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# The utilization of spatial statistics in a study of built-up densification in Yogyakarta urban area

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## Abstract

Simple spatial statistics can be used in analyzing spatially the mean center, orientation, and standard deviation of an area with built-up densification. This research maps the built-up densification of urban areas in Yogyakarta based on the Landsat TM images of 1994, 1996, and 1998, Landsat ETM images of 2001 and 2003, and Aster images of 2006, and examines the characteristics of built-up densification in the urban areas of Yogyakarta using a spatial statistic approach.

Built-up densification maps of five periods were obtained by spatial analysis of the built-up densification maps of 1994-1996, 1996-1998, 1998-2001, 2001-2003, and 2003-2006. Simple spatial statistics was applied in analyzing the built-up densification characteristics of each period. There were four spatial statistic components to describe the built-up densification, namely, the mean center position of an ellipse plane, the orientation of the ellipse, the long axis of the ellipse, and the short axis or width of the ellipse.

Built-up densification maps were extracted from the spatial resolution satellite images comprising the TM Lansat satellite images, the ETM Lansat satellite images, and the Aster satellite images. Built-up densifications maps were constructed by analyzing the serial overlay operation of the built-up density maps in two consecutive years. The spatial statistic analysis of the five built-up densification maps shows dynamic variations of mean center position, orientation, and standard deviation of the built-up densification in the urban areas of Yogyakarta.

**Keywords**: built-up densification, built-up densification maps, orientation of the ellipse, satellite images, spatial resolution, spatial statistics

## Introduction

One of urban physical development realizations is horizontal built-up densification increase which is commonly known as built-up densification. Built-up densification (built-up density) increase is reflects population increase which tends to result in negative effects. The emergence of discordant relationship between population increase and urban area management can be seen from tangible indicators such as traffic congestions, growing of slum areas, domestic water shortages, lack of public facilities, and mistreated or dysfunctional rainfall drainage (Suharyadi, 2000). Uncontrolled built-up densification will reduce the quality of life in residential areas and will lead to the rise of new problems in public health.

Built-up densification map is necessary in understanding the process of built-up densification. For speed, this map can be obtained from remote sensing survey. The utilization of remote sensing as the technique to collect the spatial data of the urban areas has been done for some time. For example, the aerial portrayal of urban areas in Boston from an air balloon (Lillesand *et al*., 2007). The accelerative development of the use of remote sensing image in urban survey has started since the launch of earth source satellite Landsat-1 about 38 years ago. The number of research focusing on urban areas (Yang , 2005) has sharply increased since the launch of the earth source satellite Landsat-1 (Herold, 2003). Yet, the use of such the remote sensing data is still limited as urban managers are still doubtful about the quality of spatial data obtained from the interpretation of remote sensing images. This should

change by now as the state of the art of spatial data by remote sensing has enabled them to be useful in measuring and understanding the spatial alignment of development . Such is the case with the Landsat image and Aster image which can be easily obtained in Indonesia.

Urban area is one of the areas that are interesting to study since it changes with time. The same is true with the urban areas of Yogyakarta. The approximate increase of built-up areas in this city's urban areas was 35 hectares per year from 1970 to 1990, of which 25 hectares per year was the increase of new residential areas reflecting the quite sharp population growth of 2.1 per cent per year (Suharyadi, 2000). Since the availability of open space or non built-up area to accommodate people's activities is smaller than the demand this has led to the rise of inappropriate or re-dwelling resulting in built-up densification with poor standards.

Furthermore, the built-up densification causes difficulties delays in environmental planning since the built-up spaces have already been dense with the city buildings. This may result in many social problems . For instance, the population with stronger economic capability will get better option to choose its residence whereas new comers that are economically weaker will be forced to reside in the areas close to their working places despite the relatively limited and inappropriate conditions (Turner , 1968 in Yunus, 2005). The situation is not helped by the scarcity data on the built-up densification characteristics due to outdated method of data collection.

The monitoring of built-up densification can be done well if only timey information is available. Built-up densification can be identified using spatial analysis of multi temporal built-up densification maps. The time period of built-up densification analyzed in this study is twelve years, from 1994 to 2006. Within this time period, the urban areas of Yogyakarta had undergone several marked phases of physical development, especially the buildings in the suburban areas after the construction of the Yogyakarta Ring Road. Within this time period too Indonesia was suffering from economic crisis. It is thus assumed that the physical development of buildings in the urban areas would vary before, during, and after the economic crisis of 1998. Hence the choice for the 1994-2006 period. This study aims at mapping the built-up densification of urban areas in Yogyakarta based on the Landsat TM images of 1994, 1996, and 1998, Landsat ETM images of 2001 and 2003, and Aster images of 2006, and examines the characteristics of built-up densification in the urban areas of Yogyakarta using a spatial statistic approach.

