

# Controlling the Urban Physical Development in Karawang and Purwakarta Regencies using Quantitative Zoning Approach

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**Abstract.** Jakarta and Bandung metropolitan areas in Indonesia are experiencing urban expansion, which makes these two metropolitan areas increasingly connected by corridors to become one mega-urban. Karawang and Purwakarta Regencies are part of the Jakarta-Bandung corridor area which then triggers the urban physical development. This study aims to 1) Determine the level of service facilities in Karawang and Purwakarta Regencies; 2) Identify the changes in built-up and paddy fields Land Use/Land Cover (LULC) of Karawang and Purwakarta Regency based on existing and future conditions, and 3) Propose recommendations to control the urban physical development in Karawang and Purwakarta Regency. Analysis of level service facilities was carried out by using the scalogram method. Changes of built-up and paddy fields LULC in the existing and future conditions (projected using the CA-Markov method) are based on LULC of 2005, 2010 and 2018. Recommendations are given based on the grouping of villages with the same characteristics using the quantitative zoning method. Results showed the village development index in 2018 as the level of service facilities indicators, has a high or more developed value in the area around the connecting accessibility route between Jabodetabek and Greater Bandung metropolitan area. Changes in built-up and paddy fields LULC also the same trend as the village development index that is characterized by a fairly large increase in the area of built-up LULC in Karawang and Purwakarta Regencies. Recommendations are given to address specific problems that exist in each village group formed based on the spatial clustering method result.

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## 1. Introduction

Jakarta Metropolitan Area (Jabodetabek) is a metropolitan area in Indonesia that was formed because the entire Jakarta Province area has a dependency and interacts with the surrounding areas such as Bogor Regency, Bogor City, Depok City, Tangerang Regency, Tangerang City, Tangerang Selatan City, Bekasi Regency, and Bekasi City. Close to Jabodetabek, there is Bandung Metropolitan Area (Greater Bandung) which was formed because Bandung City has a dependency and interacts with the surrounding areas such as Bandung Regency, Bandung Barat Regency, and Cimahi City. Jabodetabek and Greater Bandung areas are very attractive regions in Indonesia because the infrastructure and public facilities are more developed and sufficient than in other regions. The attractiveness of this area leads to urban expansion which is marked by high urbanization (Pribadi & Pauleit, 2015; Pravitasari et al., 2018) and suburbanization (Hudalah & Firman, 2012; Hidajat et al., 2013) in Jakarta Metropolitan Area and marked by high urbanization (Fuadina et al., 2020) and peri-urbanization (Budiyantini & Pratiwi, 2016; Vitriana, 2020) in Bandung Metropolitan Area, which in turn has an impact on land conversion due to the increased need for land for housing and economic activity (Pravitasari et al., 2015). This

expansion has caused the Jabodetabek and Greater Bandung metropolitan areas increasingly connected to become one mega-urban (McGee, 1995; Firman & Dharmapatni, 1995; Adair, 2007; Firman, 2017) through a corridor which according to Dorodjatoen (2009) is called Jakarta-Bandung Mega-Urban Region (JBMUR). The formation of JBMUR according to Rustiadi et al. (2021) may cause a massive socio-economic and environmental impact. Mega-urban region is an extended metropolitan field of interaction (Douglass, 2000), while the term mega-urban itself according to Laquian (2008) is a non-standard definition of the urban agglomeration process which, when viewed using satellite imagery and GIS technology, shows an increasing pattern of built-up land cover areas that combines small towns in a rural area and settlements in an urban area.

