Spatial pattern analysis using spatial metrics: a case study in Surabaya, Indonesia

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Abstract. Surabaya city tends to develop rapidly indicated by increasing built-up area of 1554.61 hectares in last 5 years. Land use development and its tendency in several cluster areas showed how spatial patterns are formed. This research aims to analyse spatial pattern of Surabaya city development. The analysis included 2 stages those are identifying the land use changes and then analysing spatial pattern using spatial metrics. The result indicates that from 2011 to 2016, land use changed in East and North Surabaya area included public facilities, commercial area, warehousing, industrial area, and mostly settlement area which is increased by 708.51 hectares in East Surabaya and 23.24 hectares in North Surabaya. In West Surabaya area, warehousing and industrial area is significantly develop and increased by 289.16 hectares. Commercial area are growing rapidly in Central and South Surabaya area which is increased by 89.56 hectares in Central Surabaya and 137.46 hectares in South Surabaya. Then, the spatial metric calculation shows that land use development in all units area tend to follow their existing land use, except South Surabaya area whose tends to develop in dispersal pattern. This spatial pattern is homogeneously develop and still relatively compact.

Keywords. Land use, Spatial pattern, Spatial metrics, Urban development

1. Introduction
Surabaya as one of metropolitan cities in Indonesia has 2.9 Million of population and about 3 Million mobilitation people per day [1]. Based on urban structure plan of East Java Province Spatial Plan 2011-2031, Surabaya is holding significant role as National Activity Center or \textit{Pusat Kegiatan Nasional} (PKN) particularly the eastern part of Indonesia. The number of population, urban mobilities, and Surabaya’s role in regional and national trading will have implications for the surrounding area, mainly the dynamics of land development. The highly dynamics land development has discovered by the large number of land conversion. The conversion of non built-up area into built-up area indicated by a large number of agricultural land conversion. It is about 75-300 hectares per year in last four years of 2012-2016 [2]. In addition to agricultural land, the development of the city in East Surabaya region began to penetrate the protected areas, especially in Wonorejo precint. In this precint, mangroves area converted into fishpond and fishpond converted into settlement area [3].

Based on Surabaya City Spatial Plan 2014-2034, Surabaya city is administratively divided into 5 parts of development unit area that are East Surabaya, West Surabaya, Central Surabaya, South
Surabaya, and North Surabaya. The land development dynamics in each area can be identified through the dominant land use characteristics. For example, East Surabaya Area is dominated by settlement area with percentage of 45% from total land areas [4]. In the opposite, West Surabaya Area is dominated by warehousing, industrial area, and settlement area. Central Surabaya Area is dominated by commercial area. South Surabaya Area is dominated by commercial and settlement area. While North Surabaya Area is dominated by port land and settlement area.

Looking at the case above, each area has a tendency of different land use pattern. The land use will continuously changing as time goes by in line with urban development. Spatial pattern is one of the most influencing factors of urban development, this is because urban development characteristics can be identified by the land use change and development.

To find out the spatial pattern of urban development, we need a method which can calculate the spatial pattern of land use. Spatial metrics method is used to quantify the spatial pattern of Surabaya city. Spatial metrics is an analytical method that can be used to analyse spatial shape and pattern of an area in quantitative form through classification and interpretation in patch, class, and landscape [5]. Spatial metrics are also capable to quantifying spatial heterogeneity within an area. The process requires a way and instrument to be able to describe the spatial pattern through various methods and mathematical models [6] [7] [8].

Based on previous studies, spatial metrics is fairly accurate and widely used method in calculating morphological changes of cities in Europe over the last 10 years, observe spatial patterns of urban land use, as well as seeing dynamics spatial patterns of land use impacted by sea level rise [9] [10] [11]. Spatial metrics has become a trending method that is widely used in international research to quantify morphology of city and observe the city planning. Even though, this method is still rarely used as urban analytical tool in Indonesia. So the authors want to analyse the Surabaya city’s spatial patterns through a spatial metric approach.

2. Methods
The method in spatial pattern analysis included literature study, data collection, and analysis. Literature study was conducted to determine the influenced factors in land use change and spatial pattern refers to several theories and previous researches. The data collection consist of secondary and primary data. Common source of secondary data is documents collected by Surabaya City Board for Planning and Development. Some required documents are covering land use map of existing year 2011 and year 2016. Then, primary data collection through ground check and observation are useful for validate existing land use map in 2016 to real condition.

