of urban residence indicates rapid city growth, along with the growth of population and volume of development in the city (Fadila *et al.*, 2017). The world is currently experiencing the largest urban development in its history. Currently, most of the world's population lives in urban areas. It is estimated that by 2030, this number the number of urban citizens will reach 5 billion people (United Nation Population Fund, 2023).

Urban development has caused urban sprawl, which is uncontrolled and unregulated urban growth that hinders sustainable development of urban or rural areas (Paramasivam & Arumugavelu, 2020) Urban sprawl usually results in the expansion of urban areas toward surrounding areas. Urban sprawl is caused by various factors (Bhatta, 2010), namely:

- **Population Growth**. High urban population growth is one of the main factors of urban sprawl. This population growth is caused by natural population growth and migration. High population growth can lead to uncontrolled urban growth, resulting in urban sprawl.
- **Government Policies**. Government policies influence the regulation and taxation of an area. Regulations in urban areas are stricter than in rural areas, and taxes in urban areas are higher than in rural areas. Regulations and taxes favor the development of areas outside the city, which can lead to urban sprawl. In addition, the lack of planning policy or failure to implement planning policy can also cause urban sprawl.
- **Economic Growth**. Economic growth and industrialization result in an increased demand for more housing land for workers. Uncontrolled and uncoordinated development of housing and other infrastructure can lead to urban sprawl.
- **Speculation**. Speculation on city growth also leads to unplanned growth. Land prices in suburban areas are expected to continue to increase, so institutions or individuals have a desire to own and develop the land.
- **Topography**. Another factor is the topography of the area. Urban sprawl can be caused by unsuitable land, such as mountains, bodies of water, and so on, resulting in discontinuous urban development.

Urban sprawl can have positive and negative impacts on urban and surrounding areas. Examples of positive impacts of urban sprawl include increased economic production in suburban areas and expanding better basic services, such as health, education, and others to suburban areas (Bhatta, 2010). However, urban sprawl also reduces agricultural and ecological productivity, increases public infrastructure costs, and increases traffic congestion, accidents, pollution, and emissions (Litman, 2015). Another impact of urban sprawl is the change in land cover in urban and surrounding areas. Urban sprawl results in the expansion of urban areas, increasing areas with building land cover around urban areas and decreasing areas with vegetation land cover, agricultural land cover, and other land covers (Mundhe & Jaybhaye, 2014. Efforts to meet the increasing human needs have put pressure on space and natural resources (Purwoko, 2009). These efforts, of course, require large amounts of costs. Therefore, a comprehensive study regarding urban planning is needed to anticipate the consequences of urban sprawl.

One of the common and recent approaches to identify land building growth as an impact of urban sprawl is by using satellite imagery and geographic information systems (GIS) to map and monitor changes in land cover over time (Alam & Banerjee, 2022). GIS is a computerized system that allows users to acquire, manipulate, analyze, and present geographical data, with the purpose to prepare, represent, and interpret facts related to the earth's surface (Niode *et al.*, 2016). Generally, GIS can visualize raw data that are not related to valuable information when combined with expert opinions (Janke, 2010). Urban and regional planning is certainly one of the common things that use GIS in its implementation.

The purpose of this research is to identify the pattern of urban development based on the growth of built-up area cover using GIS. This research use time series data on the built-up area in the Bandung Metropolitan Area, from 1988 to 2018. The study will identify the patterns of urban growth in Bandung by analyzing the movement of the geometrical center point of the built-up area. The study also identifies the movement of the geometrical center point relative to the geometric center of Bandung City, and the city's landmark.

.

This study aims to provide valuable insights into the urban growth of Bandung City while addressing the challenge of mitigating urban sprawl. By analyzing the movement of the built-up area's center point, we can determine the direction of the city's expansion. Additionally, by examining the city's growth patterns in relation to its geographic center and a prominent landmark, we can analyze how the development is interconnected with these focal points. The findings of this study hold potential to improve Bandung City by informing future urban planning and development strategies. By gaining a deeper understanding of the city's growth dynamics, decision-makers can implement sustainable and efficient development plans that help mitigate urban sprawl. Ultimately, this research endeavour aims to contribute to the overall well-being of Bandung City and foster a better urban environment for its residents.

