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Polycentric Urban Structure and Growth Dynamics in Bandar Lampung: A Kernel-Based Approach

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Abstract: The growth of the Greater Bandar Lampung Metropolitan area shows indications of the development of a polycentric spatial structure, along with the emergence of activity centers outside the core city. This study aims to identify the form of urban polycentric structures in the area as a basis for developing new growth centers. The method used is spatial analysis with the Kernel Density Estimation (KDE) approach using Landsat 8 satellite imagery data, distribution of public facilities, and population density in 2018 and 2023. The results of the analysis show the formation of several new sub-activity centers in the Metro, Central Lampung, and Pesawaran areas which have quite high activity intensity. The distribution pattern of facilities and built-up land indicates a transition from a monocentric structure to a polycentric one. These findings can be the basis for formulating spatial planning policies that support connectivity between regions and equitable development in the metropolitan area.

Keywords: polycentric structure, growth center, Kernel Density, metropolitan, Bandar Lampung

1. Introduction

It is predicted that more than 80% of the world's population will live in urban areas by 2050 (World Bank, 2023). Rapid population and urban area growth that is not accompanied by proper planning will have a negative impact on city development and economic growth. The population growth rate is 1.01 with a population reaching 9,081,792 people in 2023 (BPS in Figures, 2023) and more than 30% of the urban population still lives in slums and illegal areas (DPKCPK, 2022). If this continues to be allowed, inequality will increase, currently the percentage of poor people in Lampung Province is higher than the national rate, which is 9.29 in 2023. Thus, it is necessary to develop growth centers to equalize development.

In the 2019-2024 Lampung Province Medium-Term Development Plan (RPJMD) Document, there are national directives for the formation of the Greater Bandar Lampung Metropolitan Area consisting of several sub-districts, namely all sub-districts in Bandar Lampung City and Metro City, Trimurjo and Punggur Sub-districts in Central Lampung Regency, Pekalongan, Batanghari and Metro Kibang Sub-districts in East Lampung Regency, Merbau Mataram, Natar, Tanjung Bintang, Katibung and Jati Agung Sub-districts in South Lampung Regency and Padang Cermin Gedong Tataan, Way Lima and Negeri Katon Sub-districts in Pesawaran Regency. This area is expected to improve the function of the city and provide good services to create a conducive and inclusive city in meeting various life needs through the development of a compact, efficient city to prevent the accumulation of activities in one area.

Currently, the center of economic growth in Lampung Province is Bandar Lampung City as the Provincial Capital and also as PKN (National Activity Center) and Metro City as PKW (Regional Activity Center) which is also supported by several PKL (Local Activity Center) in

the Tanjung Bintang Urban Area, Natar-Jatiagung and Gedong Tataan. Activities and economy centered in Bandar Lampung City and support from surrounding areas such as Metro City, Central Lampung Regency, East Lampung, Pesawaran and South Lampung which are still closely related to agricultural activities and natural tourism are one of the potentials and challenges that in the development of the city will be very diverse and there needs to be good synergy of cooperation between regions to provide a good multiplier effect.

Spatial structure is an important aspect in urban development because it directly affects the distribution of social and economic activities. Along with the growth of urban areas, changes in spatial structure are not only determined by physical aspects, but also by geographical, economic, and planning policy factors. Zhang and He (2020) stated that the identification of urban spatial structure can be done through morphological, geographical, and economic approaches, while Putra et al. (2022) added that natural factors such as accessibility and geographical conditions affect the dynamics of land changes, and have implications for economic activity patterns.

Polycentric structure refers to a regional configuration that has more than one main activity center (multi-center), where each center has a relatively independent economic, social, and spatial role, but remains interconnected in one city system . The application of this structure not only supports the distribution of economic activities more evenly, but also reduces the burden on city centers , improves accessibility between regions, and encourages agglomeration efficiency and functional linkages between growth centers. Therefore , the development of a polycentric urban spatial structure is considered capable of accelerating equitable development, reducing economic inequality, and increasing regional competitiveness as a whole.