This research consists of 2 stages of analysis. The first stage is identifying the land use changes in last 5 years (2011-2016) through overlay analysis. In this overlay analysis, we compared land use map of year 2011 and year 2016 supported by ArcGIS software. The next stage is analyzing spatial pattern of land use using spatial metrics method. In running process, we used ArcGIS and Fragstats software. Spatial metrics can calculate the shape and land use patterns diversity based on raster or pixel data.

3. Results

3.1. Land Use Change Analysis of Surabaya City in 2011-2016
Land use change of Surabaya City in 2011-2016 is analysed for each development unit using raster data overlay and run by ArcGIS software. During the 5 years of 2011-2016, there was land use development trend of settlements, commercial, warehousing and industrial area growth. Conversely, protected areas and productive land such as green space, agriculture, and fishpond tend to be converted.

Land use change in each unit will be explained as follows.

- East Surabaya Area
  Several land uses classes in East Surabaya are developed in last 5 years, such as public facilities, commercial zone, settlement, and industrial zone. Settlement is the highest developed land use class in equal to 708.51 hectares, followed by public facilities by 38.28 hectares. The development of
settlements area is caused by the dominance of existing settlement land use. Furthermore, East Surabaya is planned as settlement area refers to Surabaya Spatial Plan. During development of land use plan, land use class in East Surabaya tends to convert green space included mangrove and others vegetation by 261.51 hectares. Whereas public facilities develop as a result of domino effect in settlement growth which require an increasing public facility in East Surabaya. Table 1. and Figure 1. shows land use map and tabulation of East Surabaya in 2011-2016.

Table 1. Land Use Area Comparison of East Surabaya 2011-2016

| Landuse             | 2011       | 2016       |
|---------------------|------------|------------|
|                     | Pixel      | Hectare    | Pixel      | Hectare    |
| 1. Green Space      | 96345      | 963.45     | 67602      | 676.02     |
| 2. Agriculture      | 30841      | 308.41     | 21539      | 215.39     |
| 3. River/Water Body | 20003      | 200.03     | 20005      | 200.05     |
| 4. Fishpond         | 267747     | 2677.47    | 233979     | 2339.79    |
| 5. Vacant Land      | 4406       | 44.06      | 212        | 2.12       |
| 6. Road             | 122292     | 1222.92    | 122267     | 1222.67    |
| 7. Landfills        | 4302       | 43.02      | 4302       | 43.02      |
| 8. Military Zone    | 259        | 2.59       | 259        | 2.59       |
| 9. Public Facilities| 46668      | 466.68     | 50496      | 504.96     |
| 10. Commercial Zone | 30303      | 303.03     | 31261      | 312.61     |
| 11. Settlement       | 322838     | 3228.38    | 393689     | 3936.89    |
| 12. Industrial Zone | 32524      | 325.24     | 32917      | 329.17     |
| 13. Port            | 0          | 0          | 0          | 0          |
| Total               | 978528     | 9785.28    | 978528     | 9785.28    |

Figure 1. Land Use Map of East Surabaya

- West Surabaya Area
  Developed land use classes in West Surabaya are public facilities, commercial zone, settlement, and
industrial zone. Industrial zone is the most developed land use class which increased by 289.16 hectares, followed by settlement by 226.97 hectares, public facilities by 89.36 hectares, and commercial zone by 18.94 hectares. Increasing industrial zone area is part of land use plan which is functioned as warehousing and industrial zone area (Surabaya City Spatial Plan 2014-2034). Besides, the presence of Tanjung Perak port located in border area and Teluk Lamong port could be the growth booster of industrial activities in this area. Table 2. and Figure 2. shows land use map and tabulation of West Surabaya in 2011-2016.

- **Central Surabaya Area**

  Central Surabaya is designated as regional-national scale Central Business Distric (CBD) in Surabaya city based on Surabaya Spatial Plan, so that main activity in this area is commercial. Look at the result of land use overlay analysis in 2011 and 2016, it can be explained that increased land use areas are public facilities, commercial zone, and vacant land. Commercial zone is the most significant growth with an increasing of 89.56 hectares over 5-year period. Commercial zone development in this area tends to convert settlement. It can be seen from the overlay result that settlement area converted into commercial zone by 87.78 hectares in last 5-year. While public facilities development in the area is simultaneous impact of commercial zone. In this period, public facilities have increased by 4.15 hectares. While vacant land has a tendency to be converted to built-up area by 5.01 hectares. Land use map and tabulation of Central Surabaya in 2011-2016 are shown below (Table. 3 and Figure. 3).