Karawang and Purwakarta Regencies are part of the Jakarta-Bandung corridor area which is traversed by the Cipularang (Cikampek-Purwakarta-Padalarang) toll road that connects metropolitan of Jakarta and Bandung. The corridor area in this context is an area on the accessible route connecting two major cities due to the conurbation process. The formation of this corridor has led to the development of

areas along the corridor or in the corridor area which in turn formed a very close urban-rural connection, blurring the boundaries between urban and rural areas (Firman & Dharmapatni, 1995; Firman, 2009). According to Giyarsih (2012) in the corridor area, accessibility is the strongest factor affecting population activities thus accelerating the pace of urban physical development. Urban physical development term is synonymous with changes in regional characteristics towards more developed areas, or in other words changes towards urban characteristics. Panuju & Rustiadi (2013) defines the urban physical development of a region, which can be understood from the activities of more and more regional components and their distribution (spatial scope) or more widely distributed regional components. The increase in the rate of urban physical development will lead to an increase in land conversion, especially due to the large-scale development of regional infrastructure and the increase in population growth, vegetation land has become built-up lands (Abror et al., 2016). The conversion of agricultural land into built-up land is of course very detrimental because the conversion of this land function is irreversible (Rustiadi et al., 2009) where these built-up lands are almost impossible to be converted back into agricultural lands.

Development of the Jabodetabek and Greater Bandung Metropolitan Areas as a result of the urban expansion phenomenon has caused Karawang and Purwakarta Regencies as their corridors to continue to experience urban physical development. The most representative driving factors in urban expansion or urbanization modeling that can trigger urban physical development are variables such as population growth, distance to roads or water bodies, and

number of services or infrastructure centers (de la Luz Hernández-Flores et al., 2017). If the physical development of the area is not controlled, it will cause many villages to develop into areas that are dominated by urban characteristics due to the high conversion of land use to built-up land. Research that specifically examines the spatial aspects of urban physical development that occurs in Karawang and Purwakarta Regencies as a corridor area of the Jakarta-Bandung mega-urban region is still limited. Directions or recommendations are needed for the Local Government of Karawang and Purwakarta Regencies to control the urban physical development of the area that occurs as a result of the Jabodetabek and Greater Bandung Metropolitan Areas urban expansion phenomenon. So, this research has the objectives to 1) Determine the level of service facilities in Karawang and Purwakarta Regencies; 2) Identify the changes of built-up and paddy fields LULC of Karawang and Purwakarta Regency based on existing and future conditions; and 3) Propose recommendations to control the urban physical development in Karawang and Purwakarta Regency.

## 2. The Methods

This research was conducted in one of the Jakarta-Bandung mega-urban corridors, namely the administrative area of Karawang and Purwakarta Regencies (Figure 1) which consists of 30 sub-districts and 309 villages in Karawang Regency and 17 sub-districts and 192 villages in Purwakarta Regency. This study used secondary data such as Land Use/Land Cover (LULC) maps in 2005, 2010, and 2018, administrative maps, population data, road network data, and village potential data for 2003 and 2018 in the study

