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# Analysis Spatial Pattern of Urban Growth Using Remote Sensing Data: A Study in Purwokerto, Central Java, Indonesia

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## ABSTRACT

Expansion of built-up land can lead to changes in land use and land cover (LULC), especially in urban areas. Expansion of built up land can occur due to an increase in population and the level of urbanization. Urbanization and changes in LULC have led to a substantial increase in the urban population due to migration, which has brought many acute problems in the urban environmental system. This study aims to map LULC conditions in 2008, 2013, and 2018 and to analyze the spatial pattern of urban growth from 2008 to 2018. The maximum likelihood method was used to classify LULC based on Landsat imagery and to analyze urban growth spatial patterns. Spatial analysis was carried out by dividing the four locations into 4 (four) quadrants adjusted to the cardinal directions. From the analysis conducted, the accuracy of the research in 2008 was 88%, in 2013 was 86%, and in 2018 was 88%. From this study, the urban growth of the city in Purwokerto spreads in all directions, but urban growth is more dominated in quadrant I or the northeast direction. Quadrant 1 has a strong pull from Purbalingga Regency and is traversed by the main connecting road between districts and provinces to the north and east so that it can cause expansion of built-up land in quadrant 1. The results of this study can be used as recommendations in making urban spatial plans in Purwokerto City.

**Keywords:** Spatial Pattern, Remote Sensing, Maximum Likelihood, Urban Growth

## 1. INTRODUCTION

Purwokerto City is one of the cities that experienced an increase in population and urbanization [1]. Based on data from the Badan Pusat Statistik Kabupaten Banyumas in 2009 and 2019, Purwokerto City in 2008 had a population of 519,271 people which then increased in 2018 by 598,726 people [2-3]. In addition, Purwokerto City became a Central Business District (CBD) based on Banyumas District Regional Regulation No. 10 of 2011 concerning urban spatial planning and the location of Purwokerto City is very strategic, which is located among other cities so that it is traversed by the main transportation line [4-5]. This has an impact on increasing population and urbanization so that there can be urban growth of the Purwokerto City [6-7]. The urban growth of the city is a morphological change in the form of increasing built-up land in urban areas [8-9]. The urban growth of the city has an impact on changes in land use and land cover (LULC), namely the change from non built-up land to built-up land.

The existence of remote sensing technology and geographic information systems (GIS) can be utilized in the analysis of spatial patterns of urban growth of cities in Purwokerto City. Remote sensing is capable of obtaining the data and information of an object without direct contact with the object and has a wide scope in a fast time [10]. Remote sensing capabilities that have a variety of spectral resolutions can perform information extraction of LULC. In addition, remote sensing can be used to monitor changes in LULC such as the urban growth of the city in Purwokerto City [11]. The method used in the extraction of LULC information is a supervised classification with a maximum likelihood algorithm based on the diversity of classes and the average band value in the remote sensing satellite image used [12].

Analysis and direction of spatial patterns of urban growth of cities is important to find out how the spatial pattern direction of the urban growth of the city in Purwokerto City. Analysis and direction of spatial patterns can be known using GIS modeling by dividing Purwokerto City into four quadrants based on the direction of the wind with the midpoint being at the city center [13-14]. Spatial pattern direction modeling uses temporal data from remote sensing in the form of covering object information and land use. Therefore, the analysis of spatial patterns of urban growth can be used as recommendations in the development and spatial plan in Purwokerto City.

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## 2. DATA AND METHODS

### 2.1 Study Area

Based on law No. 22 of 1999 on Local Government and Law No. 25 of 1999 on Financial Balance between the Central and Regional Governments there is a Proposed New Autonomous Regions (PNAR) of the Banyumas Regency government will expand into three districts namely PNAR Banyumas Regency, PNAR West Banyumas Regency, and PNAR Purwokerto City [15-16]. This research focuses on PNAR Purwokerto City which has its capital in East Purwokerto Subdistrict. PNAR Purwokerto City consists of nine subdistricts namely North Purwokerto, South Purwokerto, West Purwokerto, East Purwokerto, Kembaran, Sumbang, Baturraden, Kedungbanteng, and Karanglewas. PNAR Purwokerto City is located in a strategic position that is in the middle of Java Island which is surrounded by surrounding cities and traversed by the main transportation route between regions. In addition, PNAR Purwokerto City has topographic conditions with slopes from flat to very steep and has a height of about 0 meter above sea level (masl) to 3,100 masl [17].