## Method

*Area of study*

The area of study chosen was the urban areas of Yogyakarta, those, based on the physical point of view, were the urban areas bordered by Yogyakarta Ring Road as the limitation of the study, or it was more popular by the name Yogyakarta Inner Ring Road areas. Morphologically, this area of study was the areas which developed into urban areas. The chosen area of study has represented the urban zones as a whole as stated in the theory of urban area spatial structure, namely from urban frame zone to rural-urban frame zone. The division of urban zone refers to the division of the urban zone conducted by Yunus (2001), namely urban frame zone, urban-rural frame zone, rural-urban frame zone, and rural frame zone.

The area of study was not limited by the administrative border but by the physical border that was Yogyakarta Ring Road. Observed from the urban area morphology, most of the areas of study belonged to urban frame zone, however, there were some areas belonged to rural-urban frame zone morphologically.

The urban area of Yogyakarta was chosen as the area of study with some considerations, namely: (1) rapid increase of urbanization rate or large percentage of population living in the urban areas of Yogyakarta; (2) large increase in land use shift in the urban areas of Yogyakarta; (3) varied built-up densification in the urban areas of Yogyakarta; (4) the availability of remote sensing satellite image with medium spatial resolution, namely Landsat images of 1994, 1996, 1998, 2001, 2003 and Aster images of 2006, which could support the research activities; and (5) typical historical, political, and

cultural conditions of the urban areas in Yogyakarta which had distinctive urban structure compared to other urban areas.

The urban areas of Yogyakarta administratively consist of most areas of Yogyakarta City, part of Bantul Regency (some parts of Banguntapan, Sewon, and Kasihan Districts) and part of Sleman Regency (some parts of Depok, Mlati, and Gamping districts) The area of Yogyakarta City which was not the area of study is a small part of Umbulharjo District, located in the southern of Yogyakarta City. Yogyakarta City as the center area of study surrounded by some areas of Bantul and Sleman Regencies. The Yogyakarta City is divided into fourteen districts, those are Mantrijeron, Kraton, Mergangsan, Umbulharjo, Kotagede, Gondokusuman, Danurejan, Pakualaman, Gondomanan, Ngampilan, Wirobrajan, Gedongtengen, Jetis, and Tegalrejo. Astronomically, counted based on the Indonesia Global Map with the scale of 1: 25,000, sheet 1408-223 (Yogyakarta), sheet 1408-224 (Timoho), and sheet 1408-241 (Sleman), this area of study is situated between 110°19'25" – 110°25'54" E and between 7°44'37" – 7°50'15"S. The width of the area of study is about 8,000 hectares which is the volcanic area under Mount Merapi with the mean elevation 115 meters above sea level. It is located on four rivers, namely, from east to west, Tambak Bayan river, Gajahwong river, Code river, and Winongo river.

*Data analysis*

Data analysis which was used as a medium to reach the goal of the research can be categorized into two, those were remote sensing method to map built-up densification and simple spatial statistic analysis to study the characteristics of the densification,

Built-up densification map was obtained by analyzing spatially built-up densification map of those consecutive years. The extraction of built-up densification map was carried out using hybrid interpretation technique on the images of the used natural resource satellite involving extraction of the information on the built-up densification based on the combination between visual interpretations of the object delineation and the principles of spectral map digital identification to identify the object. The result of hybrid interpretation of the natural resource satellite image with medium spatial resolution was the built-up densification map related to the recording year of the remote sensing images,

The result of hybrid interpretation of the built-up densification from satellite images with medium spatial resolution was the built-up densification map related to the recording year of the satellite images. The recording year of the images used were 1994, 1996, 1998, 2001, 2003, and 2006.

The built-up densification characteristics in each period were analyzed using simple spatial statistics. There are 4 (four) components of spatial statistics that were used to describe the built-up densification characteristics, namely mean center position of an ellipse plane, orientation of the ellipse, long axis of the ellipse, and short axis or width of the ellipse.