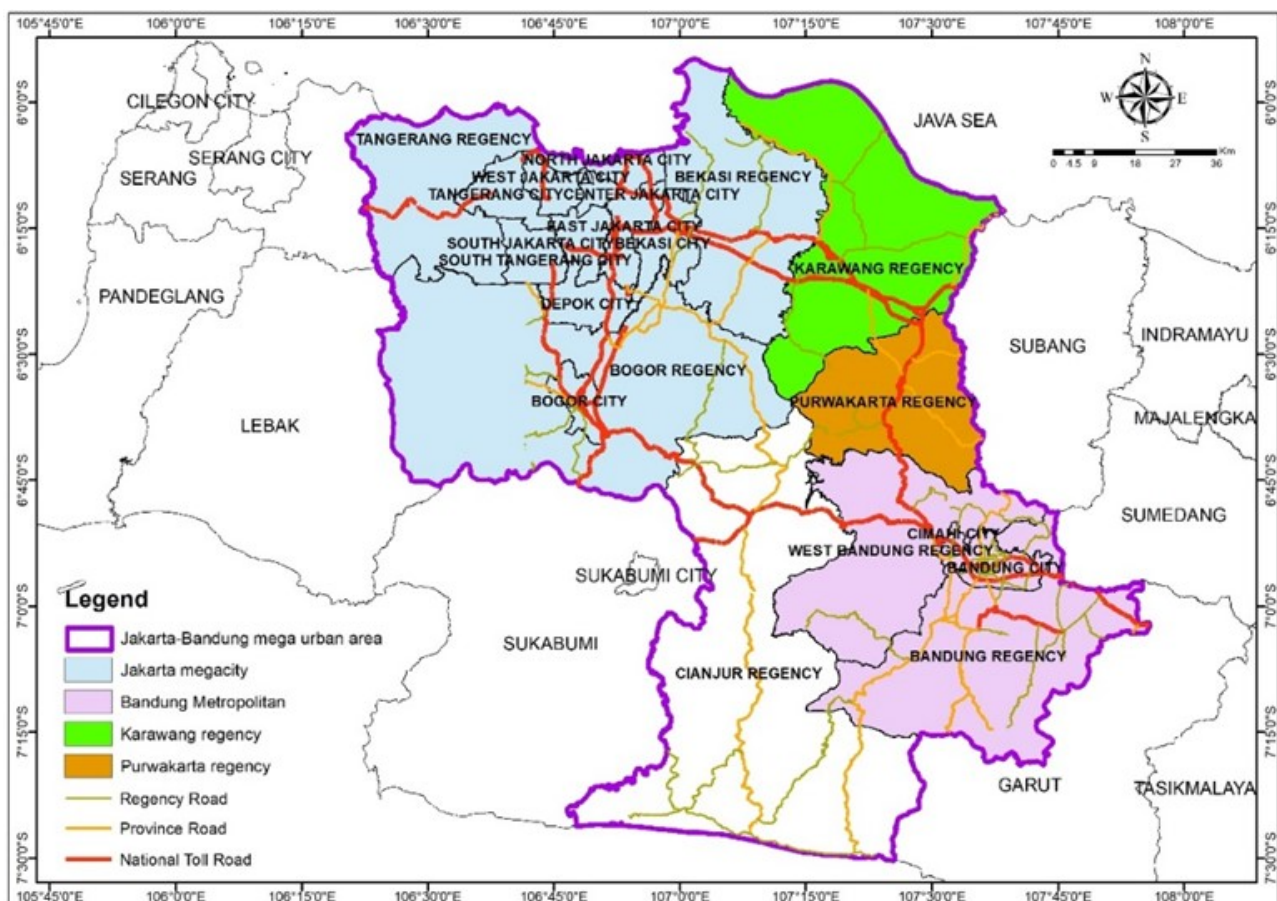


Figure 1. Location map of the study area

Table 1. The variables used in the scalogram analysis

Education	Health	Economic
Kindergarten	Hospital	Supermarkets/Convenience stores
Elementary school/Islamic elementary school	Maternity hospital	Shop/Stall/Kiosk
Junior high school/Islamic junior high school	Health center	Restaurant/Food shop beverage
Senior high school/Islamic senior high school	Auxiliary health center	Hotel/Lodging
Vocational school	Polyclinic/medical center	Commercial banks
Academy/University	doctor's place of practice	People's credit bank
Private Islam school/Private Madrasah	Midwife practice	Village unit cooperative (KUD)
Seminary	Village maternity	
	Pharmacy	

area. These secondary data of LULC were sourced from the National Institute of Aeronautics and Space (LAPAN) and the rest secondary data were sourced from the Central Statistics Agency (BPS) of Karawang and Purwakarta Regencies. All the secondary data were obtained from the Center for Regional Systems Analysis Planning and Development (Crestpent/P4W-LPPM) at IPB University.

