MEASURING THE URBAN METROPOLITANIZATION OF KEDUNGSEPUR BASED ON POLYCENTRICITY AND SPATIAL TRANSFORMATION

MENGUKUR METROPOLITANISASI PERKOTAAN KEDUNGSEPUR BERDASARKAN POLISENTRISITAS DAN TRANSFORMASI SPASIAL

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ABSTRACT

Kedungsepur, situated in Central Java Province, Indonesia, encompasses the regions of Kendal, Demak, Ungaran, Semarang, Salatiga, and Purwodadi, making it a strategically significant area. Its designation as a metropolitan area was established by Presidential Decree Number 78 of 2017, with one of its primary objectives being to promote equity by reducing urban primacy. This study seeks to assess the metropolitanization of Kedungsepur from 2016 to 2020, focusing on two key indicators: polycentricity and spatial transformation. Polycentricity is evaluated based on concentration, accessibility, and connectivity, while spatial transformation is measured by analyzing the percentage of built-up land and urban level. Polycentricity is assessed using secondary data from BPS-Statistics Indonesia, while the percentage of built-up land and urban level is determined through the interpretation of Sentinel 2A satellite imagery from 2016 and 2020. The findings indicate a moderate improvement in polycentricity during the 2016—2020 period, with partial spatial transformation occurring, particularly along highway corridors between cities. In conclusion, metropolitanization demonstrates positive progress toward its objectives, albeit requiring more balanced control over spatial transformation processes.

Key Words: Urban Metropolitanization, Polycentricity, Spatial Transformation

ABSTRAK

Kedungsepur yang terletak di Provinsi Jawa Tengah, meliputi wilayah Kendal, Demak, Ungaran, Semarang, Salatiga, dan Purwodadi, merupakan salah satu kawasan strategis di Indonesia. Penetapan Kedungsepur sebagai wilayah metropolitan adalah Peraturan Presiden Nomor 78 Tahun 2017, dengan salah satu tujuan utamanya untuk meningkatkan pemerataan pembangunan yang ditandai dengan berkurangnya (indeks) primasi kota. Penelitian ini bertujuan untuk mengukur metropolitanisasi yang terjadi di Kedungsepur pada periode sebelum perpres disahkan, yakni 2016 hingga 2020. Yang mana berfokus pada dua indikator, yaitu polisentrisitas dan transformasi spasial. Parameter untuk menentukan polisentrisitas adalah konsentrasi, aksesibilitas, dan konektivitas, sedangkan transformasi spasial diukur berdasarkan persentase luas lahan terbangun dan tingkat kekotaan. Metode untuk mengukur polisentrisitas menggunakan analisis data sekunder dari Badan Pusat Statistik (BPS), sedangkan persentase lahan terbangun dan tingkat kekotaan diukur melalui interpretasi citra satelit Sentinel 2A dari tahun 2016 dan 2020. Hasil penelitian menunjukkan pada periode 2016—2020 terdapat peningkatan dengan kategori sedang dalam polisentristas, dengan terjadinya transformasi spasial parsial, khususnya di sepanjang koridor jalan raya antarkota. Kesimpulannya, proses metropolitanisasi sudah menunjukkan kemajuan positif dalam mencapai tujuannya, meskipun memerlukan kontrol yang lebih merata terhadap proses transformasi spasial.

Kata Kunci: Metropolitanisasi Perkotaan, Polisentrisitas, Transformasi Spasial

1. INTRODUCTION

In Indonesia, the development of metropolitan cities is associated with their function as national strategic areas. Strategic areas are areas that prioritize spatial planning. The establishment of a national strategic area has a goal, one of which is to realize equitable development between regions. However, the facts show otherwise, urban growth in the metropolitan area leads to the primacy of the core city.

The main objective of establishing a metropolitan area in Indonesia as a strategic area, namely reducing the development gap in Indonesia, in the national context, is going well. However, in the internal metropolitan context, it can be said that the gap in question is between the core city and satellite cities or regional gaps. This gap can occur because of the concentration of non-primary activities in certain sub-regions or the primary city of the metropolis. Its form is the concentration of development in major metropolitan cities as a form of the primacy of the core city.

