Multiscale Spatial Assessment of Determinant Factors of Land Use Change: Study at Urban Area of Yogyakarta

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Abstract. Studies of land use change have been undertaken by different researchers using various methods. Among those methods, modelling is widely utilized. Modelling land use change required several components remarked as model variables. Those represent any conditions or factors which considered relevant or have some degree of correlation to the changes of land use. Variables which have significant correlation to land use change are referred as determinant factors or driving forces. Those factors as well as changes of land use are distributed across space and therefore referred as spatial determinant factors. The main objective of the research was to examine land use change and its determinant factors. Area and location of land use change were analysed based on three different years of land use maps, which are 1993, 2000 and 2007. Spatial and temporal analysis were performed which emphasize to the influence of scale to both of analysis’s. Urban area of Yogyakarta was selected as study area. Study area covered three different districts (kabupaten), involving 20 sub districts and totally consists of 74 villages. Result of this study shows that during 14 years periods (1993 to 2007), there were about 1,460 hectares of land use change had been taken place. Dominant type of land use change is agricultural to residential. The uses of different spatial and temporal scale in analysis were able to reveal different factors related to land use change. In general, factors influencing the quantities of land use change in the study area were population growth and the availability of land. The use of data with different spatial resolution can reveal the presence of various factors associated with the location of the change. Locations of land use change were influenced or determined by accessibility factors.

Keywords: multiscale spatial assessment, land use, Yogyakarta

1. Introduction
Studies on land use change have been conducted by the researcher along with the growing awareness to the importance of the phenomena. At the beginning of 1980s, land use and land cover change became a concern because of it has relation with global climate change by the carbon cycle [1, 5, 6, 7]. Changes in land use are also seen as a fundamental factor for the operation of the environmental and socio-economic systems, from local to global scale scale [2].

Land use change can be assessed using different methods. Among those methods, spatial modeling is widely utilized. Model is simplification of real-world phenomena [8, 11, 12]. Through a model or
modeling, a complex phenomenon is represented using simplest manner i.e. a number of components referred to as modeling variables.

Variables used in the land use change model are representation of factors related to the phenomenon. These factors often referred to as determinant factors of land use change. Land use change is considered as a complex spatial phenomenon as a result of the interaction of various determinant factors. The physical condition of land, socio-economic, demographic and policy are factors that are generally supposed to be related to changes in land use [6]. These factors interact in the manner and intensity of which varies according to time and space. Study of the determinant factors therefore is necessary as a basis of modeling the spatial dynamics of land use.

Land use change is a spatial phenomenon as well as its determinant factors. Changes in land use occupy a certain location and occur in a certain period as well. Study of spatial phenomena requires appropriate methods that are known as spatial analysis. Spatial analysis, on the other hand, has a critical issue related to the use of different scale in analysis. The same phenomenon which is analyzed at different scales, very likely leads to a different conclusion. The problem is known as MAUP, which is an abbreviation of the modifiable area unit problem [4].

The objective of this study is to examine changes in land use and the factors associated with it. The most influential factor is referred to as determinant of change. The study was conducted through a spatial analysis by taking into account the effect of scale in the process of analysis. Urban area of Yogyakarta was selected as study area. Land use change in the study area were considered intensive, particularly from agriculture to other type of land use [9, 10].

2. Study Area
The study was conducted at the Urban area of Yogyakarta (Figure 1). This area covered whole area of Yogyakarta City and some parts of Sleman as well as Bantul Districts (kabupaten). Yogyakarta City consist of 16 sub districts (kecamatan). Parts of Sleman Districts used in the study, involved 3 sub districts namely Gamping, Mlati and Depok. Depok is quite well known for rapid development as well as for being the location of Universitas Gadjah Mada, one of the famous universities in Indonesia. Bantul Districts also involved 3 sub districts namely Kasihan, Sewon and Banguntapan. The entire study area, therefore involving 20 sub districts and totally consists of 74 villages (desa).
3. Methods
Determinant factors of land use changes in the study were assessed by means of mapping and spatial analysis. Mapping was conducted to identify spatial distributions of land use changes as well as presumably factors related to the land use changes. Spatial and statistical analyses were used to assess significant factors related to area and location of land use change.

3.1. Data
Data used in this study include 1: 25,000 multi temporal land use maps, 1: 25,000 Indonesian topographic maps (RBI), demographic and socio-economic data. Multi temporal land use maps consisted of 1993, 2000 and 2007 maps respectively. Those maps originally derived from 1: 25,000 Indonesian topographic maps and updated periodically based on interpretation of remote sensing imagery.