Level of service facilities analysis was carried out using the scalogram method developed by Panuju & Rustiadi (2013) to check the level of service facilities in an area administratively based on data on the number and types of public facilities obtained from the Village Potential data. The variables in this analysis are grouped based on three aspect data facilities (Table 1). Urban physical development of service facilities level of an area can be determined by a kind of hierarchical level based on the value of the Village Development Index (VDI). In this study, a scalogram analysis was carried out to determine the VDI value of villages in Karawang and Purwakarta Regencies in 2003 and 2018.

The process of analyzing the changes of built-up and paddy fields LULC in the study area in the existing conditions is generally carried out by comparing the area and the spatial distribution of LULC in the study area in 2005, 2010, and 2018 from Landsat imagery sourced from (LAPAN) which has been systematically corrected and has been classified visually and using supervised classification methods by Center for Regional Systems Analysis Planning and Development (Crestpent/P4W-LPPM) IPB University. The LULC class of the Landsat imagery classification results consists of 7 classes, namely: built-up land, paddy fields, dryland, mixed garden, forest, water bodies, and clouds. The focus of LULC in this study is on the built-up and paddy fields LULC class. This is because one of the indicators of an increase in urban physical development is an increase in built-up LULC, then paddy fields LULC is selected to be identified as well because the areas of Karawang and Purwakarta Regencies are still dominated by agricultural lands, especially in Karawang Regency as one of Indonesia's national rice barn areas. The process of analyzing the changes in built-up and paddy fields LULC in the study area in future conditions is carried out by using predictive analysis of LULC. Prediction of LULC is carried out using the Cellular Automata-Markov Chain (CA-Markov) modeling method in IDRISI Selva software.

CA-Markov model represents LULC whose changes depend on the LULC of neighboring lands (Yudarwati et al., 2017). The basic concept of CA-Markov is to measure the probability of a series of events in the present to predict

future events (Fitriyanto et al., 2019) with a transition matrix that explains the probability of change in each cell/pixel from one LULC to another between two categories time point (Nadoushan et al., 2015; Siddiqui et al., 2018). In simulating LULC changes in this study, predictions of changes in 2018 were carried out as a model validation process based on LULC data from 2005 and 2010, then the prediction of LULC in 2031 was carried out based on the LULC data from 2005 and 2018, for which the time interval was 13 years. Validating the LULC prediction results is using the Kappa accuracy test to compare the predicted LULC map of 2018 with the actual LULC map of 2018. According to Mondal et al. (2016), the kappa value is a technique for validating the predicted results of LULC in the CA-Markov modeling. The Kappa value is classified as substantial if it is between 0.61-0.80 and classified as close to perfect if it is between 0.81-1.00 (Landis & Koch, 1977; Mondal et al., 2016). If the kappa value of the 2018 prediction is good enough, then the existing LULC data can then be used to predict the LULC map of 2031.

Recommendations to Karawang and Purwakarta Regencies Local Government to control the urban physical development in Karawang and Purwakarta Regency are given based on the village area units which have the same characteristics as the results of the previous analysis. Villages that have the same characteristics are obtained by forming a regional typology. Identification of areas/regions based on characteristics and typology can be done with cluster analysis, so that information on the number, the characteristics, and which areas are included in each sub-region will be obtained through the process of dividing a set of data into subsets or clusters (Han et al., 2012). Cluster analysis is one of the multiple variable techniques whose main purpose is to classify a set of observed objects and is specifically used to help manage regional management or planning policy become more efficient (Jatayu et al., 2020).

In this study, the cluster analysis method used is the spatial clustering method developed by Rustiadi & Kobayashi (2000) namely Rustiadi's Quantitative Zoning Method. According to Rustiadi & Kobayashi (2000), contiguity or continuity between polygons shows areas that are related to one another and have the same characteristics, and are influenced by the distance that is close to each other. The spatial clustering in this study uses one of Russia's Quantitative Zoning Method from Rustiadi & Kobayashi (2000), namely the contiguous spatial clustering method with geographic variables for each data unit in the

form of X and Y coordinates of each spatial unit and the imposition of contiguity weights for each spatial unit.