| Landuse         | 2011 Pixel | Hectare | 2016 Pixel | Hectare |
|-----------------|------------|---------|------------|---------|
| 1. Green Space  | 22186      | 221.86  | 30760      | 307.6   |
| 2. Agriculture  | 77429      | 774.29  | 72991      | 729.91  |
| 3. River/Water Body | 12985 | 129.85  | 12985      | 129.85  |
| 4. Fishpond     | 278423     | 2784.23 | 250479     | 2504.79 |
| 5. Vacant Land  | 57073      | 570.73  | 18450      | 184.5   |
| 6. Road         | 108737     | 1087.37 | 108725     | 1087.25 |
| 7. Landfills    | 2224       | 22.24   | 2224       | 22.24   |
| 8. Military Zone| 1513       | 15.13   | 1513       | 15.13   |
| 9. Public Facilities | 8079 | 80.79   | 17015      | 170.15  |
| 10. Commercial Zone | 14905 | 149.05  | 16799      | 167.99  |
| 11. Settlement  | 406141     | 406.41  | 428838     | 4288.38 |
| 12. Industrial Zone | 161005 | 1610.05 | 189921     | 1899.21 |
| 13. Port        | 0          | 0       | 0          | 0       |

| Total           | 1150700    | 11507   | 1150700    | 11507   |
Table 3. Land Use Area Comparison of Central Surabaya 2011-2016

| Landuse             | 2011  |          | 2016  |          |
|---------------------|-------|----------|-------|----------|
|                     | Pixel | Hectare  | Pixel | Hectare  |
| 1. Green Space      | 2536  | 25.36    | 1414  | 14.14    |
| 2. Agriculture      | 0     | 0        | 0     | 0        |
| 3. River/Water Body | 2818  | 28.18    | 2817  | 28.17    |
| 4. Fishpond         | 0     | 0        | 0     | 0        |
| 5. Vacant Land      | 0     | 0        | 501   | 5.01     |
| 6. Road             | 30916 | 309.16   | 30914 | 309.14   |
| 7. Landfills        | 0     | 0        | 0     | 0        |
| 8. Military Zone    | 0     | 0        | 0     | 0        |
| 9. Public Facilities| 9726  | 97.26    | 10141 | 101.41   |
| 10. Commercial Zone | 18734 | 187.34   | 27690 | 276.9    |
| 11. Settlement      | 83526 | 835.26   | 74845 | 748.45   |
| 12. Industrial Zone | 398   | 3.98     | 332   | 3.32     |
| 13. Port            | 0     | 0        | 0     | 0        |
| Total               | 148654| 1486.54  | 148654| 1486.54  |
Figure 3. Land Use Map of Central Surabaya

- South Surabaya Area
  Increased land use area in South Surabaya included public facilities, commercial zone, and industrial zone. Commercial zone is the most significant developed land use by 137.46 hectares, followed by industrial zone by 70.14 hectares. Commercial zone tends to convert settlement by 132.01 hectares. While industrial zone tends to grow by converting vacant land by 55.43 hectares and settlement by 13.76 hectares (Table 4 and Figure 4). Based on Surabaya City Spatial Plan, main function of South Surabaya is settlement. But, land use change trend in the last 5 years are commercial zone and industrial zone. It can be caused by the position of South Surabaya which directly adjacent to the West and Central Surabaya so that the activities in both areas are strongly intervened.

Table 4. Land Use Area Comparison of South Surabaya 2011-2016

| Landuse            | 2011       | 2016       |
|--------------------|------------|------------|
|                    | Pixel      | Hectare    | Pixel      | Hectare    |
| 1. Green Space     | 33684      | 336.84     | 28563      | 285.63     |
| 2. Agriculture     | 4764       | 47.64      | 4698       | 46.98      |
| 3. River/Water Body| 10910      | 109.1      | 10910      | 109.1      |
| 4. Fishpond        | 6633       | 66.33      | 6563       | 65.63      |
| 5. Vacant Land     | 6268       | 62.68      | 14         | 0.14       |
| 6. Road            | 104209     | 1042.09    | 104334     | 1043.34    |
| 7. Landfills       | 0          | 0          | 0          | 0          |
| 8. Military Zone   | 25799      | 257.99     | 25535      | 255.35     |
| 9. Public Facilities| 40076     | 400.76     | 42897      | 428.97     |
| 10. Commercial Zone| 14692     | 146.92     | 28438      | 284.38     |
| 11. Settlement     | 357052     | 3570.52    | 345121     | 3451.21    |
| 12. Industrial Zone| 24892      | 248.92     | 31906      | 319.06     |
| 13. Port           | 0          | 0          | 0          | 0          |
| Total              | 628979     | 6289.79    | 628979     | 6289.79    |
North Surabaya Area
From overlay analysis result, agriculture, public facilities, commercial zone, settlement, and industrial zone are developed. Agriculture is the most significant increased area. This is due to the people behavior in this area who tend to use fishpond into agricultural areas, so community can functionate a land to be fishpond and agricultural. Viewed from built-up area development in this area, the most significant developed land class is settlement by 23.24 hectares, followed by commercial zone development which grew as much as 20.16 hectares.