Bandar Lampung City currently shows a tendency to develop towards a polycentric structure. Based on spatial planning directive documents and satellite imagery interpretation over the past six years, there is a distribution of growth in activities and infrastructure that extends from the main city center (Tanjung Karang Pusat, Rajabasa, and Panjang Districts) to secondary areas such as Sukarame, Labuhan Ratu, Kedaton, Way Halim, and Kemiling. These areas have experienced significant increases in population density, economic activity, and the provision of public facilities, indicating the growth of new sub-centers outside the old city center . This phenomenon indicates the potential for decentralization of activities to reduce intra-city disparities and strengthen the carrying capacity of the surrounding areas.

However, unlike Bandar Lampung City, the spatial structure at the Lampung Province level is generally still centralized. The center of economic activities and public services is still very centralized in Bandar Lampung City as the provincial capital . Meanwhile, Metro City, which has been designated as the Regional Activity Center (PKW) and is expected to become a secondary city, has not functioned optimally as a buffer for growth. Other regencies such as South Lampung, Pesawaran, and East Lampung also show limited regional functions and development inequality. This is reflected in the still high Gini index value of 0.302 in 2024 (BPS, 2024), as well as the high poverty rate that exceeds the national average.

Based on these conditions, a study of the polycentric urban spatial structure is important to understand how urban growth patterns can support equitable development in the Bandar Lampung Raya metropolitan area. This study aims to identify the form of polycentric spatial structure that has the most influence on regional economic growth, based on spatial indicators such as built-up land area, distribution of public facilities, and population density. The approach used involves spatial analysis through the Kernel Density method to identify new growth centers.

2. Method

This research method uses a quantitative deductive and explanatory approach within the framework of the positivist paradigm. The main focus is to explain existing conditions and make projections based on data analysis and related literature reviews. With this approach, the study aims to provide an in-depth understanding of the spatial structure and dynamics of polycentricity in an urban context. The quantitative deductive approach allows researchers to test hypotheses about the relationship between polycentric spatial structure and economic indicators, such as population growth, suburbanization, and facility distribution, with a solid data base and in-depth statistical analysis.

The basic concept of this study focuses on the polycentric spatial structure in the urban context, which refers to the formation of several activity centers in a city , in contrast to the monocentric model which only has one main center. Land use classification is carried out using the supervised classification method for each type of land use. In this study, land is categorized into four types: built-up land, vegetation, water bodies, and wetlands (Ashfa, 2016). Land use identification is an important part of the *Kernel Density analysis* to determine the urban polycentric structure. This process utilizes Landsat 8 satellite imagery through QGIS.

This research was conducted in Bandar Lampung Raya City, focusing on areas that have several centers of economic activity and services, thus allowing for an in-depth analysis of the economic impact and distribution of activities in various centers. This research will last for 10 (ten) months, starting from August - June 2025. This period includes the data collection, analysis, and preparation of the final report phase. The data collection method in this study is by collecting secondary data needed by related agencies.

3. Results and Discussion

3.1 . Analysis of Identification of Urban Polycentric Structure

Built-up Land Cover Analysis

Built-up land cover analysis was conducted in the delineation area of Bandar Lampung Raya Metropolitan City using *Google Earth Engine* in 2019 and 2024 respectively. Land cover was interpreted into 4 classes, namely, water bodies, built-up land, agriculture and vegetation. Meanwhile, to interpret the urban polycentric structure in Bandar Lampung Raya Metropolitan City, built-up land class land cover was used.

Land cover classification in the built-up land category is identified through the existence of settlements, industrial areas, trade services, government offices , airports or ports, and mining areas. Vegetation land cover is classified based on the existence of forests, trees, and shrubs. Meanwhile, water land cover includes sea areas, rivers, ponds, lakes, and ponds. Meanwhile, agricultural land cover is identified based on rice field areas.

Land cover analysis in this study was conducted quantitatively using the *supervised classification method* . The land cover map produced from the classification process was then evaluated for its accuracy through testing using a *confusion matrix* . This test is based on sampling reference points using the *stratified random sampling method, which is used to compare the classification results with reference data. The results of this test are in the form of overall accuracy* and *kappa index* values , which are used to measure the level of accuracy of land cover classification.