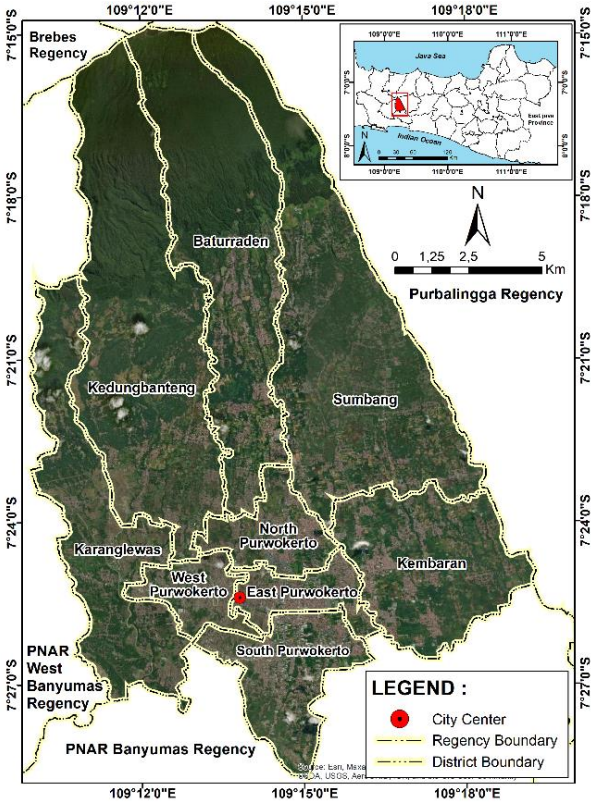


Figure 1. Study Area

Source: (Geospatial Information Agency, 2019; and U. S. Geological Survey, 2019)

### 2.2 Data Collection

The data used is geospatial shapefile data from the Badan Informasi Geospasial (BIG), Landsat 5 Thematic Mapper (TM) satellite images in 2008, Landsat 8 Operational Land Imager (OLI) in 2013, and in 2018 from the U.S. Geological Survey (USGS). The image data used must be done geometric and radiometric correction process for further image processing.

The use of Landsat image data is used because it has a spectral resolution in the form of multispectral and temporal resolution which is suitable for monitoring changes in LULC and urban growth. Landsat imagery has several generations, namely Landsat 1 to Landsat 9 which has a spatial resolution of 30 meters and a temporal duration of 16 days. Therefore, LULC mapping from 2008 to 2018 can use Landsat 5 TM and Landsat 8 OLI. Meanwhile, the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) image is not used because there is damage in the form of a gap in the recording so that it cannot represent the object properly. The data along with their sources and image characteristics can be seen in Table 1. and Table 2.

Table 1. Data and Sources

| No. | Data | Information | Provider | Source |
|---|---|---|---|---|
| 1 | RBI Map of Banyumas Regency Scale 1:25.000 | Geospatial data shapefile | BIG | https://tanahair.indonesia.go.id/portal-web |
| 2 | Landsat 5 TM Image 2008 | LULC in 2008 | USGS | https://earthexplorer.usgs.gov/ |
| 3 | Landsat 8 OLI Images 2013 and 2018 | LULC in 2013 and 2018 | | |
| 4 | Google Earth image of Purwokerto City 2008, 2013, and 2018 | LULC in 2008, 2013, and 2018 | Google Maps | https://www.google.com/maps |

Table 2. Satellite Data

| Satellite | Sensor | Acquisition Date | Resolution (m) | Bands |
|---|---|---|---|---|
| Landsat 5 | TM | 28 Juli 2008 | 30 | Blue, Green, Red, Near Infrared, Short-Wave Infrared I, & Short-Wave Infrared II |
| Landsat 8 | OLI | 24 Juni 2013 | 30 | Coastal Aerosol, Blue, Green, Red, Near Infrared, Short-Wave Infrared I, & Short-Wave Infrared II |
| Landsat 8 | OLI | 5 Mei 2018 | 30 | Coastal Aerosol, Blue, Green, Red, Near Infrared, Short-Wave Infrared I, & Short-Wave Infrared II |

Source: (U. S. Geological Survey, 2019)

### 2.3 Classification

LULC classification use pixel-based digital classification with maximum likelihood algorithm. The classification is carried out on Landsat 5 TM image data in 2008, Landsat 8 OLI image in 2013, and Landsat 8 OLI image in 2018. There is a classification scheme used based on the Standar Nasional Indonesia (SNI) Badan Standarisasi Nasional (BSN) in 2014 on mapping LULC for mapping scales of 1:100,000 with modifications [18]. There are five classes that can be seen in Table 3.