2. STUDY AREA LOCATION

Bandung is a city located in West Java, Indonesia. It is situated approximately 140 kilometers Southeast of Jakarta, the capital of Indonesia. Bandung is nestled in a basin surrounded by mountains, including the Tangkuban Perahu, Burangrang, and Manglayang Mountains. The city's location in a basin has resulted in its geography being dominated by hilly terrain, with elevations ranging from 700 to 1,000 meters above sea level. The study area is located between the latitudes of 6.9220° S to 7.0734° S and the longitudes of 107.5664° E to 107.7388° E. Bandung is a hub for transportation and commerce in West Java, with a population of approximately 2.5 million people as of 2022 (Badan Pusat Statistik). Even though the main study focuses on Bandung City, the study also gathered built-up area data from districts around Bandung City (Figure 1). Districts around Bandung City were taken from several different regencies outside Bandung City, which are districts around Cimahi City, West Bandung Regency, and Bandung Regency. Data from regencies were included in the study to taking account the effects of the growth of the built-up area surrounding Bandung City due to the growth of Bandung City itself.

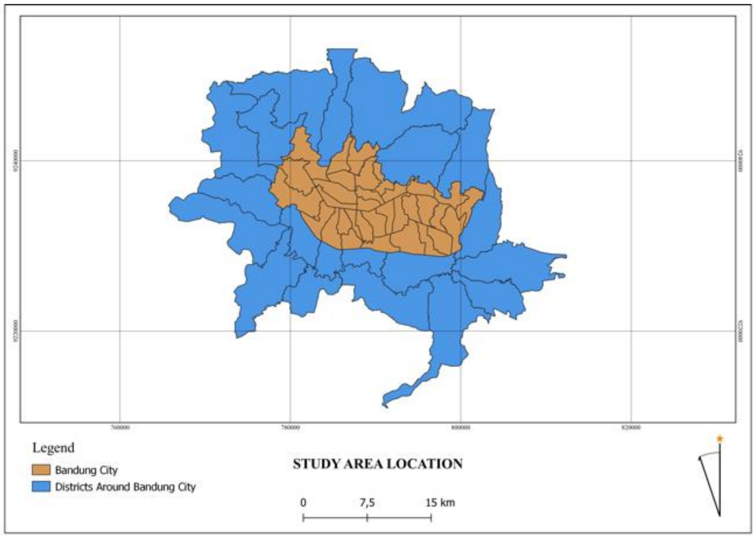

Figure 1. Orange colour indicating Bandung City and blue indicating surrounding district, Cimahi City, West Bandung Regency, and Bandung Regency

3. DATA AND METHODOLOGY

In this study, the following data are used to help determine the pattern of urban growth of the study area: A vectorized time series of geographic impervious data from 1988 – 2018, and vector data of administrative region boundaries. Impervious data of urban areas are a predominant indicator of human settlements (Gong *et al*., 2019). Therefore, the impervious data of urban area were used as the built-up area variable in this study.

The impervious data was acquired from the "Tsinghua FROM-GLC Year of Change to impervious Surface" dataset which is a global artificial impervious area (GAIA) data. The data source is currently the longest temporal coverage of GAIA currently available in the world, with the temporal coverage of 33 years (Gong *et al*., 2019). The GAIA dataset comprised of imagery captured by the Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI). These images underwent classification through a supervised classification method and have overall accuracy of 89% and spatial resolution of 30 m (Gong *et al*., 2019). Additionally, the administrative region boundaries data was sourced from Indonesia's Geospatial Information Agency (BIG).