The function of the primary city which is also a channel or international trade network has contributed to the increase in primacy due to the accumulation in the primary city originating from the resources of the suburbs (Gilbert & Gugler, 1989). The next impact, namely the expected downward trickle effect, could not be enjoyed by Rondinelli (1986) and could not reach the lower hierarchical area (Morphet, 2018).

Consequently, there is a need to increase attention to the role of the satellite city. These satellite cities can consist of small towns and medium cities. This view arises because large cities' uncontrolled and continuous growth tends to be inefficient (Glaeser & Shapiro, 2003). However, calculations regarding the relationship between urban growth and economic efficiency have not been carried out comprehensively (Leaf, 1994).

The phenomenon of metropolitanization in Indonesia took place rapidly on the island of Java, triggered by the process of industrial agglomeration. The center of Indonesia's manufacturing industry which is concentrated on Java Island tends to form a bipolar pattern, namely at the western end of Java Island (Jabodetabek) and at the eastern end of Java Island (Gerbangkertasusila) (Kuncoro, 2002). By paying attention to this pattern, it is necessary to develop a metropolitan that functions as a counterweight, which is located in the central part of Java Island, namely Kedungsepur. It is in this context that a study on Kedungsepur is important to do.

Kedungsepur is part of 10 priority metropolitan areas to be developed in Indonesia. Some of the things that make Kedungsepur one of the priorities, among others, the slope of the land is relatively safe to develop, and the availability of basic connectivity from all directions. In terms of income, Kedungsepur contributes a quarter of the Gross Regional Domestic Product (GDP) of Central Java (Badan Pusat Statistik Provinsi Jawa Tengah, 2019). In addition, currently, Presidential Decree (*Peraturan Presiden*) Number 78 of 2017 has been issued concerning Kedungsepur as a Metropolitan Area.

The characteristics of a metropolitan area are influenced by its spatial structure, which is informed by demographic factors and the concept of polycentricity. This study determines variables based on the population metrics of each urban center. Expanding on Bourne (1971), which posits that a core city in a metropolitan area is one with a population exceeding one million. In a metropolitan area with only one core city, it is termed monocentric; however, if there are multiple core cities present, it is classified as polycentric. This research further explores the distinction between monocentric and polycentric metropolitan areas. The aim is to assess the metropolitanization process in Indonesia, particularly in Kedungsepur Metropolitan Area, by comparing the urban conditions before and following the implementation of Presidential Decree Number 78 of 2017, analyzing changes between 2016 and 2020. This study integrates insights from Vasanen's (2012) examination of functional polycentricity, Dadashpoor, Malekzadeh, & Saeidishirvan's (2022) typology of metropolitan spatial structures, and research on the evolution of metropolitan spatial structures (Giuliano et al, 2021), to provide a comprehensive understanding of metropolitan dynamics in the context of Indonesian urban development.

2. DATA AND METHODS

2.1. Location

The Kedungsepur, in this research, is a metropolitan area that encompasses several cities (municipalities) and regencies in Indonesia, including Kendal Regency, Demak Regency, Ungaran City (part of Semarang Regency), Salatiga Municipality, Semarang Municipality, and Purwodadi City (part of Grobogan Regency). Kedungsepur is an area designated in Presidential Decree Number 78 of 2017 concerning Spatial Plans for Urban Areas around these cities. This area is the focus of research on spatial dynamics and the process towards metropolitan status (metropolitanization). In this context, the Kedungsepur region is elucidated through specific variables that influence its development into a metropolitan city, such as polycentricity and spatial transformation.

2.2. Data Collection

The spatial dynamics within the Kedungsepur area are analyzed in this study, with a focus on variables influencing the progression toward a metropolitan city, a process termed "metropolitanization." This metropolitanization process is primarily characterized by two spatially-bound variables: the polycentric and spatial transformation. The concept of polycentricity incorporates sub-variables such as concentration, accessibility, and connectivity, as defined by Galster et al. (2001) and Lee (2007), with modifications. Population-based analyses are employed to assess all polycentricity variables. Spatial transformation, on the other hand, is gauged through changes in the proportion of built-up areas and urban levels, utilizing interpretations of satellite imagery.