Accuracy test in compiling land cover maps with Google Earth Engine in the Metropolitan City of Bandar Lampung Raya in 2019 and 2024 can be seen in Appendix 1. The *overall accuracy value* on the land cover map of the Metropolitan City of Bandar Lampung Raya in 2019 is 80% which is categorized as having a good level of accuracy, while in 2024 the value is 78.9% and which is categorized as having a fairly good level of accuracy with an *overall accuracy value* exceeding 70-79% and *kappa* more around 0.40 - 0.60 which is categorized as sufficient or moderate (*moderate agreement*).

Table 1Area of Land Cover Change in the Metropolitan City of Bandar Lampung Raya in 2019 and 2024

Land Classification	Land Area (Ha)		Land Change (Ha)
	Year 2019	**Year 2024**	
Vegetation	89,929.6	57,312.1	-32,617.5
Water Body	24.4	1.7	-22.6
Built-up Land	38,931.4	65,611.7	26,680.32
Agricultural land	79,589.9	85,549.7	5,959.8
Total Area	**208,475.3**		

Source: Analysis Results, 2025

Based on **Table 1** , there was a significant change in land cover in the Bandar Lampung Raya Metropolitan City area between 2019 and 2024. In 2019, the dominant type of land

cover was vegetation with an area of 89,929.6 hectares, followed by agricultural land (79,589.9 hectares), built-up land (38,931.4 hectares), and water bodies (24.4 hectares). However, in 2024 there was a shift in dominance, where built-up land became the largest land cover category with 65,611.7 hectares, followed by agricultural land (85,549.7 hectares), vegetation (57,312.1 hectares), and water bodies which experienced a drastic reduction to only 1.7 hectares.

Changes in land area during the period show that vegetated land experienced the most significant decrease, which was 32,617.5 hectares, indicating a large-scale conversion to other uses such as settlements or infrastructure. Water bodies also experienced a decrease of 22.6 hectares, which was likely caused by reclamation, sedimentation, or conversion to other land uses. In contrast, built-up land showed a very significant increase of 26,680.32 hectares, reflecting the high intensity of urbanization in this metropolitan area. Agricultural land also experienced an increase of 5,959.8 hectares, which can be assumed to be the result of the conversion of part of the vegetated area or the development of new agricultural areas. Overall, these changes indicate a shift in the orientation of land use towards increasingly dominant human development and activities, which requires special attention in spatial planning and sustainable environmental management.

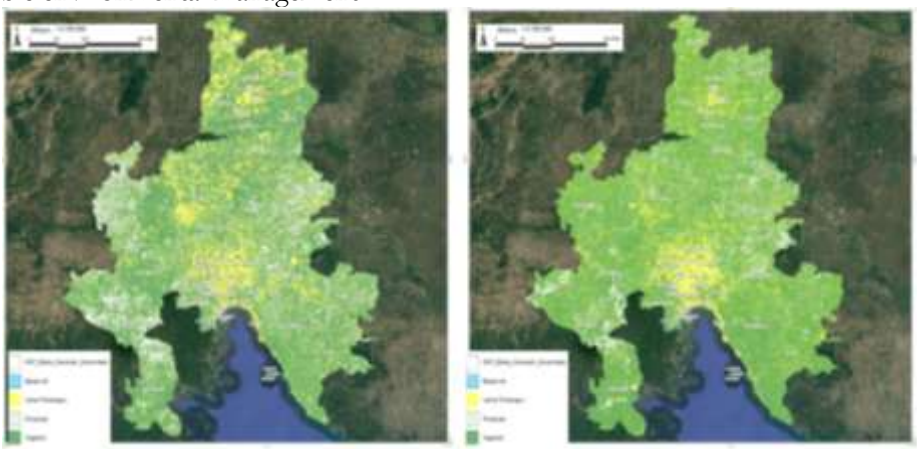

Figure 1. Land Cover Analysis of Bandar Lampung Raya Metropolitan City in 2019 and 2024

Source: Analysis Results, 2025

The results of the analysis of built-up land cover in the Metropolitan City of Bandar Lampung Raya between 2019 and 2024 show a significant increase in the intensity of development in several buffer districts such as Jati Agung, Natar, Gedong Tataan, and Tegineneng. This change indicates the expansion of built-up areas that are no longer concentrated only in the core area of Bandar Lampung City, but are starting to expand to the south and east. This phenomenon reflects a shift in the spatial structure of the region towards a polycentric city form , where several new growth nodes are starting to form as secondary activity centers. This dynamic is important to consider in regional planning, because the direction and pattern of uneven development distribution opens up opportunities to develop a network of new city centers to reduce the burden on the main city center and realize a more balanced and sustainable metropolitan area structure.