The results of subsequent classifications are performed by majority filters to remove alienated pixels and improve pixels to become more homogeneous [19]. The majority filter uses a moving window size of 3x3 so that the classification results are not too generalized. After that, accuracy tests were conducted to find out the level of accuracy in the results of the LULC in 2008, 2013, and 2018. The accuracy test uses matrix confusion obtained from field sample data. Field samples were obtained from field observations, interviews, and observations from Google Earth.

Table 3. LULC Class

| No. | Class | Description |
|---|---|---|
| 1 | Agriculture | Land used to produce agricultural crops such as irrigation rice fields, rain fields, and moors |
| 2 | Built-up | Buildings made for residence and/or non-residential areas such as settlements, buildings, industry and others. |
| 3 | Open Space | Open or empty land without buildings or other vegetation covers |
| 4 | Vegetation | All vegetation except agricultural vegetation |
| 5 | Water Body | All existing bodies of water such as rivers, lakes, reservoirs, and so on |

Source : (SNI BSN, 2014) with modifications

### 2.4 Urban Growth Analysis

Changes that occur morphologically or physically in an urban area in the form of an increase in the amount of land built is known as the urban growth of the city [8-9]. The urban growth of the city resulted in changes in LULC from non built-up land turned into built-up land. These changes can occur due to increasing population and urbanization in urban areas from year to year. The urban growth of the city that occurs has a certain direction that can be observed based on the spatial pattern of the amount of built-up land and built-up land that exists. The spatial pattern of the urban growth of the city can be known with the help of remote sensing data such as extraction from temporal Landsat Imagery data. Data extraction used in the form of classification results in the form of built-up land classes and non built-up land temporally in PNAR Purwokerto City.

Determination of spatial pattern of urban growth based on changes in LULC of built-up land and non built-up land classes in PNAR Purwokerto City in 2008, 2013 and 2018 [20]. The spatial pattern direction of urban growth is divided into four quadrants according to the direction of the wind with the midpoint being at the center of the city [13]. The division of the direction of urban growth is presented in Figure 2. and the flow of work from this research in full can be seen in Figure 3.

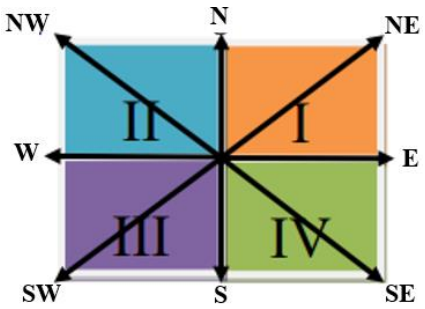


Figure 2. Illustration of dividing the urban growth direction

Source: (Nugroho and Rahardjo, 2014)