This study employs satellite imagery interpretation as part of the data collection process, encompassing various elements such as association, site, shadow, height, pattern, texture, shape, size, and hue (Mahmud & Achide, 2012; Weber et al, 2005). Scholars like Sutanto (1986) and Somantri (2016) have emphasized the significance of interpreting temporal images to detect changes in urban land use patterns. Such interpretation offers insights for analyzing and comparing the spatial and temporal dynamics of urban areas (Giyarsih et al, 2003).

The assessment of built-up land and urban level changes in Kedungsepur relies on the interpretation of two satellite images captured at different points in time. Specifically, Sentinel 2A imagery from 2016 and 2020 is utilized. The 2016 imagery serves as a baseline to understand the initial scenario before the establishment of the Kedungsepur Metropolitan Area through a presidential decree. Conversely, the 2020 imagery enables an assessment of Kedungsepur's state four years after being designated as one of the strategic economic areas under the Metropolitan Kedungsepur initiative. Furthermore, secondary data from the Ministry of Transportation is utilized to compute people's movement and road connectivity, Statistics of Indonesia (BPS) and field observations are employed to validate the accuracy of interpretation.

2.3. Data Analysis

The observation of the city's physical transformation can be conducted by employing an approach that utilizes image interpretation of built-up land, roads, and buildings, as outlined in various publications (Appleyard & Lintell, 1972; Dewi & Kurniawati, 2013; Fan et al, 2008; Hermawati, 2006; Jayanti, 2012; Kazaz, 2001; Moughtin, 2007; Sumayku et al, 2016; Surtiani, 2006; Yunus, 2008). The process of image interpretation entails the computation and examination of the fluctuation in the proportion of developed land. Utilizing Sentinel 2A imagery, renowned for its high resolution in regional land use mapping, the interpretation yields land use maps categorized according to the Indonesian standard (SNI 7645-1:2014). This comprehensive analysis spans six regencies/cities, covering a total area of 5,413.46 km². The classification standard encompasses five distinct land cover categories: water bodies, open land, built-up land, forests, and vegetated areas.

Employing a quantitative methodology, this research employs deductive reasoning, deriving variables and indicators from established theoretical frameworks. Secondary data analysis techniques are applied, employing formulas alongside satellite image interpretation to assess spatial transformations in land cover.

Statistical descriptive analysis is utilized to analyze the concentration of people movement. This analysis necessitates the origin-destination locations of people's commutes. Subsequently, the scores for the highest and lowest people movement are calculated from the data using formulas.

$$Score\ range = \frac{X_{max} - X_{min}}{m}$$

X_{max} : Highest Score
X_{min} : Lowest Score
m   : Score Range.

The scoring classification involves dividing the total score (the highest minus the lowest people movement) into three (m, the desired score range). This results in three categories: low, medium, and high, as detailed in the following Table 1. Additionally, Table 2 indicates that the highest score is 3,198,539, while the lowest score is 106.

Table 1. People Movement Score Range

Category	Score Range
Low	<1,069,743
Medium	1,069,743—2,139,380
High	>2,139,381

Accessibility is assessed by considering the distance between two areas, typically the core city and its satellite, wherein distance serves as a metric of separation to ascertain the ease of access or reachability of a particular location or region (Bhat et al., 2002).

$$a = \frac{D_{ij}}{D_j}$$

a   : Accessibility index
D_{ij} : The closest distance from the core city (Semarang) to the surrounding regency/municipality
D_j : Average distance to the core city (Semarang).

Conversely, connectivity is gauged by enumerating the direct road networks linking these two areas. In contrast to accessibility, connectivity emphasizes the interconnection network between locations (nodes) irrespective of distance (Rodrigue, 2020). The methodology devised by K.J. Kansky, known as the connectivity formula, is utilized to assess the intensity of inter-city interactions utilizing road networks (Muta'ali, 2015).

$$\beta = \frac{e}{V}$$

β   : Connectivity index
e   : Numbers of cities in one region/area
V   : Numbers of roads connecting the cities.

3. RESULT AND DISCUSSION

3.1. Polycentricity

The first variable to be analyzed is city polycentricity. The first indicator is the concentration of population movement. So far, the tendency of population movement in monocentric cities is towards the core city. Data at Kedungsepur shows that movement is carried out as a form of interaction, both for reasons of work, fulfilling life needs, disseminating information, or complementing one another's natural resources.