## Results

*Built-up densification of the Urban Areas in Yogyakarta*

High urbanization rate in the urban areas in the last two decades causes the increasing need for space to support the population to reside or to do other activities. The increasing need for space can be observed from two significant phenomena in the urban areas, namely, the expansion of built-up area to non built-up area, and the occurrence of built-up densification in the built-up area. The expansion commonly happens in the urban-rural frame zone and rural-urban frame zone, and the built-up densification can take place in the urban frame zone or urban-rural frame zone. The factors influencing built-up densification are relatively more complex than the expansion process. In the area where expansion occurs, built-up densification may then also occur in the future . Built-up densification which occurs in the urban areas is directly influenced by the increase in urbanization rate and indirectly by the population welfare rate.

Built-up densification map of the urban areas in Yogyakarta resulted from the process of hybrid interpretation of satellite image using medium spatial resolution was a series of maps of built-up

densification of 1994, 1996, 1998, 2001, 2003, and 2006. Based on the series of built-up densification maps, the production of built-up densification maps of the periods of 1994-1996, 1996-1998, 1998-2001, 2001-2003, and 2003-2006 could be realized. A built-up densification map is a map which describes the built-up densification change in a particular period of time. To analyze the characteristics of built-up densification in the urban areas of Yogyakarta between 1994 and 1996, the spatial analysis was conducted using geographical information system facility.

Based on the serial maps of built-up densification of the urban areas in Yogyakarta, the built-up densification map can be produced. A built-up densification map describes the process of built-up densification change. It is obtained by overlaying one built-up densification map above the other one in which they are produced in two consecutive years. For example, the built-up densification map of 1994 and that of 1996 can produce the built-up densification map of 1994-1996. The built-up densification map can be classified into 7 (seven) categories as follows:

1. Low densification to medium densification
2. Low densification to high densification
3. Medium densification to high densification
4. Non built-up to low densification
5. Non built-up to medium densification
6. Non built-up to high densification
7. Permanent densification of built-up area
8. Non built-up

The built-up densification maps of the urban areas in Yogyakarta are shown in details in Figure 1 and Tables 1 to 5.

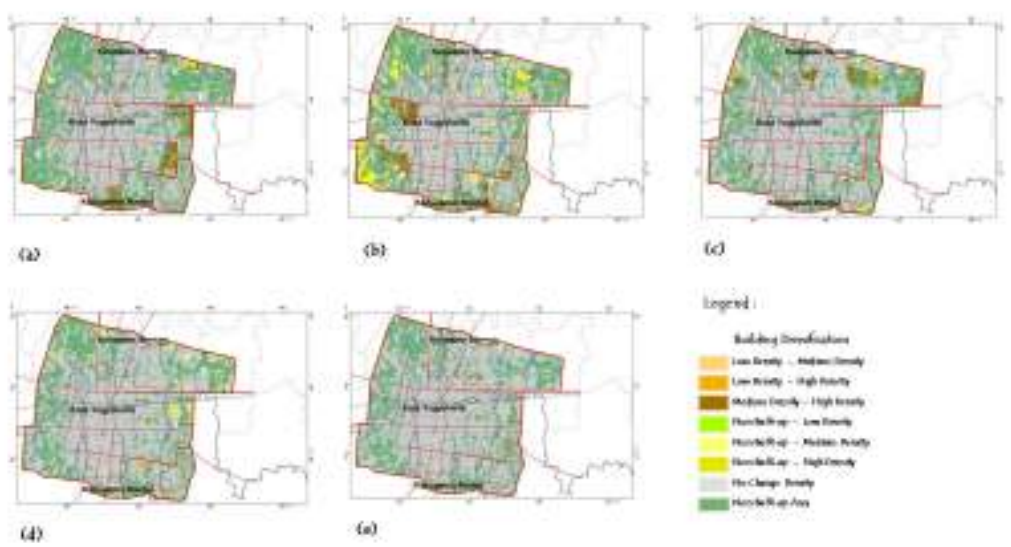


Figure 1. Building Densification Map (a) The years of 1994-1996, (b) The years of 1996-1998, (c)The years of 1998-2001, (d) The years of 2001-2003, and (e) The years of 2003-2006

Figure 1(a) and Table 1 (Built-up Densification map and table of 1994 -1996) show that built-up densification of the urban areas in Yogyakarta occurred in all densification categories. The largest built-up densification occurred in the medium built-up densification to high built-up densification, with the width of 243 hectares. The distribution was mostly in the east and southeast of the area of study. The narrowest built-up densification occurred in the low built-up densification to high densification category, with the width of just 1.50 hectares.