This study aims to analyze the urban growth of Bandung City using two methods. The first method involves analyzing the movement of the geometrical center point of the built-up area. The analysis uses 33 years of impervious data with an interval of 3 years starting from 1988 until 2018. The study analyzes each change of direction on the 11 years point of the geometrical center of the built-up area. The second method involves analyzing the direction of the center point relative to the city center of Bandung City and the city's landmark.

To analyze the urban growth based on the city center, the study uses the geographic center of the city. This center point is calculated from the average of the coordinate positions of the region boundary. Meanwhile, the study also considers Gedung Sate, a government building, as the central place for the growth of the city. As the office of the governor of West Java and the provincial parliament, Gedung Sate also serves as a popular tourist attraction. Therefore, the analysis of urban growth based on the city's landmark is based on Gedung Sate.

The mean spatial is the predominant method of this study. The mean spatial method calculates the average coordinate value of a collection of geographic data. The result of this method is a single point located at the geographic center of the data collection (ESRI). Graves (2023) define the mathematical formula of mean spatial method for two-dimensional data with horizontal (x) and vertical (y) axis and (n) number of data at the feature (i) is as follows:

$$Mean\ Spatial\ (x, y) = \left(\frac{\sum_{i=1}^{n} x_i}{n} \ , \ \frac{\sum_{i=1}^{n} y_i}{n} \right)$$

The mean spatial method approach essentially has the same concept as the concept of equilibrium in a system that has a center of the mass point. Meriam and Kraige (2015) explained that the center of mass point can be defined as the point where the mass of a system is concentrated. The position of the center of the mass point is determined by the mass distribution in the system. If the system is symmetrical (has homogeneous mass), then the center of the mass point is the same as the geometric center point of the system. However, if the system is asymmetrical, then the center of mass point will have an offset from the geometric center point of the system (Meriam and Kraige, 2015)

The application of the Mean Spatial method in spatial analysis is not limited to symmetrical systems. Each point of geographic data can have different masses (weights). Graves (2023) also defines the mathematical formula of mean spatial, which has different weights (w) for asymmetrical systems with horizontal (x) and vertical (y) axes and the number of data (n) at the feature (i), is as follows:

$$Mean\ Spatial\ (x,y) = \left(\frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \ , \ \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i} \right)$$

This study solely utilizes the impervious surface classification for its data. Consequently, in the application of the mean spatial method within this study, the system has homogeneous mass, enabling the exclusion of weight variable from the calculation.

4. RESULTS AND DISCUSSIONS

4.1. Pattern of urban growth

The result of mean spatial method on each year of the impervious data from 1988-2018 was made with a total of 11 points (Figure 2). The amount of areas covered by impervious surfaces is a good measure of urban development (Barnes *et al.*, 2001). As shown in (Figure 2), the result of mean spatial shows the direction of Bandung City's growth was headed Southwest