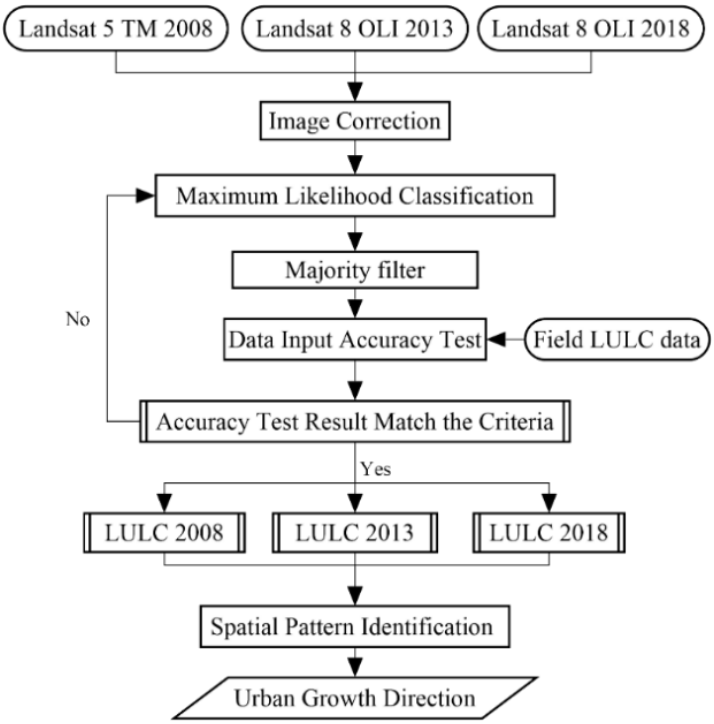


Figure 3. Flow Chart of Research Method

## 3. RESULT AND DISCUSSION

The result and discussions of this study are divided into three parts, namely (1) Accuracy Assessment; (2) Land Use and Land Cover (LULC) Change in 2008, 2013 and 2018; and (3) Spatial Pattern Direction of Urban Growth.

### 3.1. Accuracy Assessment

The accuracy test is obtained by calculating the results of the confusion matrix which contains a comparison between the data from the classification and the reference data in the field using a sample of 150 points. A sample of 150 points in the study area was used for the period 2008, 2013, and 2018 which had reached the target accuracy of 85%. The accuracy test on the LULC maps in 2008, 2013, and 2018 is based on the results of interviews, observations from Google Earth data from 2008 to 2018, and the results of observations in the field.

Based on Table 4., Table 5., and Table 6. The accuracy of the 2008 classification results was 88% and the kappa index by 0.819, the accuracy in 2013 by 86% and the kappa index by 0.792, and the accuracy in 2018 by 88% and the kappa index by 0.827. The results of the classification have an acceptable accuracy because it has exceeded the minimum accuracy of 85% [21]. Classification results in 2008 and 2018 had kappa index values that fall into very strong categories, while classification results in 2013 had kappa indexes in strong categories [22].

In the results of the accuracy test, it was seen that the water body class and open space class had errors in classification that were quite a lot more than other classes. This happens because the open space class can be reduced to agricultural class or vice versa. Open space can have spectral value in the agricultural land class. These similarities can occur because image recording is done during the dry season with the condition of agricultural land that lacks water with a small amount of rice so that it can be reduced to open space land [23]. Meanwhile, the class of water bodies in the PNAR of Purwokerto City has an area that is not too large, namely some water bodies that have a size of no more than 30 square meters so it cannot be elaborated on Landsat images that have a spatial resolution of 30 meters. Therefore, in the water body class, there is a mixture of pixels of other objects around it that can cause errors in classification.

Table 4. Confusion Matrix and Classification Accuracy in 2008

| 2008 | | Reference Data | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Agriculture | Built-up | Open Space | Water Body | Vegetation | |
| Classification | Agriculture | 57 | 5 | 4 | 1 | 4 | 71 |
| | Built-up | 0 | 48 | 1 | 0 | 0 | 49 |
| | Open Space | 2 | 0 | 1 | 0 | 0 | 3 |
| | Water Body | 0 | 0 | 0 | 1 | 0 | 1 |
| | Vegetation | 0 | 0 | 1 | 0 | 25 | 26 |
| Total | | 59 | 53 | 7 | 2 | 29 | **150** |

Overall accuracy = 88,00 %
Kappa index = 0,819

Table 5. Confusion Matrix and Classification Accuracy in 2013

| 2013 | | Reference Data | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Agriculture | Built-up | Open Space | Water Body | Vegetation | |
| Classification | Agriculture | 50 | 3 | 0 | 1 | 5 | 59 |
| | Built-up | 1 | 51 | 1 | 0 | 0 | 53 |
| | Open Space | 3 | 0 | 1 | 0 | 0 | 4 |
| | Water Body | 0 | 0 | 0 | 1 | 0 | 1 |
| | Vegetation | 3 | 1 | 3 | 0 | 26 | 33 |
| Total | | 57 | 55 | 5 | 2 | 31 | **150** |