**Table 1. Built-up densification in 1994 – 1996**

| No | Building densification | Spacious (acres) |
|---|---|---|
| 1 | Non built-up – low density | 42,69 |
| 2 | Non built-up – medium density | 38,85 |
| 3 | Non built-up – hight density | 18,48 |
| 4 | Low – medium density | 65,74 |
| 5 | Low –hight density | 1,50 |
| 6 | Medium – hight density | 243,30 |
| 7 | Not change the density | 4.356,37 |
| 8 | Non built-up | 3.674,02 |
| | Total | 8.440,96 |

*Source*: Hybrid interpretation, 2010

Built-up densification in 1996-1998 can be observed in Figure 1(b) and Table 2 (Built-up Densification map and table of 1996-1998). The built-up densification of the urban areas in Yogyakarta occurred in all densification categories. The largest built-up densification still occurred in the medium built-up densification to high built-up densification class, with the width of 346 hectares. The built-up densification which was large enough also occurred in non built-up to high densification category, with the width of 260 hectares. The distribution of the built-up densification was relatively similar in all areas of study.

**Table 2. Built-up densification in 1996 – 1998**

| No | Building densification | Spacious (acres) |
|---|---|---|
| 1 | Non built-up – low density | 70,35 |
| 2 | Non built-up – medium density | 137,40 |
| 3 | Non built-up – hight density | 260,25 |
| 4 | Low – medium density | 86,87 |
| 5 | Low –hight density | 13,70 |
| 6 | Medium – hight density | 346,36 |
| 7 | Not change the density | 4.320,00 |
| 8 | Non built-up | 3.206,02 |
| | Total | 8.440,96 |

*Source*: Hybrid interpretation, 2010

In the period of 1998-2001, the phenomena of built-up densification did not occur widely compared to the previous periods. It is assumed that the economic crisis which happened in Indonesia by the end of 1990s played an important role influencing the slow built-up densification process in the urban areas of Yogyakarta. Built-up densification occurring in the period of 1998-2001 is shown in Figure 1(c) and Table 3 (Built-up Densification map and table of 1998-2001). The largest built-up densification still occurred in the medium densification to high densification category, however, the built-up area width in which the built-up densification happened was narrower than the previous periods, that was 193 hectares. The distribution of the built-up densification shifted to north and northeast of the area of study.

**Table 3. Built-up densification in 1998 – 2001**

| No | Building densification | Spacious (acres) |
|---|---|---|
| 1 | Non built-up – low density | 36,53 |
| 2 | Non built-up – medium density | 26,92 |
| 3 | Non built-up – hight density | 24,12 |
| 4 | Low – medium density | 82,16 |
| 5 | Low –hight density | 20,55 |
| 6 | Medium – hight density | 193,34 |
| 7 | Not change the density | 4.938,89 |
| 8 | Non built-up | 3.118,46 |
| | Total | 8.440,96 |

*Source*: Hybrid interpretation, 2010

The phenomena of built-up densification of the period 2001-2003 underwent a few changes. Figure 1(d) and Table 4 (Built-up Densification map and table of 2001-2003) show that the largest built-up densification occurred in the non built-up to high densification class, with the width of 123 hectares. The phenomena of built-up densification changed compared to the previous periods. The built-up densification of the previous period which occurred mostly in the medium densification to high densification category shifted into the non built-up to high densification category. The distribution of the built-up densification was mostly in the northwest and northeast of the area of study.

**Table 4. Built-up densification in 2001 – 2003**

| No | Building densification | Spacious (acres) |
|---|---|---|
| 1 | Non built-up – low density | 123,84 |
| 2 | Non built-up – medium density | 43,94 |
| 3 | Non built-up – hight density | 60,50 |
| 4 | Low – medium density | 13,10 |
| 5 | Low –hight density | 25,13 |
| 6 | Medium – hight density | 18,34 |
| 7 | Not change the density | 5.265,93 |
| 8 | Non built-up | 2.890,19 |
| | Total | 8.440,96 |

*Source*: Hybrid interpretation, 2010

In the period of 2003-2006, the built-up densification occurred in several densification categories, namely non built-up to high densification category, low densification to medium densification category, low densification to high densification category, and medium densification to high densification category. The distribution of the built-up densification was in the north of the area of study. The distribution and width of built-up densification of the urban areas in Yogyakarta for the period of 2003-2006 are shown in Figure 1(e) and Table 5 (Built-up Densification map and table of 2003-2006).