Table 5. Land Use Area Comparison of North Surabaya 2011-2016

| Landuse          | 2011   | 2016   | 2011   | 2016   |
|------------------|--------|--------|--------|--------|
| 1. Green Space   | 6501   | 4939   | 65.01  | 49.39  |
| 2. Agriculture   | 1600   | 14629  | 16     | 146.29 |
| 3. River/Water Body | 12854  | 12853  | 128.54 | 128.53 |
| 4. Fishpond      | 22414  | 5715   | 224.14 | 57.15  |
| 5. Vacant Land   | 635    | 674    | 6.35   | 6.74   |
| 6. Road          | 54126  | 54344  | 541.26 | 543.44 |
| 7. Landfills     | 0      | 0      | 0      | 0      |
| 8. Military Zone | 78478  | 78479  | 784.78 | 784.79 |
| 9. Public Facilities | 11990  | 12297  | 119.9  | 122.97 |
| 10. Commercial Zone | 17279  | 19295  | 172.79 | 192.95 |
| 11. Settlement   | 131405 | 133729 | 1314.05| 1337.29|
| 12. Industrial Zone | 24376  | 24704  | 243.76 | 247.04 |
| 13. Port         | 14075  | 14075  | 140.75 | 140.75 |
| **Total**        | 375733 | 375733 | 375733 | 375733 |
3.2. Spatial Pattern Analysis of Land Development with Spatial Metric

Surabaya’s spatial pattern is analysed using spatial metrics method. We select several assessment criteria that can be used to describe spatial pattern, such as LPI (Largest Patch Index), ED (Edge Density), GYRATE_AM (Area Weighted Mean Radius of Gyration), SHAPE_AM (Area Weighted Shape Index) FRAG_AM (Area Weighted Mean Fragmentation Index), PLADJ (Percentage of Like Adjacencies), IJI (Interspersion Juxtaposition Index), and COHESION (Cohesion Index).

LPI is the largest percentage of patches in a class compared to the total area of the landscape. Increasing the value of LPI shows that there is an expansion of the area on land use that dominates the area. ED shows the total area of pixels in a patch that is directly tied to a patch on another class. Improved ED values indicate that there is a wide increasing of some patches and there are more pixels in a patch that tangent with patches in other classes. GYRATE_AM shows the formation of certain clusters within a region. This metric can also calculate the average distance of each cell in a continuous patch and the center point of the patch. In other words, GYRATE_AM is able to measure how far the patch stretches in a landscape being observed.

SHAPE_AM is a metric that measures the complexity of the shape and the irregularity of a patch in a particular class. SHAPE_AM metric value ranges from 1 - unlimited. SHAPE_AM = 1 indicates that the shape of a patch in that particular class is square or compact, while the higher the SHAPE_AM value indicates that the patch form in the class is increasingly complex and irregular. FRAG_AM shows the index fragmentation of the class, where the higher the value of FRAG_AM then a class will be increasingly collected / not fragmented into small patches. The value of FRAG_AM 0 indicates that the trend of the class in the analysed landscape is not fragmented while the value below 0 indicates that a class type is fragmented and scattered into small patches and the higher the value the larger the fragmentation occurs.

PLADJ is a metric that shows the percentage of pixel-pixel similarities contained in that class. PLADJ metrics that show a value of 100 indicate that in the class there are no pixels/areas that have different information from the pixels/areas of the majority that make up the class. The higher the PLADJ
The value the higher the continuity and the density of the patch in the class. IJI is a metric that measures the proximity and diversity of mixtures of different patch types adjacent to classes analysed within a certain radius. The IJI metric value ranges from 0-100 and represented in percent. The high IJI metric value indicates that the class has a fairly complex patch and often parallels other patches of different class types whereas the low IJI metric values indicate the complexity and low distribution of patches.