Overall accuracy = 86 %
Kappa index = 0,792

Table 6. Confusion Matrix and Classification Accuracy in 2018

| 2018 | | Reference Data | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Agriculture | Built-up | Agriculture | Water Body | Vegetation | |
| Classification | Agriculture | 46 | 0 | 0 | 2 | 2 | 50 |
| | Built-up | 1 | 53 | 1 | 0 | 0 | 55 |
| | Open Space | 5 | 4 | 5 | 0 | 1 | 15 |
| | Water Body | 0 | 0 | 0 | 0 | 0 | 0 |
| | Vegetation | 2 | 0 | 0 | 0 | 28 | 30 |
| Total | | 54 | 57 | 6 | 2 | 31 | **150** |

Overall Accuracy = 88.00 %
Kappa index = 0,827

### 3.2. Land Use and Land Cover (LULC) Change in 2008, 2013 and 2018

The condition of the LULC in PNAR Purwokerto City during 2008 to 2018 experienced a change in area in each class. Based on Table 7., and Table 8. In 2008 the LULC classes were dominated by the agricultural land class, while in 2013 and 2018 it was dominated by vegetation classes. Meanwhile, major changes occurred in the agricultural land class in 2008-2013 decreased by 10,954,800 $m^2$ or by -4.22%, and in 2013-2018 decreased by 33,221,700 $m^2$ or by -12.80%. The change in agricultural land goes hand in hand with the increasing class of built-up land and open space land. This can be observed based on Figure 4. which presents the conditions of LULC in 2008, 2013, and 2018. Increasing population and urbanization are factors that can cause an increase in the built-up land. The more people in one city then need a place to live so that the more residents the more built-up land there [24]. Therefore, from 2008 to 2018 there has been an increase in population resulting in changes in LULC with increasing built-up land and open space land that replaces agricultural land.

Based on Figure 4. The majority of the scattered vegetation classes are in the northern part of PNAR Purwokerto City. This is because the northern part is the slope of Slamet volcano which has a rather steep to very steep and is at an altitude of more than 700 masl so there is rarely any influence from human activities that can cause land changes. The class of agriculture land is spread outside the city which is at an altitude of 0 masl to 400 masl and has a flat slope to ramps. These conditions have a fairly large water supply and there is little built-up land such as settlements so that there are many classes of agricultural land. The distribution of open space land classes dominates the northern and eastern parts. The class of open land in PNAR Purwokerto City is some agricultural land when after harvesting that looks only a wasteland without

vegetation in the form of rice so that it can be reduced into open land. In addition, open land classes can be hardened fields or fields with little grass and other open space lands. The built-up land class has a scatter pattern that clustered in the city center and is in a topography that is flat to sloping. The cluster distribution pattern is the center of city activities in PNAR Purwokerto City with built-up lands such as government offices, hospitality, shopping centers, places to eat, settlements, tourist attractions, and others.