**Table 5. Built-up densification in 2003 – 2006**

| No | Building densification | Spacious (acres) |
|---|---|---|
| 1 | Non built-up – low density | 0,00 |
| 2 | Non built-up – medium density | 0,00 |
| 3 | Non built-up – hight density | 0,92 |
| 4 | Low – medium density | 25,74 |
| 5 | Low –hight density | 1,12 |
| 6 | Medium – hight density | 38,97 |
| 7 | Not change the density | 5.484,94 |
| 8 | Non built-up | 2.889,26 |
| | Total | 8.440,96 |

*Source*: Hybrid interpretation, 2010

If the observation period of built-up densification is combined as one serial observation, built-up densification of the urban areas in Yogyakarta from 1994 to 2006 can be described as fluctuating. From the beginning of the observation (in 1994) until 1998, the built-up densification process in the urban area of Yogyakarta was relatively rapid, and the area class which underwent the built-up densification was mostly the medium densification to high densification. The physical development of the medium densification built-up to high densification signifies that the urbanization rate in the area of study was high. The phenomena of built-up densification changed in the period of 1998-2001, during which not much built-up densification in the urban areas of Yogyakarta took place. In the period of 1998-2001, the built-up densification was just only as wide as 381 hectares. The built-up class which underwent built-up densification was mostly the low densification to high densification class. The decrease in built-up densification during the period of 1998-2001 might be influenced by the national economic crisis. In the period after 2001 until 2006, in which the economic condition was getting better, the characteristics of the area where built-up densification occurred changed. In this period, built-up densification occurred mostly in non built-up to low densification category, and the distribution was around northern Yogyakarta Ring Road. The distribution of built-up densification which occurred mostly around Northern Ring Road and in the non built-up to low densification category signifies that the physical development of the buildings tended to be a built-up area expansion rather than built-up densification.

*Characteristics of built-up densification in the urban areas of Yogyakarta*

The characteristics of built-up densification were obtained by simple spatial statistic analysis to identify the mean center, orientation and standard deviation of an area with built-up densification. The variables used in analyzing the mean center, orientation and standard deviation of built-up densification were relative location, the number of areas with built-up densification, and azimuth orientation of built-up densification. The number of areas undergoing built-up densification was obtained from built-up densification map of a particular period, and the azimuth orientation of built-up densification was calculated based on the coordinate value of the built-up densification. The analysis on mean center, orientation and standard deviation of the built-up densification used simple spatial statistic calculation in the ellipse plane developed by Ebdon (1996).

The mean center, orientation and standard deviation of built-up densification are described in the shape of ellipse plane. As an example, if the built-up densification occurs evenly in the area of study, from both the width of the building undergoing densification and the azimuth orientation, the orientation of built-up densification will be described as a circle located in the center of the area of study. On the other hand, if built-up densification occurs only in one of the azimuth orientations from the center point of the area of study, for example to the north, the orientation of built-up densification will be described as ellipse orienting to the north. There are 4 (four) spatial statistic components that can be read from the map of built-up densification orientation, those are: mean center position of an ellipse plane, orientation of the ellipse, long axis of the ellipse, and short axis or width of the ellipse.

The center position of the ellipse signifies the tendency of built-up densification mean center. The long axis of the ellipse shows the distance deviation of dominant built-up densification. The short axis (width) of the ellipse indicates the distance deviation of minor built-up densification, and the orientation direction gives a description on the tendency orientation of the densification process.

The maps describing the orientation of built-up densification of the urban areas in Yogyakarta are shown in Figures 2. Each period of built-up densification is described with one ellipse plane which gives the information on the orientation and tendency of built-up densification occurrence.

Built-up densification of the urban areas in Yogyakarta occurred in 1994-1996 is shown in Figure 2(a). (Orientation of built-up densification of 1994-1996). Based on Figure 2 (a) it can be seen that the orientation of built-up densification is described as ellipse plane with the orientation to southwest-northeast, and the relative position is in the center of urban area describing that the built-up densification spread evenly. There was a tendency of built-up densification to southwest and northeast. The shape of ellipse plane for the orientation of built-up densification with long axis which is relatively long and the short axis which is also long shows that the distance deviation of built-up densification was large enough which means the built-up densification occurred in the area far from the center of the area of study.

The orientation of built-up densification in the urban areas of Yogyakarta in 1996-1998 is described as an ellipse with its relative location in the center of the area of study with the orientation direction to southwest-northeast, showing that there was a tendency of built-up densification to southwest-northeast. The shape of ellipse with long axis and short axis which are relatively short indicates that built-up densification occurred around the center of the area of study. The built-up densification orientation of 1996-1998 will be shown in details in Figure 2(b) (Orientation of built-up densification of 1996-1998).