### 3. Results and Discussion

#### Level of Service Facilities

The level of service facilities of a region according to Panuju & Rustiadi (2013) can be understood from the increase in activities and their distribution. Regions with more types of activity are more developed areas and better at supporting human activities (Munibah et al., 2018). The level of service facilities can be determined by the height of the VDI, where the higher the index value, the more developed a region and vice versa. The results of level of service facilities analysis using the scalogram method can be seen in Table 2 and Figure 2.

VDI result based on the scalogram method in Karawang and Purwakarta Regencies in Figure 2 shows the distribution in the range 0 to 105 which are divided into 3 interval categories based on the Natural Break division, namely the VDI values ranging from 0–15 classified as low, 15.01–42 classified as moderate, and 42.01-105 classified as high. Generally, the distribution value of VDI ranges in Karawang Regency has increased the level of service facilities when seen from the increase in the average VDI value, which in 2003 was 11.93, increased to 13.37 in 2018. It is the same as Purwakarta Regency which has an average VDI value of 9.60 in 2003 then increased to 11.46 in 2018. The increase in the average value of VDI certainly shows that more villages have a greater VDI value in 2018 compared to 2003, or in other words, these villages are increasingly developing in 2018. Villages near the

connecting accessibility route between Jabodetabek and Greater Bandung metropolitan experienced an increase in VDI values from those initially dominated by low-classified VDI values in 2003 increase to medium and high VDI classification values in 2018.

#### Changes in Built-Up and Paddy Fields LULC in Existing and Future Conditions

Changes of built-up and paddy fields LULC in future conditions uses the Business as Usual (BaU) scenario approach based on past and present socio-economic trends with the assumption that the trends of the existing years (2005-2018 in this study) will continue in the future (Samie et al., 2017; Hamad et al., 2018). This LULC prediction analysis according to Singh et al. (2015), Parsa et al. (2016), and Hamad et al. (2018) aims to model land-use change and also to simulate and predict changes that occur in an area within a certain period. The kappa accuracy test result of the LULC 2018 prediction map is 0.84 which this result according to Landis & Koch (1977) and Mondal et al. (2016) is classified as near perfect because it is valued between 0.81-1.00. Because the results of the predicted LULC in 2018 are quite high, the LULC data used in this study then can be used to predict LULC maps in 2031. The LULC areas in Karawang and Purwakarta Regencies in existing and future conditions are presented tabularly in Table 3 and spatially in Figure 3.

Based on Table 3, the area of built-up LULC has continued to increase from 2005, 2010, and 2018, on the other hand, the area of paddy fields LULC has continued to decrease. Figure 3 shows that the increase in built-up LULC in Karawang and Purwakarta Regencies tends to occur in the

Table 2. Sum of villages in each VDI category in 2003 and 2018

VDI Category	Karawang Regency		Purwakarta Regency	
	2003	2018	2003	2018
Low	245	218	170	159
Moderate	57	82	17	29
High	7	9	5	4
Average VDI Value	11.93	13.37	9.60	11.46