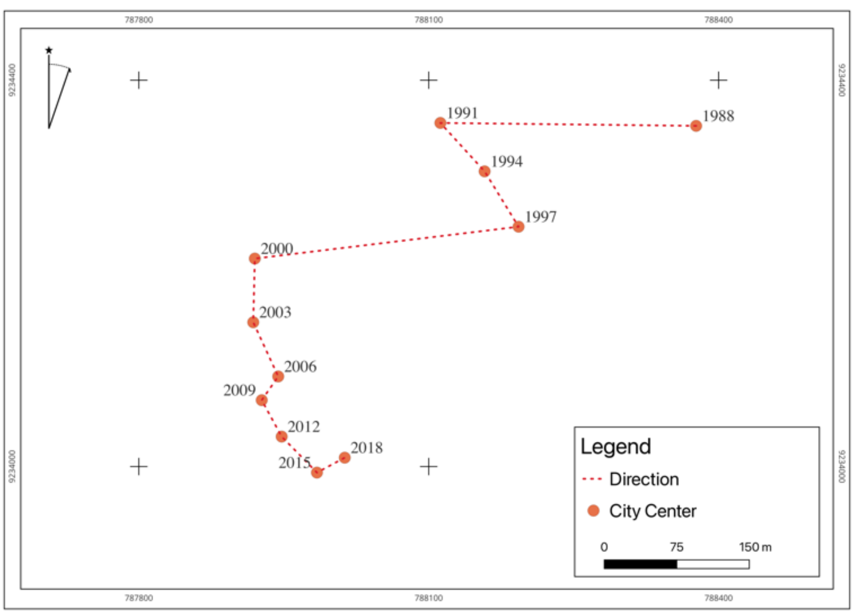

Figure 2. The movement of the city's center point of the built-up area.

In the year 1988 until 1991 and 1997 until 2000, the movement of the city's center is at its highest (Table 1). Those years also had the same direction, which was directed to the West. The data also shows that the majority of the growth direction went to the South, except for 1997-2000, and in 2009-2018. The last 3 points of the result (2009-2018) have consistently headed into the eastern part of the city. This may indicate the change in built-up area behaviour from 2009 until 2018

BULLETIN OF GEOLOGY, VOL. 7, NO. 3, 2023
DOI: 10.5614/bull.geol.2024.8.1.1

.

Table 1. Distance and angle of mean spatial through the years.

Year	Distance (m)	Angle (°)	Direction
1988 – 1991	264.550	270.644	West
1991 – 1994	67.846	140.747	Southeast
1994 – 1997	67.196	148.750	Southeast
1997 – 2000	274.790	262.954	West
2000 - 2003	65.984	185.427	South
2003 - 2006	61.780	158.236	South
2006 - 2009	29.915	217.071	Southwest
2009 - 2012	43.006	156.067	Southeast
2012 - 2015	52.154	140.330	Southeast
2015 - 2018	32.644	63.912	Northeast

4.2. Subdivided Areas

In accordance with the research methodology, the area is subdivided into 8 different directions (Figure 3). The geometrical center of the study area is located at (6.9128° S, 107.6182° E), and The Gedung Sate is located at (6.9025° S, 107.6187° E). The two coordinate is used in this study as a pivot point to determine the growth's direction (Figure 4 and Figure 5).

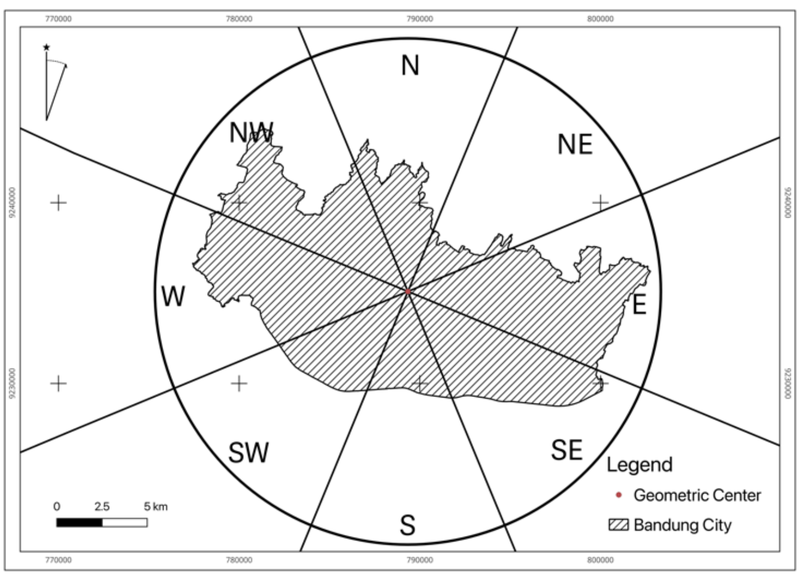

Figure 3. Eight subdivided areas from the geometrical center.