Population Density Analysis

Population density in the delineation area of the Greater Bandar Lampung Metropolitan City is calculated based on the ratio of population to area, with analysis down to the sub-district level in each district/city included in the area. This population density analysis is conducted to see the spatial distribution and concentration of the population and how the centers of activity and settlements are in the delineation area of the Greater Bandar Lampung Metropolitan City. The distribution of population density will be classified into 4 classes, namely very low, low, high and very high.

In the Metropolitan City of Bandar Lampung Raya, there are 5 Regencies and Cities consisting of 39 sub-districts with the number and population density described in **Table 2.** In the last five years, there have been variations in population density changes that reflect spatial and demographic shifts in various sub-districts in the Metropolitan area of Bandar

Lampung Raya. Several sub-districts that previously had high densities showed a downward trend, while the outskirts or buffer areas tended to experience a significant increase in population density.

Table 2Number of Population and Population Density in Bandar Lampung Raya Metropolitan City

Subdistrict	Area of the Region	Population (people)		Population Density (people/km ²)	
		2019	2024	2019	2024
City of Bandar Lampung					
West Betung Bay	18.26	32,002	38.185	1,753	2,091
East Betung Bay	10.39	44,727	48,592	4.305	4.677
South Betung Bay	3.49	42,262	38,075	12.109	10,910
The Earth is Sane	4.52	60,939	56.101	13,482	12,412
Long	13.64	79,800	72,061	5,850	5.283
East Cape Karang	2.07	39,855	37,031	19,254	17,889
Peace	8.34	56,482	52,169	6,772	6.255
North Betung Bay	4.38	54,337	49.123	12,406	11.215
Central Cape Karang	3.5	54,906	49,063	15,687	14,018
Unable	2.78	30,164	24,662	10,850	8,871
West Cape Karang	11.54	58,754	61,773	5,091	5.353
The roundabout	21.33	70,491	85,823	3.305	4.024
Langkapura	5.3	36,454	43,365	6,878	8.182
Palace	3.77	52,685	50,997	13.975	13,527
Rajabasa	12.93	51,578	55,318	3.989	4.278
Cape of Joy	9.24	49,160	61,871	5.320	6,696
Queen's Labuan	6.1	48,159	47.257	7,895	7,747
Sukarame	10.92	61,130	66,797	5,598	6.117
Sukabumi	25.04	61,574	72,674	2.459	2.902
Halim Way	6.25	66,041	66,727	10,567	10,676
Metro City					
South Metro	15.03	15,474	18,762	1,030	1.248
West Metro	11.54	29.130	29,641	2,524	2,569
East Metro	12.89	41,346	41,758	3.208	3.240
Central Metro	11.6	52,827	56,682	4,554	4.886
North Metro	22.15	28,634	35,450	1.293	1,600
Central Lampung Regency					
Trimurjo	64.88	48,979	60,236	755	928
Back	60.74	36,045	42,886	593	706
East Lampung Regency					
Metro Kibang	76.78	24.158	24,800	315	323

Subdistrict	Area of the Region	Population (people)		Population Density (people/km ²)	
		2019	2024	2019	2024
Pekalongan	100.13	50,949	53,738	509	537
Batanghari	148.88	62.121	60,511	417	406
South Lampung Regency					
Mataram Merbau	130,089	49,587	60,233	381	463
Natar	261,075	196,264	203,709	752	780
Star Cape	165,945	77,410	89,312	466	538
Jati Agung	250,182	116,687	129,171	466	516
Katibung	161,975	69.114	76,403	427	472
Pesawaran Regency					
The Tataan Building	146.51	99.982	109,696	682	749
Katon Country	150.05	66,860	75,283	446	502
Field of Mirrors	172.78	29,181	29,701	169	172
Way Five	128.01	31,148	39,400	243	308

Source: Central Statistics Agency (BPS), 2019-2025

Changes in population density that occurred between 2019 and 2024 in the Greater Bandar Lampung Metropolitan area are not only quantitative, but also indicate spatial shifts in the structure of regional growth.