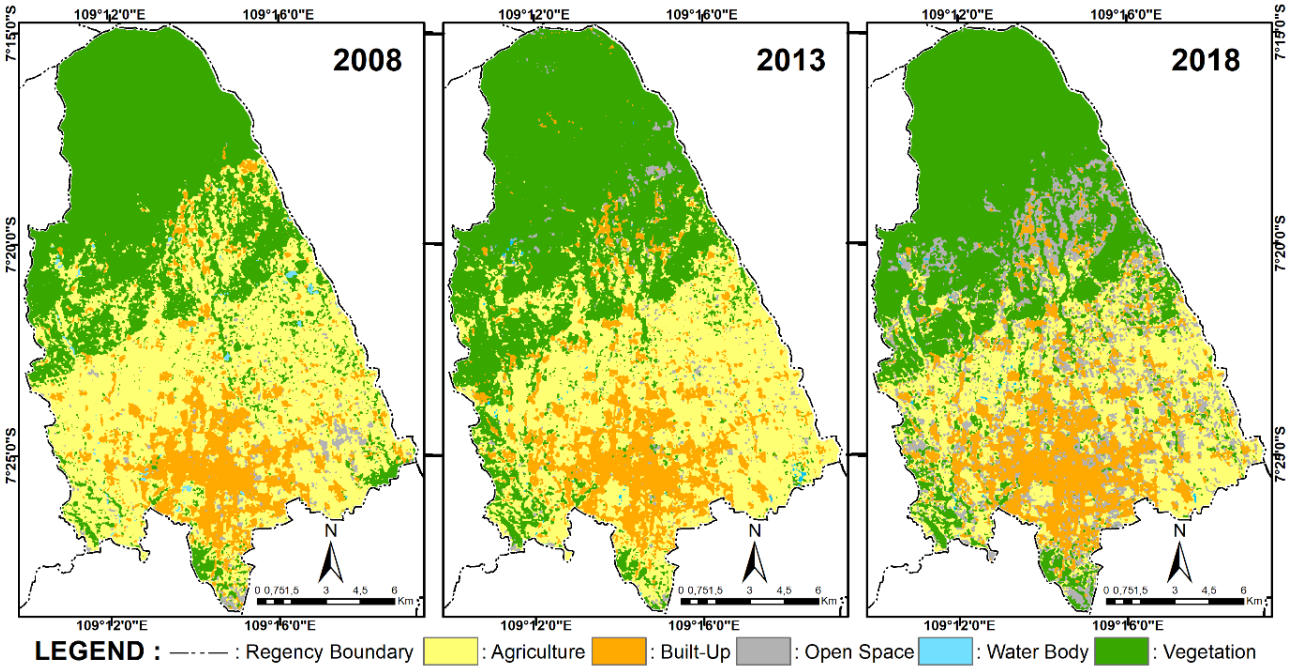


Figure 4. Multi-temporal LULC Map

Table 7. Area LULC Classes

| Class | Area ($m^2$) | | | Area Changes ($m^2$) | |
|---|---|---|---|---|---|
| | 2008 | 2013 | 2018 | 2008 - 2013 | 2013 - 2018 |
| Agriculture | 110.212.200 | 99.257.400 | 66.035.700 | -10.954.800 | -33.221.700 |
| Built-up | 34.016.400 | 37.312.200 | 42.813.000 | +3.295.800 | +5.500.800 |
| Open Space | 4.389.300 | 4.743.000 | 34.732.800 | +353.700 | +29.989.800 |
| Water Body | 1.207.800 | 485.100 | 427.500 | -722.700 | -57.600 |
| Vegetation | 109.812.600 | 117.840.600 | 115.629.300 | +8.028.000 | -2.211.300 |
| **Total** | **259.638.300** | **259.638.300** | **259.638.300** | **0** | **0** |

Table 8. Proportion LULC Classes

| Class | Area (%) | | | Area Changes (%) | |
|---|---|---|---|---|---|
| | 2008 | 2013 | 2018 | 2008 - 2013 | 2013 - 2018 |
| Agriculture | 42.45 | 38.23 | 25.43 | -4.22 | -12.80 |
| Built-up | 13.10 | 14.37 | 16.49 | +1.27 | +2.12 |
| Open Space | 1.69 | 1.83 | 13.38 | +0.14 | +11.55 |
| Water Body | 0.47 | 0.19 | 0.16 | -0.28 | -0.02 |
| Vegetation | 42.29 | 45.39 | 44.53 | +3.09 | -0.85 |
| **Total** | **100.00** | **100.00** | **100.00** | **0.00** | **0.00** |

### 3.3. Spatial Pattern Direction of Urban Growth

The urban growth of the city in the PNAR Purwokerto City from 2008 to 2018 can be seen based on changes LULC in the form of existing built-up and non built-up land classes. Based on Figure 5. PNAR Purwokerto City is divided into four quadrants with the middle point in the city center. Visually the map shows the spatial pattern of the urban growth of the city spreading in all directions, but growth is dominated in quadrant 1, namely in the northeast direction. Based on Table 9. There was an increase in the area of the land class built by 4,588 km$^2$ and had an average growth of 2,294 km$^2$/year.

The urban growth of the dominant city is in quadrant 1 or leads to the northeast caused because in the northeast there is Purbalingga Regency that has the potential for interaction between cities that can increase the increase in built-up land [25]. On the border of Purbalingga Regency with PNAR Purwokerto City, there is a Faculty of Engineering, Jenderal Soedirman University and there are also several excellent tourist attractions of Purbalingga located on the border. In addition, in quadrant 1 there are main roads such as provincial and district roads that connect between regions, there is Muhammadiyah Purwokerto University, central campus of Jenderal Soedriman University, several schools, settlements, factories, and others. This is a factor that can cause the urban growth of the city in quadrant 1, namely the increasingly built-up land that replaces non built-up land such as agricultural land, vegetation land, open space land, and water bodies in quadrant 1.