4.3. Mean spatial result relative to the geometrical city's center and Gedung Sate

It is safe to assume, that developed areas have a higher percentage of built-up areas than less developed areas (Sudhira *et al*, 2004). Each movement of the direction on the center point indicates a certain direction has a more developed area than others. As shown in Figure 4 and .

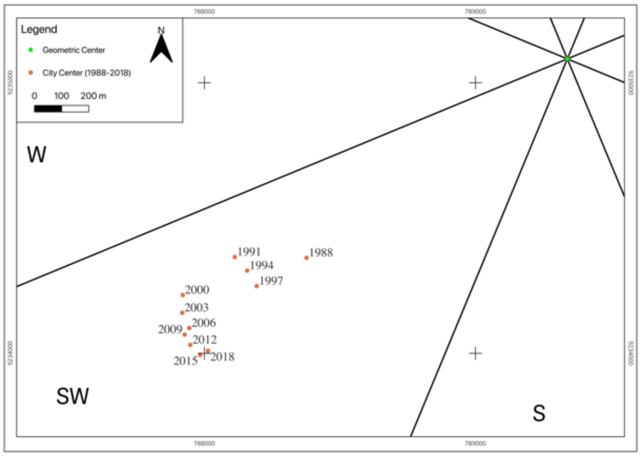

Figure 4. Mean spatial result relative to city's center.

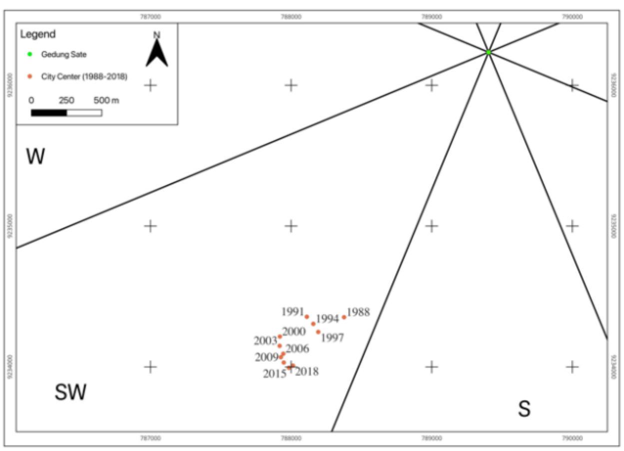

Figure 5. Mean spatial result relative to Gedung Sate.

The data from Table 2 provides the city center's distances, angles, and directions relative to Gedung Sate and the city's center. From the data, we can infer that the built-up area of Bandung has been expanding towards the Southwest from 1988 to 2018. The result also shows the rate of expansion toward Southwest appears to have slowed down in recent years. The result shows the distance from the city's center in 2015 and 2018 is almost the same, with only a 32m decrease from Geometric Center, and 28m from Gedung Sate. Overall, the table indicates that Bandung's built-up area has been

Figure 6, both of the data show consistent results. The mean spatial result relative to the city's center (Figure 4) and the mean spatial result relative to Gedung Sate (Figure 5) have the same general direction, which is headed into the Southwestern part of the city

expanding towards the Southwest, and the rate of expansion has been slowing down in recent years.

Comparing the two tables (from Geometric Center and Gedung Sate), the study shows that the distance from the Gedung Sate is always greater than the distance from geometric city's center. This is due to that the Gedung Sate is located further to the northeast of the city's center. Additionally, except for the year 2015-2018, the distance from both reference points increases gradually over time.

Bandung City's growth towards the southern part of the city is may due to several factors, including the topography of the region. The northern part of Bandung is predominantly characterized by steep terrains and mountains. Sometimes, urban sprawl is caused due to unsuitable physical terrain for continuous development, this often causes leap-frog development sprawl (Harvey & Clark, 1965; Barnes *et al.,* 2004). But it is also important to mention in many instances, those development problems cannot be overcome (Bhatta, 2010). On the other hand, one driving factor of growth towards the west is the presence of transportation infrastructure that connects Bandung to the capital city of Indonesia, Jakarta. The construction of toll roads had many positive effects on the socio-cultural and economic aspects of the areas (Siswoyo, 2020). The Jakarta-Cikampek and Cipularang toll road, for example, provides a direct link between the two cities, making it easier for people and goods to travel between them.