The 2019 map shows that the highest population density is concentrated in the center of Bandar Lampung City, especially in sub-districts such as **Tanjung Karang Pusat** , **Enggal** , and **Teluk Betung Utara** , which are marked in dark red with a very high category. These areas are downtown areas that have long developed as centers of administration, trade, and services.

However, on the 2024 map, there is a spread of red to buffer areas such as **Kemiling** , **Langkapura** , **Tanjung Senang** , and part of **Sukarame** , which were previously included in the medium or low category. This change indicates urban expansion and increased population activity to the west and southwest of the city. Some areas such as **Enggal** and **Tanjung Karang Pusat** actually show a degradation in density, which can be associated with a shift in the function of the area or the onset of land saturation in the city center.

This phenomenon shows symptoms of decentralization and urbanization pressure to the suburbs of the core city, which is in line with the concept of polycentric metropolitan growth. Areas that experience significant density growth tend to become potential new growth centers, along with the development of road infrastructure, housing, public facilities, and commercial facilities that support the increasing attractiveness of the area.

This condition is an important basis for planning and developing the metropolitan area as a whole. Identification and strengthening of new growth centers are crucial in order to achieve equitable development, spatial efficiency, and mitigation of the burden and pressure of development in the city center. Thus, the direction of the development policy for the Greater Bandar Lampung Metropolitan area needs to consider this dynamic in order to realize a sustainable, inclusive, and adaptive urban system to demographic and spatial changes.

Figure 2. Map of Population Density Distribution Per District in the City Metropolitan Bandar Lampung Raya in 2019 and 2024

Source: Analysis Results, 2025

Based on the analysis of population density changes between 2019 and 2024 and spatial depiction on the map, it can be seen that there has been a significant shift in activity centers from the core area of Bandar Lampung City to buffer areas such as Kemiling, Langkapura, and Tanjung Senang. The increase in density in this area indicates the formation of new growth centers that develop in parallel with the main city center , thus indicating the emergence of a *polycentric spatial structure in the Greater Bandar Lampung Metropolitan area. This polycentric structure reflects a more widespread* urban growth pattern that is no longer focused on one dominant point, which in turn becomes an important foundation in regional planning to create a balanced, integrated, and sustainable metropolitan area.

Kernell Density **Analysis**

Kernel density analysis is used to determine the agglomeration of urban development that occurs in the Bandar Lampung Raya Metropolitan Area. Agglomeration is identified through spatial activity concentration that is overlaid with population density and built-up land. So that the results of the analysis can visualize the distribution pattern of the density of certain spatial entities that can provide an overview of the tendency of high intensity concentrated in certain areas.

On the map (Figure 3) there are indications especially in the central-southern region around Bandar Lampung City which is indicated by a darker purple color gradation. This indicates the existence of a major growth center, both activity and economic centers. This pattern also emphasizes that the existence of Bandar Lampung City as a hub of urban activity in the metropolitan area has been going on for at least the last five years 2019-2024. However, this can also indicate the direction of expansion pressure to the eastern and northern corridors, which have the potential to be developed as new growth centers .

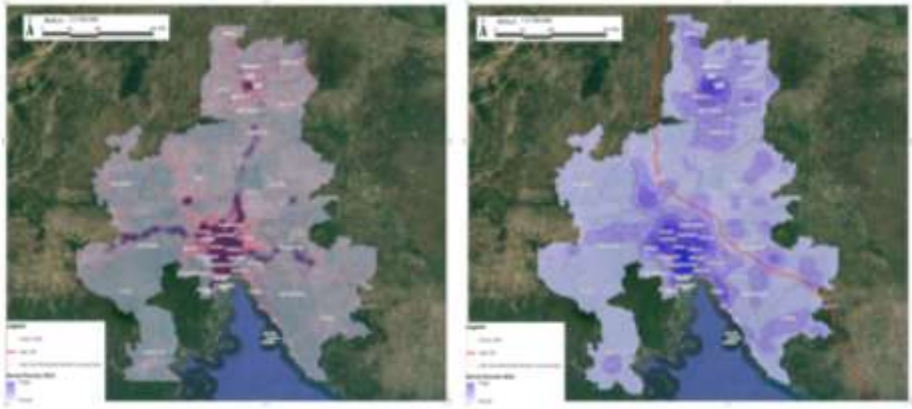

Figure 3. Kernell Density Map of Bandar Lampung Raya Metropolitan City 2019 and 2024