Based on the data from Table 2, the highest movement of people occurred from Demak to Purwodadi with a total movement of 3,209,017 people/year. The high category shows the need to interact both to look for work and to fulfill their daily needs. The lowest movement of people, from Ungaran to Salatiga, is 106 people/year. Low movement indicates that each regency/city has tried to meet the needs of its population so that interaction for its interests is low. The high population movement in satellite cities shows that the concentration of population movement is no longer in the core city, so this indicator shows the existence of polycentrality in Kedungsepur.

Table 2. People Movement at Kedungsepur in 2020

No	People Movement		2020	Category
	Origin	Destination		
1	Kendal	Purwodadi	176,509	Low
2	Kendal	Semarang	2,653	Low
3	Kendal	Ungaran	895,175	Low
4	Kendal	Demak	229,043	Low
5	Kendal	Salatiga	402	Low
6	Demak	Purwodadi	3,209,017	High
7	Demak	Kendal	228,074	Low
8	Demak	Semarang	1,526	Low
9	Demak	Ungaran	586,930	Low
10	Demak	Salatiga	108	Low
11	Ungaran	Purwodadi	1,490,959	Medium
12	Ungaran	Kendal	871,087	Low
13	Ungaran	Semarang	754	Low
14	Ungaran	Demak	591,685	Low
15	Ungaran	Salatiga	106	Low
16	Purwodadi	Kendal	176,906	Low
17	Purwodadi	Semarang	3,490	Low
18	Purwodadi	Ungaran	1,406,559	Medium
19	Purwodadi	Demak	3,198,539	High
20	Purwodadi	Salatiga	510	Low
21	Semarang	Purwodadi	5,469	Low
22	Semarang	Kendal	4,063	Low
23	Semarang	Ungaran	1,157	Low
24	Semarang	Demak	2,224	Low
25	Semarang	Salatiga	816	Low
26	Salatiga	Purwodadi	733	Low
27	Salatiga	Kendal	483	Low

No	People Movement		2020	Category
	Origin	Destination		
28	Salatiga	Semarang	879	Low
29	Salatiga	Ungaran	148	Low
30	Salatiga	Demak	134	Low
	Total		13,086,138	

Source: Ministry of Transportation of the Republic of Indonesia, processed (Author, 2021).

The development of industrial activities in the suburbs is a form of activity development in the Kedungsepur. The development of industrial activities in suburban metropolitan areas leads to indications of deconcentration of work (Ingram, 1998). The development of this activity is closely related to changes in the structure of the region that are caused by changes in movement patterns. This change is known as the Daily Urban System (DUS) (Van Der Laan, 1998). This concept is the first time applied to explain structural changes in the Netherlands. This concept illustrates that a metropolitan area consists of 2 elements. The main cities are the core city and the surrounding suburbs the core city. In this concept, movement (commuting) is a very important component.

The second indicator is accessibility. The classification of accessibility in Kedungsepur is accomplished by delineating three levels of classification. The determination of accessibility classification in Kedungsepur consists of high, medium, and low. This is measured through the formulation of intervals between classes.

$$score\ range = \frac{highest\ index - lowest\ index}{number\ of\ classification}$$

The calculated score range in determining the accessibility threshold value in Kedungsepur is 0.66, as depicted in Table 3.

Table 3. Accessibility Classification in Kedungsepur

Accessibility Index	Classification
0.07—0.73	High
0.74—1.39	Medium
1.39—2.05	Low

Based on Table 4 data, the highest accessibility is in Semarang as the core city followed by Ungaran. The high accessibility in this area is attributed to Semarang as the core city, boasting excellent road infrastructure. Conversely, Ungaran secures the second-highest accessibility ranking due to its proximity to the core city, Semarang, which is approximately 15 km away. In the medium classification, Kendal and Demak exhibit relatively similar figures as they are merely 2 km apart from the core city. Kendal, being closer to Semarang, flanks the core city on its western (Kendal) and eastern (Demak) sides. This stands in contrast to Purwodadi, which exhibits the lowest accessibility due to its distance from the core city exceeding 50 km. Following suit is Salatiga, characterized by low accessibility, exacerbated by its location within the Semarang Regency area. The classification of low accessibility occurs predominantly due to the significant distance from the core city of Kedungsepur. By comparing cities in close proximity to the core city and those situated farther away, a dynamic accessibility level emerges, where the further from the core city, the higher the accessibility index tends to be. The area's extent is also one of the reasons for the difficulty or ease of accessing a particular region, aside from road conditions and distance. Thus, accessibility has begun to spread to satellite cities and is showing symptoms of polycentricity in Metropolitan Kedungsepur.