The biggest reasons for urban growth are the natural population increase and migration to urban areas (Bhatta, 2010). The potential main driving factor of the pattern of urban growth that headed into the Southwestern part of Bandung City may have been caused by the rapid population growth, especially in the Southern and Western parts of the city. West Bandung Regency had a consistent population increase between 2018 and 2020 (Badan Pusat Statistik). Districts in Bandung Regency such as Margaasih, Margahayu, and Dayeuhkolot (which is located in the southwestern part of Bandung Regency) also have consistent population growth from 2017 until 2019 (Badan Pusat Statistik).

BULLETIN OF GEOLOGY, VOL. 7, NO. 3, 2023
DOI: 10.5614/bull.geol.2024.8.1.1

Table 2. Distance and angle of mean spatial relative to geometric center and Gedung Sate through the years.

Place	*Year*	*Distance (m)*	*Angle (°)*	*Direction*
Geometric Center	1988	1,211.010	232.332	Southwest
	1991	1,427.838	243.449	Southwest
	1994	1,415.793	240.758	Southwest
	1997	1,419.715	238.047	Southwest
	2000	1,665.864	238.124	Southwest
	2003	1,702.716	236.262	Southwest
	2006	1,713.153	234.219	Southwest
	2009	1,741.350	233.887	Southwest
	2012	1,747.202	232.488	Southwest
	2015	1,741.450	230.785	Southwest
	2018	1,709.385	230.582	Southwest
Gedung Sate	1988	2,142.008	208.670	Southwest
	1991	2,390.399	218.654	Southwest
	1994	2,296.564	217.004	Southwest
	1997	2,324.245	215.511	Southwest
	2000	2,506.028	216.352	Southwest
	2003	2,560.423	215.507	Southwest
	2006	2,591.653	214.321	Southwest
	2009	2,621.567	214.327	Southwest
	2012	2,641.364	213.496	Southwest
	2015	2,652.805	212.395	Southwest
	2018	2,624.418	212.045	Southwest

5. CONCLUSIONS

In conclusion, the study has successfully identified the pattern of urban growth in Bandung City using geospatial analysis. The results showed that the urban growth of Bandung City has been mainly directed to the southwest. However, in recent years, the study shows a slowdown in growth towards the southwest and began moving towards the northeast. These findings suggest that the urban development patterns in Bandung City may begin to shift. The study highlights the importance of using geospatial analysis to understand urban growth patterns. The study was able to identify the movement of urban growth over time. This approach can be particularly useful in cities where data on urban growth patterns are limited, or where the city's physical size makes it difficult to obtain accurate information through traditional survey methods.

The present study, while contributing valuable insights to the field, is not without its limitations. One such limitation is the spatial resolution of the data used, which is 30 meters. This resolution may not have classified all impervious surfaces accurately, especially for regions who have geographic features smaller than 30 meters in area. In addition to the limitation of spatial resolution, another significant constraint of the study is the proximity of the city center to the city's landmark. This proximity poses challenges in discerning the distinct effects of the landmark on the city center. The close spatial relationship between the two makes it difficult to disentangle the impacts of the landmark from the overall pattern of the urban growth. To address these limitations, future studies can utilize higher-resolution data for more accurate identification of impervious surfaces. Additionally, selecting pivot points further away from the city center would enable clearer assessment of how a certain place can influence the pattern of urban growth.

REFERENCES

Alam, T. and Banerjee, A. 2023. Characterizing land transformation and densification using urban sprawl metrics in the South Bengal region of India. *Sustainable Cities and Society*, *89*, p.104295.