Source: Analysis Results, 2025

Statistical zone map (Figure 4) based on the results of urban agglomeration kernel density analysis interpreted by the red to green color gradation indicates that there is quite high

urban development pressure in Bandar Lampung City and Metro City, while other areas such as South Lampung, East Lampung, Central Lampung, and Pesawaran have not shown dominant activity when compared to the two cities. The disparity in urban growth is a concern in order to be able to plan metropolitan areas so that there will be even growth in the future. The formulation of policies for decentralizing the role and function of cities and strengthening supporting infrastructure for the outskirts must be strengthened, so as to be able to realize a more balanced and sustainable metropolitan area structure.

Therefore, the kernel density results can be the main reference that clarifies the spatial rules of the city between the main development center and the suburbs to achieve the best potential of each district and city, even though Bandar Lampung City is the node of all economic and transportation activities in the Metropolitan City of Bandar Lampung Raya.

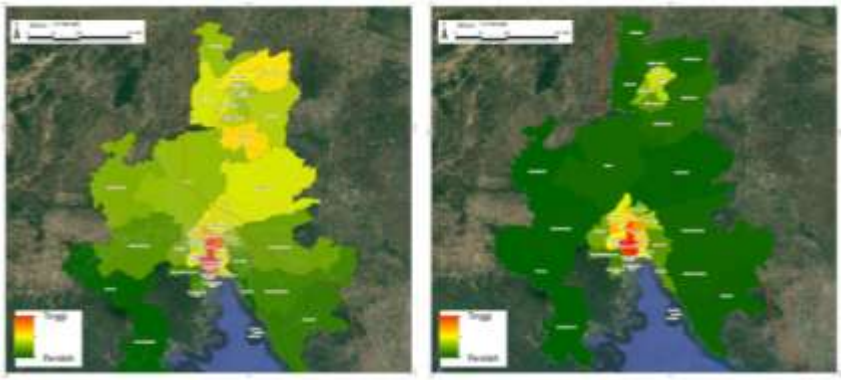

Figure 4. Statistical Kernell Density Zone of Bandar Lampung Raya Metropolitan City in 2019 and 2024

Source: Analysis Results, 2024

4. Conclusion

Based on the results and discussion of the analysis conducted, here are some conclusions from this study:

a) There have been significant changes in land cover.
The increase in built-up land area by 26,680.32 hectares in the five-year period (2019–2024), from 38,931.4 ha to 65,611.7 ha. Vegetation land decreased drastically to 32,617.5 ha, followed by a decrease in water bodies by 22.6 ha, indicating a massive conversion to built-up use.

b) Land cover is dominated by Built-up Land
In 2024, built-up land becomes the dominant category, replacing vegetation which previously dominated in 2019.

c) Polycentricity Distribution Pattern
The distribution of built-up land is no longer concentrated in the city center (Kedaton, Tanjungkarang, Panjang Districts), but has expanded to the outskirts such as Sukarame, Way Halim, Tanjung Bintang, and Punggur. This indicates the emergence of new growth centers that support the hypothesis of polycentric structures.

d) Zonal Statistics Confirms Physical Growth Locations
Districts such as Kedaton, Rajabasa, Sukarame, Tanjungkarang Pusat, and Telukbetung Selatan show very high built-up land intensity. On the other hand, districts in the north and east such as Pubian, Padang Ratu, and Anak Tuha are still classified as very low in built-up land growth.

e) Indications of Transformation Towards a Polycentric City
The expansion of built-up areas to the outskirts supports the transformation of the city structure from monocentric to polycentric, which is in accordance with the dynamics of urbanization and the need for equitable development.

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