COHESION is used to measure the physical connectedness of a particular class to be analysed. The value of COHESION increases with the increasing distribution of patches in one class of the same class. In other words, the higher increasing value of COHESION, the higher physically connected of inter patches in one type of class. COHESION values close to 0 indicate that in one class there are many patches that are not connected or fragmented. While the higher the value of COHESION indicates that the patches in one class are connected to each other.

Table 6. Spatial Metrics Value of 5 Units Area of Surabaya

| Development Units | Year | LPI  | ED    | GYRATE_AM | SHAPE_AM | FRAC_AM | PLADJ | IJI | COHESION |
|-------------------|------|------|-------|-----------|----------|---------|-------|-----|----------|
| East Surabaya     | 2011 | 12.18| 220.69| 607.43    | 8.40     | 1.15    | 94.40 | 44.00 | 99.38    |
|                   | 2016 | 11.49| 221.13| 586.30    | 8.44     | 1.15    | 94.38 | 40.20 | 99.38    |
| West Surabaya     | 2011 | 16.12| 155.00| 864.12    | 11.77    | 1.15    | 96.01 | 47.53 | 99.70    |
|                   | 2016 | 16.12| 155.28| 855.00    | 11.76    | 1.15    | 96.00 | 47.91 | 99.70    |
| Central Surabaya  | 2011 | 12.02| 310.10| 377.56    | 9.73     | 1.18    | 91.96 | 40.52 | 99.30    |
|                   | 2016 | 12.02| 352.24| 375.77    | 9.76     | 1.19    | 91.60 | 41.41 | 99.27    |
| South Surabaya    | 2011 | 10.45| 263.92| 523.36    | 12.94    | 1.18    | 93.26 | 40.49 | 99.54    |
|                   | 2016 | 10.44| 260.64| 531.86    | 12.91    | 1.18    | 93.34 | 41.02 | 99.54    |
| North Surabaya    | 2011 | 6.03 | 230.96| 389.58    | 7.38     | 1.16    | 94.0  | 46.27 | 99.27    |
|                   | 2016 | 6.03 | 232.50| 389.57    | 7.44     | 1.16    | 93.98 | 46.94 | 99.27    |

Table 6 above shows the analysis result. Interpretation of spatial metrics values for each development unit area can be explained as follows.

- **East Surabaya**
  Refers to LPI value, the largest patch experienced intervention from the growing land use class. In this case, fishpond as the largest patch will be involved by settlement growth. The ED value shows that settlement is rapidly growing. Based on GYRATE_AM value, the developing land use class over time has the proximity of distance and even form into one cluster. Based on SHAPE_AM value, land use class development still relatively compact, although not perfectly square, this is because the development tends to follow the roads and existing land use. FRAC_AM value shows that the land use class growth leads to an increasing patch/cluster growth. PLADJ value show there is no new land use appears and develops massively. Based on the IJI value, land use development tends to be the same, it does not indicate the complexity or diversity of land use classes in this area. Then, based on COHESION Index values, land use classes growing in this area tend to be more physically connected.

- **West Surabaya**
  Same as the previous explanation on point 1, in West Surabaya, fishpond as the largest patch will be involved by industrial area growth, so that industrial area is rapidly growing. Then, same as East Surabaya area, the developing land use class over time has the proximity of distance and even form into one cluster. This development still relatively compact and tends to follow the roads and existing land use. The land use class growth leads to an increasing patch/cluster growth and there is no new land use appears and develops massively. Land use development tends to be the same, it does not indicate the complexity or diversity of land use classes. Then, land use growth tend to be more physically connected.

- **Central Surabaya**
  In Central Surabaya, the largest patch isn’t involved by land use class growth. Settlement as the
largest patch will not be involved by commercial area growth, and commercial area is rapidly growing. The developing land use class over time has the proximity of distance and even form into one cluster. This development still relatively compact and tends to follow the roads and existing land use. The land use class growth leads to an increasing patch/cluster growth and there is no new land use appears and develops massively. Land use development tends to be the same, it does not indicate the complexity or diversity of land use classes. Then, land use growth tend to be more physically connected.

- **South Surabaya**
  in South Surabaya, green space as the largest patch will be involved by commercial area, industrial area, or public facilities growth. In this area, commercial area is rapidly growing and tends to develop in dispersal pattern. The land use class growth leads to an increasing patch/cluster growth and there is no new land use appears and develops massively. Land use development tends to be the same, it does not indicate the complexity or diversity of land use classes. Then, land use growth tend to be more physically connected.