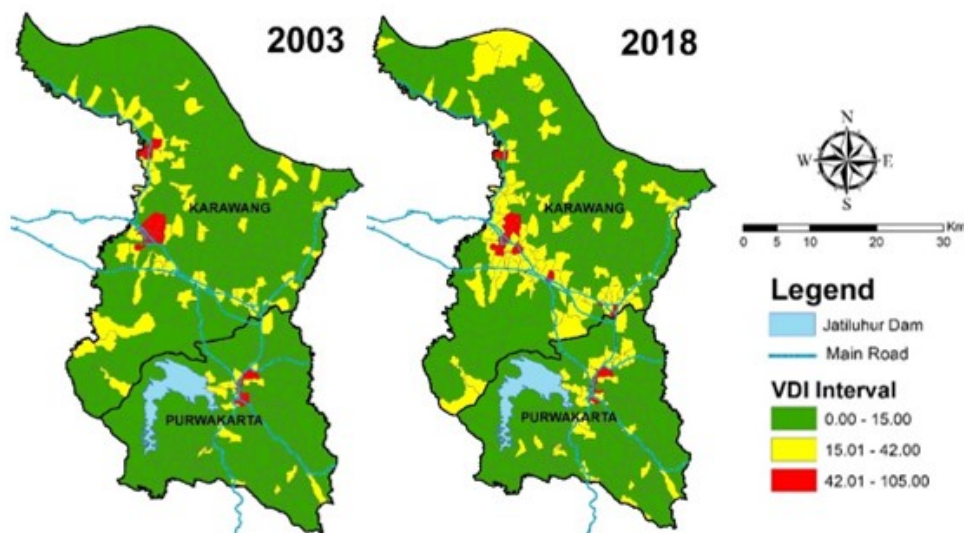


Figure 2. Spatial distribution of the Village Development Index in Karawang and Purwakarta regencies in 2003 and 2018



vicinity of the connecting accessibility route between Jabodetabek and Greater Bandung metropolitan. The increase in built-up areas that spreads randomly from the access route to the surrounding area causes the existing paddy fields area to be converted into built-up LULC. Figure 3 also shows that spatially, the built-up LULC of 2031 the projection results will continue to increase and be denser in the area around the connecting accessibility route between Jabodetabek and Greater Bandung metropolitan.

When viewed from the area based on Table 3, in 13 years after 2018 there will be an increase in built-up LULC by more than 2,000 hectares, while paddy fields LULC has also increased by around 1,000 hectares. The increase that occurred in paddy field LULC occurred because, in the 2005-2018 trend, other types of LULC also affected the simulation results and prediction of LULC in 2031. In the process of analyzing the LULC prediction using CA-Markov in this analysis, several types of LULC have a probability of turning into paddy fields based on the probability matrix of LULC transition 2005-2018 periods, although some types of LULC have the opposite probability, which reduces the area of paddy field LULC. So, this causes the LULC of paddy fields as predicted by land cover in 2031 to be increased by several cells/pixels in an area.

**Recommendation to Control the Urban Physical Development**

Urban physical development that occurred in Karawang and Purwakarta Regencies based on the previous analysis results showed a fairly large increase in the area of built-up

LULC in the study area, especially in the area around the connecting accessibility route between the Jabodetabek and Greater Bandung metropolitan area. Prediction analysis of future LULC (2031) with the BaU scenario approach resulted in an unavoidable increase in built-up LULC in that area. The distribution of the VDI value shows that the urban physical development in Karawang and Purwakarta Regencies tends to be high in areas that are close to the Jakarta-Bandung connecting accessibility route where Karawang and Purwakarta Regencies are areas in the northern corridor of Jakarta Bandung Mega-Urban Region. So that the urban physical development based on the VDI value is of course related to the changes in built-up LULC that occurred in Karawang and Purwakarta Regencies. If this situation continues, there will be regional economic inequality between the central part of Karawang Regency and other areas in the north and south that are still dominated by agricultural activities, the same case between areas in the central part of Purwakarta Regency and the western and eastern parts that are still dominated by agricultural and horticultural activities. If this continues, it will negatively impact the Karawang and Purwakarta Regencies, which is one of Indonesia's "national rice barns" areas. Based on the West Java Spatial Plan of 2009-2029, the Karawang Regency, one of the regencies with the most significant rice production in Indonesia, especially West Java Province, is directed as a wetland agricultural area. At the same time, Purwakarta Regency is directed so that its cultivation activities do not interfere with the irrigation system and water reserves.