Table 4. Accessibility Index between Areas in Kedungsepur

Regency/Municipality	Large (km²)	Kedungsepur (%)	Distance to core city (km)	Accessibility Index	Classification
Kendal	1,118.13	20.65	25	0.91	Medium
Demak	900.12	16.63	27	0.99	Mediun
Ungaran	950.21	17.55	15	0.55	High
Salatiga	57.36	1.06	39	1.43	Low
Semarang	373.78	6.90	2	0.07	High
Purwodadi	2,013.86	37.20	56	2.05	Low
Means of Kedungsepur			27.33	1.00	

Source: BPS-Statistics of Central Java Province 2020

The third indicator is connectivity. Kedungsepur is a developed area. Cities in Kedungsepur have a Beta index value criterion of >1, which means that this index states that Metropolitan Kedungsepur is an advanced economy. The highest connectivity value is in Salatiga as a satellite city. The highest connectivity situation indicates the emergence of a new city center supported by the construction of the Semarang-Solo toll road. The development of this toll road facilitates interactions between Salatiga and other cities, including the core city of Semarang, regardless of the actual distance between the two cities. Contrasting conditions can be observed in Ungaran, which is closer to Semarang. Despite having numerous roads, Ungaran's infrastructure is insufficient to generate a high level of connectivity. So, based on connectivity indicators, it shows the existence of polycentricity. The complete value of the regional connectivity index in Kedungsepur can be seen in Table 5.

Table 5. Connectivity Index between Regency/Municipality of Kedungsepur

Regency/Municipality	Road (e)	City (V)	Connectivity Index (β)	Classification
Kendal	9	7	1.29	advanced
Demak	5	5	1.00	advanced
Ungaran	11	9	1.22	advanced
Salatiga	4	1	4.00	advanced
Semarang	6	2	3.00	advanced
Purwodadi	9	8	1.13	advanced

Source: Data Processed, 2021

3.2. Spatial Transformation

The second variable of the process of metropolitanization is spatial transformation. This spatial transformation has two indicators, namely the percentage of built-up land and the urban level. The area of built-up land in Kedungsepur in 2016 and 2020 is shown in Figure 1.

Based on Figure 1, it can be seen that the concentration of built-up land in 2016 was in the core city (Semarang) followed by one of the satellite cities, namely Salatiga. The spread is also seen to occur along urban corridors both towards Kendal and Ungaran in Semarang Regency. The following map, built-up land in 2020, which shows the concentration of built-up land in the period after the designation as a metropolitan area.
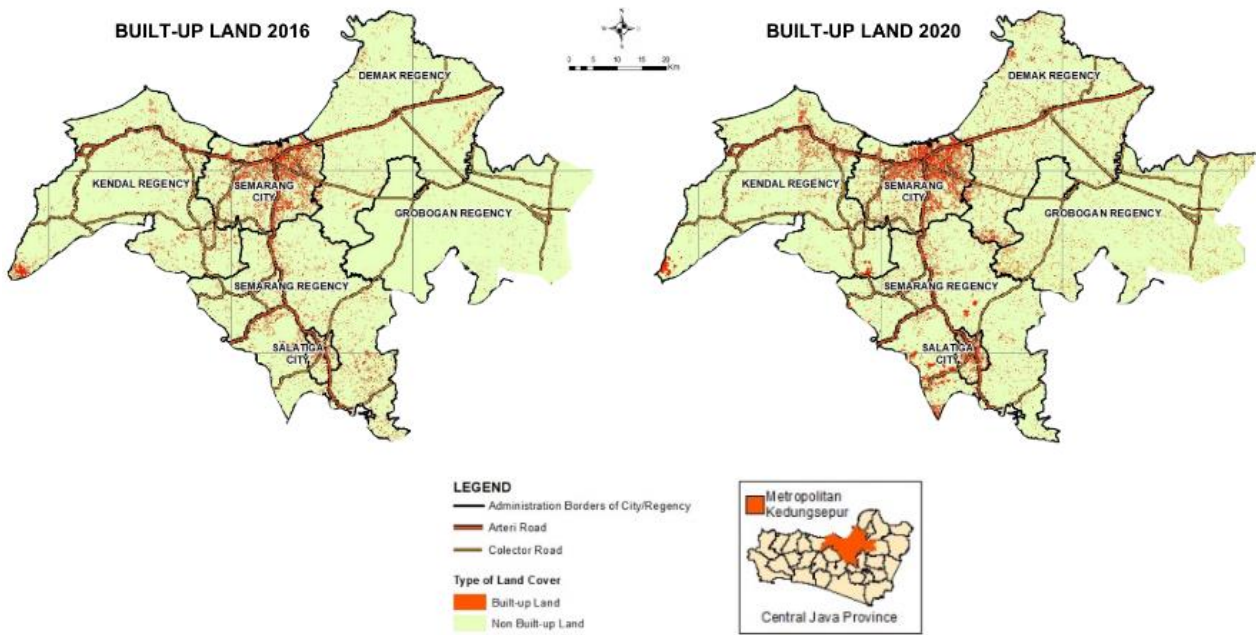
Figure 1. Built-up Land in Kedungsepur 2016 and 2020