The shape of ellipse with long axis and short axis which are almost identical that makes it resemble a circle shows that the built-up densification of the urban areas in Yogyakarta in 1998-2001 spread almost evenly. The location of ellipse is situated to the north of the center of the area of study indicates that built-up densification occurred mostly in the north of the center of the area of study. The orientation direction of the ellipse is to the north which shows the tendency of built-up densification to the north. The orientation of built-up densification of the period 1998-2001 can be seen in details in Figure 2(c). (Orientation of built-up densification of 1998-2001).

Built-up densification of the urban areas in Yogyakarta occurred in 2001-2003 is described as an ellipse plane located in the east to the center of the area of study and orienting to the north-south, giving the description that built-up densification occurred mostly in the north and east, with the tendency orientation of built-up densification to the north. The shape of ellipse which has a long axis gives a description that built-up densification occurred in the area which was relatively far from the center of the study area. The built-up densification orientation is shown in detail in Figure 2(d) (Orientation of built-up densification of 2001-2003).

Built-up densification of the urban areas in Yogyakarta which occurred in 2003-2006 is shown in Figure 2(e). The orientation of built-up densification which is in the shape of an ellipse orienting to north-south and its relative position which is in the center of the urban area indicates that the built-up densification spread evenly with the tendency of built-up densification to the north of the study area . The thin elliptical shape of built-up densification shows that the built-up densification was aligned with the long axis, which means that it occurred far from the center of the study area.

Based on the series of figures of built-up densification orientation in the urban areas of Yogyakarta, it can be summarized that between 1994 and 1996 the densification orientation was to the east. In contrast, for the period of 1996-1998, the densification orientation was to the southwest, and after 1998 to the north and northeast of the study area.

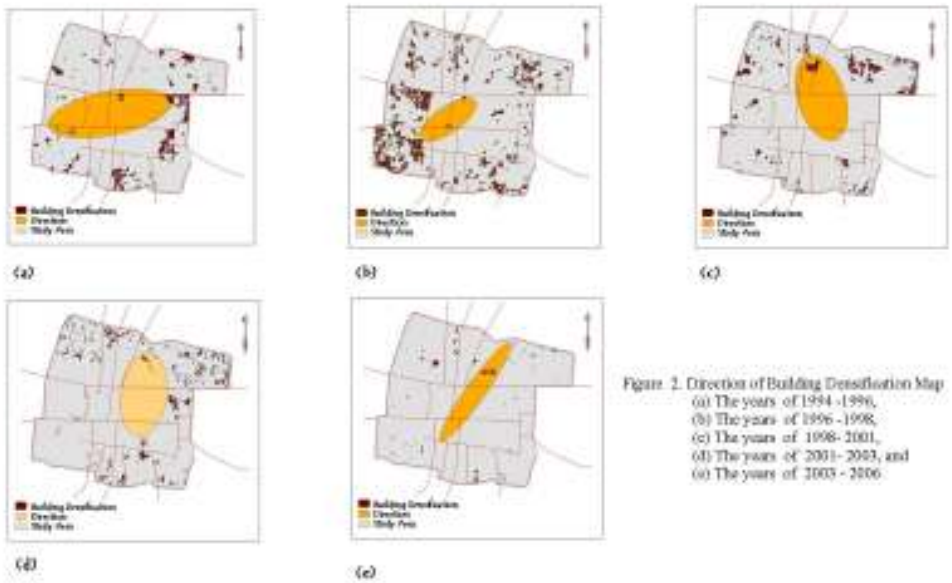


Figure 2. Direction of Building Densification Map
(a) The years of 1994 -1996,
(b) The years of 1996 - 1998,
(c) The years of 1998- 2001,
(d) The years of 2001- 2003, and
(e) The years of 2003 - 2006

## Conclusion

Built-up densification map of the urban area in Yogyakarta can be extracted from natural resource satellite image with medium resolution. The built-up densification maps of the urban areas in Yogyakarta for five periods of study were obtained by spatial analysis of the multi temporal built-up densification maps. It can be concluded from this analysis that the built-up densification of the urban area in Yogyakarta was varied and relatively dynamic toward the mean center, and in terms of orientation and standard deviation. However, the width of area which underwent densification tended to reduce, which means that high built-up densification occurred only in the period after the Yogyakarta Ring Road fully functioned, or alternatively in the period before the economic crisis. The orientation of the built-up densification was to the east between 1994 and 1996, to the southwest between 1996-1998 and to the north and northeast after 1998.

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