Table 3. LULC area in Karawang and Purwakarta Regencies (ha)

Land Cover Type	Land Cover Area (ha)			
	2005	2010	2018	2031
Built-up	17,862.16	23,093.52	28,566.23	30,786.36
Paddy Fields	157,689.15	146,141.17	142,158.32	143,042.53
Others	114,848.38	121,165.00	119,675.14	116,570.79
Total	290,399.69	290,399.69	290,399.69	290,399.69

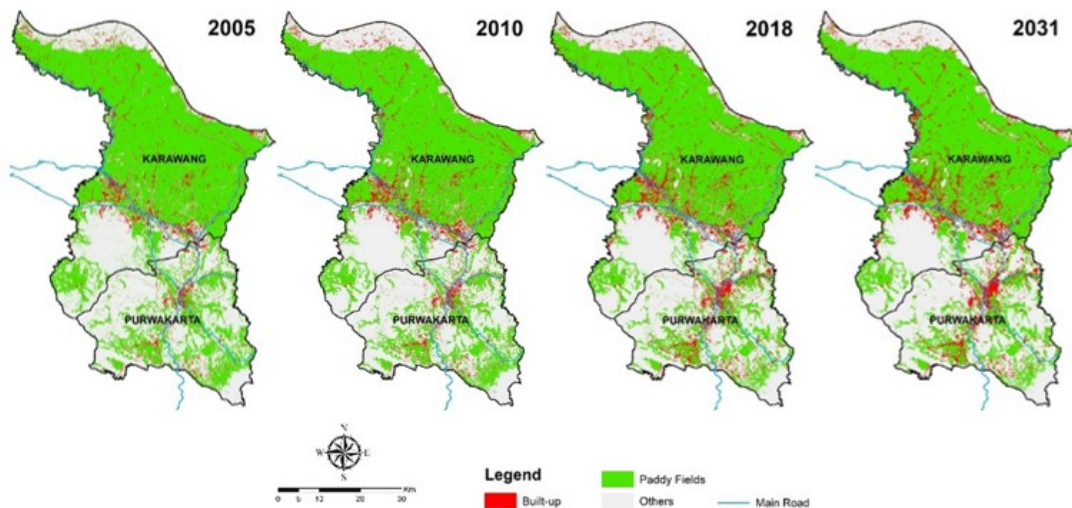


Figure 3. Built-up and paddy fields LULC maps of Karawang and Purwakarta Regencies in 2005, 2010, 2018, and 2031 (projection result)

The trend of urban physical development that is happening based on previous analysis certainly must get the attention of the Regional Government of Karawang and Purwakarta Regencies so that directions are needed. Directions are compiled in each group of village units based on the village with the same characteristic. These different characteristics of the village lead to different directions or policy approaches between regions. The ideal policy is a set of policies following the characteristics and potential of each regional unit. This is because the level of complexity of the problem in each area unit is different and varies. Village groupings can help identify problems with these distinct regional characteristics. This needs to be done so that the directions and policies given to the Local Governments of Karawang and Purwakarta Regencies can be more focused and directed in accordance with the characteristics of the results of the formed village groupings. Village grouping is analyzed using spatial clustering analysis. Spatial clustering is a technique of grouping areas not only based on similarity or proximity of characteristics but also the distance between one area and another (spatial proximity) will be a consideration (Rustiadi & Kobayashi, 2000). The variables used in this spatial clustering analysis are Population Density in 2018, VDI in 2018, percentage of Built-Up Area in 2018, percentage of Paddy Fields Area in 2018, and Distance to Main Road.

Based on the background of this study regarding how the possibility of changes in the villages in Karawang and Purwakarta Regencies with rural characteristics into urban characteristics due to the impact of urbanization, suburbanization, and the impact of the Jakarta-Bandung Mega-Urban formation that affects a conurbation process, the authors deliberately (purposive) conducted a spatial clustering analysis to divide the clusters in Karawang and Purwakarta Regencies into 3 clusters, namely the Urban cluster, Rural cluster, and Sub-Urban cluster. The Sub-Urban cluster is a cluster based on the village that still has a rural characteristic but gradually becomes an urban characteristic, still in the process of transition from the rural

characteristic village into an urban characteristic village. This division of clusters into the Urban cluster, Rural cluster, and Sub-Urban cluster is also a zoning concept that usually exists in Southeast Asia's peri-urban especially in the Jabodetabek metropolitan area, Indonesia where the Sub-Urban cluster is commonly referred to by the term *desakota* (McGee, 2021; Winarso et al., 2015; Pribadi & Pauleit, 2016). Clusters formed based on the spatial clustering analysis results can be seen in Figure 4., while the characteristics of each cluster based on the spatial clustering analysis results can be seen in Table 4.