In the map of built-up land in 2020, the percentage of built-up land has begun to be more intensive in urban centers. The land built in the core city spreads outwards, especially to the west towards Kendal. The Salatiga, which is a satellite city, has also experienced an increase in the intensity of built-up land. The growth of built-up land is also visible along the inter-city corridors, in all directions. Thus, based on the built-up land indicator, it can be seen that there is a spatial transformation in Kedungsepur, especially the formation of new activity centers and also development along inter-urban corridors.

Figure 2 shows data from the second spatial transformation indicator, namely the urban level. The map showing the urban level in 2016 and 2020. In the map of urban level in 2016, areas classified as 'city' are seen in the core city, which is surrounded by subdistricts classified as 'rather town'.
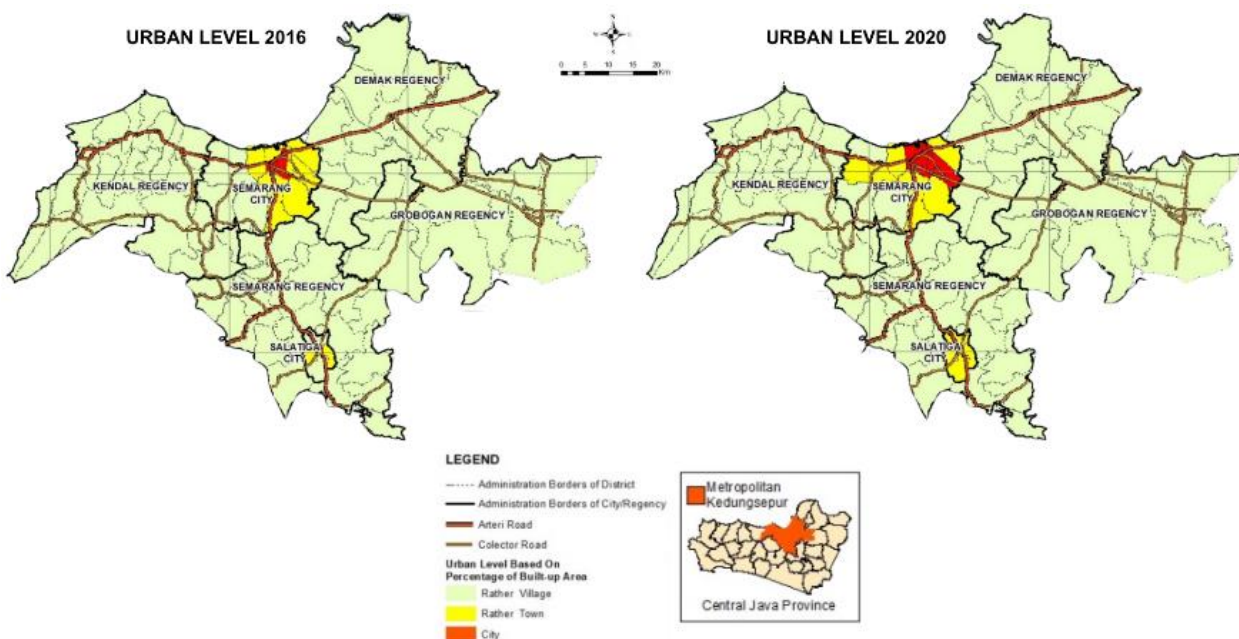