Badan Pusat Statistik (BPS) (2023, 11 January). Penduduk Indonesia https://bandungkab.bps.go.id/indicator/12/33/1/jumlah-penduduk-menurut-jenis-kelamin-dan-kecamatan.html

Badan Pusat Statistik (BPS) (2023, 11 January). Jumlah Penduduk Jawa Barat https://bandungkab.bps.go.id/indicator/12/280/1/jumlah-penduduk-menurut- kabupaten-kota-di-provinsi-jawa-barat.html

Bhatta, B. 2010. *Analysis of Urban Growth and Sprawl from Remote Sensing Data.* Springer, Kolkata. Pp. 4-7

Barnes, K.B., Morgan III, J.M., Roberge, M.C. and Lowe, S., 2001. *Sprawl development: its patterns, consequences, and measurement*. Towson University, Towson, 1, p.24.

Caves, R. W. 2004. *Encyclopedia of the City*. Routledge, London. p. 99.

ESRI (2023, 12 January) Mean Spatial https://doc.arcgis.com/en/insights/latest/analyze/find-spatial-mean.htm

Fadilla L, Subiyanto S and Suprayogi A 2017 *Analisis Arah dan Prediksi Persebaran Fisik Wilayah Kota Semarang Tahun 2029 Menggunakan Sistem Informasi Geografi dan CA Markov Model* pp.3-4

Gong, P., Li, X., Wang, J., Bai, Y., Chen, B., Hu, T., Liu, X., Xu, B., Yang, J., Zhang, W. and Zhou, Y., 2020. Annual maps of global artificial impervious area (GAIA) between 1985 and 2018. *Remote Sensing of Environment*, *236*, p.111510.

Graves, S. (2023, 11 January) Economic Geography: Measures of Central Tendency and Trade Areas http://www.csun.edu/~sg4002/courses/340/340_lab_mean_ctr_theissen.html

Harvey, R.O. and Clark, W.A., 1965. The nature and economics of urban sprawl. *Land Economics*, *41*(1), pp.1-9.

Janke, J.R., 2010. Multicriteria GIS modeling of wind and solar farms in Colorado. *Renewable Energy*, *35*(10), pp.2228-2234.

Litman, T., 2015. Evaluating transportation land use impacts: considering the impacts, benefits and costs of different land use development patterns. https://trid.trb.org/View/1424022

Meriam, J.L., Kraige, L.G. and Bolton, J.N., 2020. *Engineering mechanics: dynamics*. John Wiley & Sons., pp 244-246

Mundhe, N.N. and Jaybhaye, R.G., 2014. Impact of urbanization on land use/land covers change using Geo-spatial techniques. *International journal of geomatics and geosciences*, *5*(1), pp.50-60.

Niode, D.F., Rindengan, Y.D. and Karouw, S.D., 2016. Geographical information system (GIS) untuk mitigasi bencana alam banjir di Kota Manado. *Jurnal Teknik Elektro dan Komputer*, *5*(2), pp.14-20.

Purwoko, A., 2009. Analisis Perubahan Fungsi Lahan di Kawasan Pesisir dengan Menggunakan Citra Satelit Berbasis Sistem Informasi Geografis (Studi Kasus di Kawasan Suaka Margasatwa Karang Gading dan Langkat Timur Laut). *Jurnal Perencanaan Dan Pengembangan Wilayah*, *4*.

Paramasivam, B. and Arumugavelu, I., 2020. Urban sprawl. In *Sustainability in Urban Planning and Design*. IntechOpen.

Sudhira, H.S., Ramachandra, T.V. and Jagadish, K.S., 2004. Urban sprawl: metrics, dynamics and modelling using GIS. *International Journal of Applied Earth Observation and*

Geoinformation, *5*(1), pp.29-39.

Siswoyo, M., 2020. The Impact of Toll Road Development: An Analysis Based on Public Administration Ecology. *Journal of Southwest Jiaotong University*, *55*(3).

United Nation Population Fund (2023, 22 Feb) Urbanization https://www.unfpa.org/urbanization