Generally, based on Figure 4., the spatial distribution of regional typology in Karawang and Purwakarta Regencies was dominated by Rural typology (cluster) that was mainly located spread from the northern part to the middle part of Karawang Regency, where which is related to the existing LULC condition in that area that is a mainly Paddy Fields LULC. The spatial distribution of the Sub-Urban cluster was located spread from the middle part of Karawang Regency to the southern part of Purwakarta Regency, where this is related to the existing LULC condition in that area that has a low area of Built-up and Paddy Fields LULC. Meanwhile, the spatial distribution of the Urban cluster was located mainly in the middle part of Karawang and Purwakarta Regencies. The spatial distribution of this Urban Cluster is in line with the spatial distribution of Karawang and Purwakarta Regencies existing built-up land cover type in 2018.

One of the negative impacts based on the results of this spatial clustering analysis is that villages in Karawang and Purwakarta Regencies, especially those with clusters of sub-urban characteristics, tend to develop and change towards villages with urban characteristics. This change will certainly have an impact on increasing built-up areas. Spatially as shown in Figure 4., if these developments and changes are not controlled, then more than half of the Karawang and Purwakarta Regencies will change to an area with urban characteristics ranging from the central of Karawang Regency to the southern part of Purwakarta Regency. The results of this spatial clustering analysis can be a kind of warning for the Karawang and Purwakarta Regencies Local governments to develop villages according to the potential of their natural resources, not always focusing to develop them into the urbanized area. Villages in the Rural Cluster should be maintained as a rural characteristic, while the Sub-Urban Cluster can be an option to develop the urbanized area, but as much as possible maintain its current condition according to the existing potential.

For this reason, spatial planning can control the rate of urban physical development in the Karawang and Purwakarta Regencies. The use of lands/space should in



Figure 4. Karawang and Purwakarta Regencies cluster map

Table 4. Characteristics of each cluster

Variable Name	Rural	Sub-Urban	Urban
Village Development Index	Low	Low	High
Population Density	Low	Low	High
Percentage of Built-up area	Low	Low	High
Percentage of Paddy Fields area	High	Low	Low
Distance to Main Road	Far	Far	Near

accordance with the spatial pattern of the Spatial Plan Document of Karawang and Purwakarta Regencies. Consistency between land use and spatial patterns is something that must be considered, if there are indications of inconsistency, Karawang and Purwakarta Regencies Local Government must enforce strict spatial use control instruments.

#### 4. Conclusion

Urban physical development that occurred in Karawang and Purwakarta Regencies shows that there has been a shift from regional characteristics, which were initially still dominated by rural characteristics, turned into areas with urban characteristics, especially in the central part of these two regencies. These regional characteristics shift was characterized by an increase in the level of service facilities in Karawang and Purwakarta Regencies from 2003 to 2018. Changes in built-up and paddy fields LULC also has the same trend as the village development index that is characterized by a fairly large increase in the area of built-up LULC in Karawang and Purwakarta Regencies in the 2005-2018 period and the future of 2031 projected LULC. Villages in every cluster should be developed according to their characteristics and natural resources potential. With the spatial planning approach, recommendations that can be given to villages in each cluster are to implement strict enforcement of spatial use control instruments. Consistency between land use and spatial patterns of the Spatial Plan Document of Karawang and Purwakarta Regencies can control the rate of urban physical development that occurs in these regencies.

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