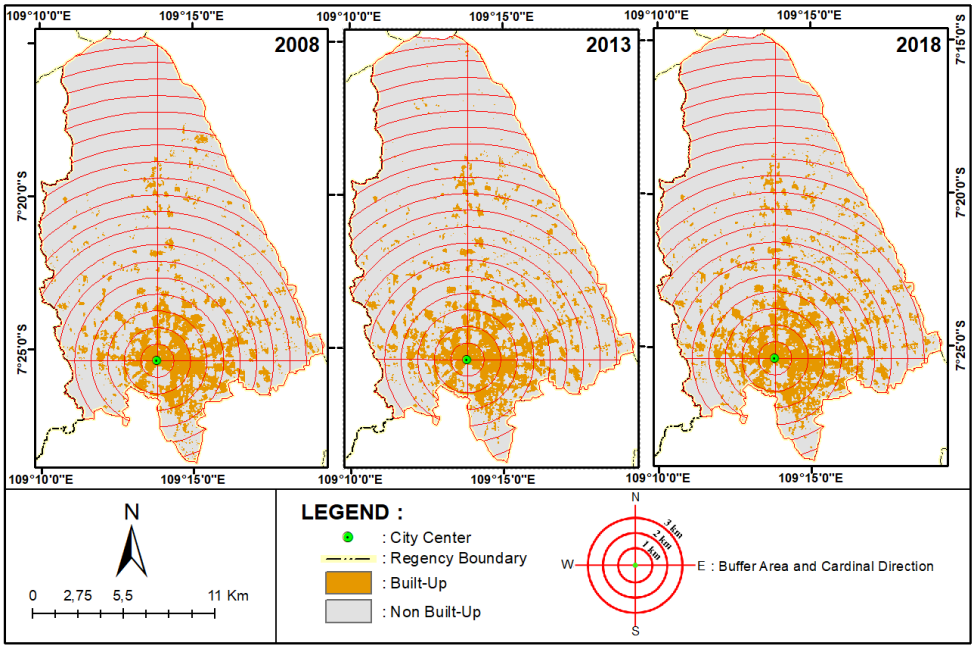

Figure 5. Multi-Temporal Built-up Land Map

**Tabel 9.** Identification of Built-up Changes During 2008 – 2018 Based on Quadrant Direction

| Quadrant Class | Area ($Km^2$) | Built-up Area in 2008 | | Built-up Area in 2018 | | Built-up Changes | | Average Changes ($Km^2$/year) |
|---|---|---|---|---|---|---|---|---|
| | | $Km^2$ | % | $Km^2$ | % | $Km^2$ | % | |
| 1 | 104,575 | 14,504 | 13,869 | 19,092 | 18,257 | 4,588 | 4,387 | 2,294 |
| 2 | 115,913 | 7,428 | 6,408 | 10,222 | 8,819 | 2,795 | 2,411 | 1,397 |
| 3 | 14,460 | 2,534 | 17,527 | 3,288 | 22,736 | 0,753 | 5,209 | 0,377 |
| 4 | 24,691 | 9,543 | 38,649 | 10,211 | 41,357 | 0,669 | 2,708 | 0,334 |

## 4. CONCLUSION

Based on the results and discussion of the study there are two conclusions, namely, first, the results of land use and land cover (LULC) using pixel-based classification with maximum likelihood algorithm have an accuracy of more than 85%. The results of the 2008 class have an accuracy of 88% with a kappa index of 0.819, in 2013 it has an accuracy of 86% with a kappa index of 0.792, and in 2018 it has an accuracy of 88% with a kappa index of 0.827. There are two classes of LULC that dominate, namely the class of agricultural land and vegetation land. In addition, changes in LULC mostly occurred in the class of agricultural land which decreased from 2008 to 2018 accompanied by an increase in built-up land class in PNAR Purwokerto City. Second, the direction of the spatial pattern of urban growth that occurred in the PNAR Purwokerto City from 2008 to 2018 is spread in all directions, but the majority occurred in quadrant 1 or northeast direction. In quadrant 1, the land class increase was built-up land by 4,588 $km^2$ with an average growth of 2,294 $km^2$ / year. The urban growth of the city can occur due to interactions between the surrounding areas and the existence of urban activities that occur such as universities, factories, shopping centers, tourist attractions, and others.

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