Figure 2. Urban Level in Kedungsepur 2016 and 2020

Following map, urban level in 2020, shows an increase in the classification of cities. The urban area around the city is increasingly expanding. Likewise, the urban area around one of the satellite cities, namely Salatiga, is also expanding. This shows that a new activity center has been formed outside the core city. Thus, the process of spatial transformation in the Kedungsepur occurred quite intensively in the period after its determination as a national strategic area.

3.3. Metropolitanization of Kedungsepur

Studies on spatial transformation, both with indicators of the percentage of built-up land and the level of urban areas at Metropolitan Kedungsepur, can be consulted based on numerous publications (Astuti, 2010; Giyarsih, 2010; Hestuadiputri, 2007; Mahendra & Pradoto, 2016; Rahayu, 2013; Rahma Hayati, 2008; Rustiadi & Sunsun, 2017; Yunus, 1987) regarding the hierarchy and nature of urban areas. The results are relatively consistent, namely that over time the spatial transformation will continue to occur. However, this process should be carried out in a planned manner, so that it can support certain goals, in this case towards a designed metropolitanization.

The study found that physical changes in cities that tend to be without planning can be oriented to changes that are directed not only to be concentrated in the core city but are directed to form new centers in satellite cities, which have a lower hierarchy (Appleyard & Lintell, 1972; Dewi & Kurniawati, 2013; Fan et al., 2008; Hermawati, 2006; Jayanti, 2012; Kazaz, 2001; Moughtin, 2007; Sumayku et al., 2016; Surtiani, 2006; Yunus, 2008). Thus, the number of local activity centers that are formed is increasing.

Before the Presidential Decree Number 78 of 2017 was issued, the condition of Kedungsepur city was not well-planned, resulting in centralized development only in the core city. This is reflected in the lack of growth in built-up land in satellite cities and the minimal connectivity between these cities. Sources supporting these findings can be found in studies conducted by Gilbert and Gugler (1989), who highlighted that the imbalance in urban development, especially in satellite cities, can lead to concentration in the core city center. Additionally, Morphet (2018) also noted that the lack of connectivity between areas around the core city can hinder equitable economic distribution.

With the issuance of the presidential decree, it indicates the political will of the government to address the imbalance in development around the Kedungsepur region. The government's planning focus then shifted to developing satellite cities as an effort to equalize development in the region. The impact of this decree is evident in the increased connectivity between cities and changes in urbanization levels post-decree, as indicated in studies by Lee (2007). The research shows that policy changes leading to the development of satellite cities can bring significant changes in urbanization levels in the region, aligning with the objectives of the applied presidential decree.

Based on the urban level as a percentage of the built-up area in 2016 and 2020, most of the areas in the Kedungsepur Urban Corridor are "rather village". The "city" areas form one of the spatial distribution patterns are clustered in Semarang (Briggs, 2007; Mahendra & Pradoto, 2016; Mulyadi, 2007; Umam et al, 2012). Furthermore, Semarang as the core city, affects the nearby areas around it in the "city" category (Pebrian & Ratnasari, 2013). In line with Giyarsih et al. (2003) and Kurniawan (2016), the stages of spatial transformation start from the rural center at several points in the road corridor which are generally transportation connecting nodes.

4. CONCLUSION

The research findings indicate that from 2016 to 2020, there was an improvement in polycentricity, falling into the moderate category. This improvement is evidenced by three indicators: enhanced concentration, improved accessibility, and increased connectivity. Spatial transformation has also shown improvement, as evidenced by the growth in both the percentage of built-up land area and urban development not only around the core city but also in satellite cities. Urban transformation is occurring, particularly along highways connecting city corridors. This suggests that the process of metropolitanization is positively progressing toward its objectives, albeit requiring more balanced control over spatial

transformation processes. It is suggested that accompanying the process of metropolitanization with more balanced control over spatial transformation is essential, as uncontrolled growth could have adverse environmental consequences.

5. ACKNOWLEDGMENTS

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