- **North Surabaya**
  in North Surabaya, the largest patch isn’t involved by land use class growth. Military zone as the largest patch will not be involved by settlement and commercial area growth. In this area, settlement is rapidly growing. The developing land use class over time has the proximity of distance and even form into one cluster. This development still relatively compact and tends to follow the existing land use. The land use class growth leads to an increasing patch/cluster growth and there is no new land use appears and develops massively. Land use development tends to be the same, it does not indicate the complexity or diversity of land use classes. Then, land use growth tend to be more physically connected.

4. **Conclusion**
Generally, land use develop in most of all areas in Surabaya city. However, land use change tend to be various growth according to its characteristic. Land use growth included settlement and commercial area in East Surabaya, settlement and industrial area in West Surabaya, commercial area and public facilities in Central Surabaya, industrial, and commercial area in South Surabaya, and also settlement and commercial area in North Surabaya.

This spatial pattern in all areas tends to follow its existing land use, except South Surabaya which tends to develop in dispersal pattern. Based on the land use class, spatial pattern of land development in Surabaya tends to be homogeneous. By following trend for last 5 years, we can identify that in the future there is no land use heterogeneity. Based on the city morphology or city shape, the land use development in all areas are still relatively compact. Based on combined analysis and theories study, several factors encouraged urban development into compact shape included spatial pattern driving factors (proximity to existing land use, proximity to roads, and proximity to hub such as transportation and public facilities), homogeneity of land use, as well as urban functions that affect major urban activities.

We recommend some requires of further study in examined factors that encourage the spatial pattern and land use modelling. This factor is necessary to be an input in the land use planning of Surabaya. In addition, this step can be used as a preventive measure for the government in the face of urban development which has a very high land dynamic. Another research might be examined the land use development prediction of Surabaya for several years ahead through land use modelling. Land use prediction is useful as the planning reference in the next few years.

5. **References**
[1] Badan Pusat Statistik (BPS – Central Bureau of Statistics). 2016. Kota Surabaya dalam Angka 2016 (Surabaya City in Figures, 2016)
[2] Putra, Y.M.P. 2016. Lahan Pertanian di Surabaya Menyusut (Agricultural Land in Surabaya was Shrinked), http://www.republika.co.id/ accessed on September 2017
[3] Rachmatullah, T. 2016. Deviation Rate of Land Conversion in Protected Area of Wonorejo Urban Village Surabaya. Jurnal Teknik ITS, Vol. 5 No. 1, ISSN 2337-3539

[4] Surabaya City Spatial Plan 2014-2034. Peraturan Daerah Kota Surabaya No. 12 tahun 2014 tentang Rencana Tata Ruang Wilayah Kota Surabaya 2014-2034 (Surabaya Legislation Act No. 12/2014 on Regional Spatial Plan 2014-2034), Surabaya’s House of Representative, 2014.

[5] McGarigal, K., S A. Cushman, M.C. Neel, and E. Ene. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: www.umass.edu/landeco/research/fragstats/fragstats.html.

[6] Minh Hai, P., & Yamaguchi, Y. (2007). Characterizing the Urban Growth From 1975 to 2003 of Hanoi City Using Remote Sensing and A Spatial Metric. Vol. 21 (2), 104–110.

[7] Reis, J. P., Silva, E. M., and Pinho, P. 2015. Spatial Metrics to Study Urban Patterns in Growing and Shrinking Cities. Urban Geography, Vol. 37, 246-271.

[8] Herold, M., Couclelis, H., and Clarke, K.C. 2003. The Role of Spatial Metrics in the Analysis and Modeling of Urban Land Use Change. Computers, Environment and Urban Systems, Vol. 29 (2005) 369–399

[9] Prastacos, P., & Chrysoulakis, N. 2011. Urban Atlas, Land Use Modelling and Spatial Metric Techniques. Regional Analysis Group Institute of Applied and Computational Mathematics, 1-15.

[10] Wijaya, A., Susetyo, C., Diny, A.Q., Nabila, D.H., Pamungkas, R.P., Hadikunnuha, M., and Pratomoatmojo, N.A. 2017. Spatial Pattern Dynamics Analysis at Coastal Area Using Spatial Metric in Pekalongan, Indonesia. Preprints 2017, 2017050149 (doi: 10.20944/preprints201705.0149.v1)

[11] Jatayu, Anoraga. 2017. Mathematical Model Influence of Spatial Pattern of Land Use on Surface Temperature Improvement in East Surabaya Area. Surabaya: Institut Teknologi Sepuluh Nopember (http://repository.its.ac.id/id/eprint/43975)

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