Time series of demographic and socio-economic data, from year 1993 up to 2007, were obtained from secondary sources. Books namely Sleman District in Figures, Bantul District in Figures and Yogyakarta City in Figures were used as main source. Those books were published by Central Bureau of Statistics (Badan Pusat Statistik).

3.2. Mapping of Land Use Change as Dependent Variable
Land use change maps were obtained by overlaying land use maps of 1993, 2000 and 2007. Those maps show the spatial distribution of land use change over the period of 1993 – 2000 and 2000-2007 (Figure 2). Land use changes were simplified in to two categories namely change and persistence. The location where the change occurs is referred to as change, while the location where the change does not occur is referred to as persistence.

Figure 1. Study area
Quantities as well as spatial distribution of land use changes were vary across time periods. In the 1993-2000 periods, total area of land use change was 704.9 ha. Those changes were taken place in the city as well as in urban fringe area. In the urban fringe area, land use change mostly distributed in the northern and eastern part of study area. In the 2000-2007 periods, total area of land use change was 769.4 ha and mostly taken place in urban fringe area. Detail information about quantities and spatial distribution of land use change in the study area are shown in Table 1.

Table 1. Area of land use change by administrative division

| District     | Sub district | Area of Land Use Change (Ha) |
|--------------|--------------|------------------------------|
|              |              | 1993-2000 | 2000-2007 |
| Bantul       | Banguntapan  | 99.67      | 177.21     |
|              | Kasihan      | 83.39      | 60.31      |
|              | Sewon        | 108.08     | 109.88     |
| Sleman       | Depok        | 168.27     | 195.17     |
|              | Gamping      | 51.52      | 117.16     |
|              | Mlati        | 66.78      | 88.21      |
| Yogyakarta   | Gondokusuman | 3.93       | 9.75       |
|              | Kotagede     | 10.28      | 0.81       |
|              | Mantrijeron  | 3.43       | 8.05       |
|              | Mergangsan   | 14.56      | 2.58       |
|              | Tegalrejo    | 79.57      | 8.3        |
|              | Umbulharjo   | 7.33       |            |
|              | Wirobrajan   |            |            |
| **Total**    |              | 704.86     | 769.38     |
3.3. Mapping of Predetermining Factors as Independent Variable
Any conditions or factors presumably related to land use change are referred to as predetermining factors. Identification of those factors was conducted based on literature and local knowledge about study area.

3.3.1. Presumably Variable Related to Area of Land Use Change. Factors presumably related to the quantity or area of land use change consisted of 6 (six) variables. Each variable was given a name and a specific code for purpose of analysis. Table 1 shows the presumably variables related to area of land use change. Those variables were used in analysis to assess determinant factors of area or quantity of land use change.

Table 2. Presumably variables related to area of land use change

| No | Variable Name | Variable Code | Description                     |
|----|----------------|---------------|---------------------------------|
| 1  | Tegal          | Var_A1        | Area and proportion of dry field |
| 2  | Kebun          | Var_A2        | Area and proportion of mix garden|
| 3  | Sawah          | Var_A3        | Area and proportion of rice field|
| 4  | Pdd            | Var_A4        | Number of population            |
| 5  | Tum_Pdd        | Var_A5        | Rate of population growth       |
| 6  | Kpdt           | Var_A6        | Population density              |

The first three variables were used to represent availability of land, which is land available for conversion. Previous analysis indicates that dominant type of land use change in the study area was conversion from agricultural land to settlement. Therefore, availability of agriculture land supposedly determines the quantity of land use change. The last three variables were used to represent demand for land. Quantity of land use change, particularly conversion from agricultural land to settlement, supposedly determines by increasing demand for residential use.

3.3.2. Presumably Variable Related to Location of Land Use Change. Factors presumably related to the location of land use change consisted of 7 (seven) variables. Each variable was given a name and a specific code for analysis. The first six variables (Var_L1 to Var_L6) were representing the accessibility of land. Accessibility can be expressed in terms of money, time, preference, effort or any concept of cost (Braimoh and Onishi, 2007). In this study, accessibility was measured in terms of distance to targets (government office, university, existing settlement and roads). The seventh variable (slope) represents topographic condition. Table 2 shows the presumably variables related to location of land use change.

Table 3. Presumably variables related to location of land use change

| No | Variable Name | Variable Code | Description                        |
|----|----------------|---------------|------------------------------------|
| 1  | Jr_Kntr        | Var_L1        | Distance to government office       |
| 2  | Jr_kmps        | Var_L2        | Distance to university             |
| 3  | Jr_Bang        | Var_L3        | Distance to existing settlement     |
| 4  | Jr_JalAll      | Var_L4        | Distance to roads                   |
| 5  | Jr_JalLok      | Var_L5        | Distance to access roads (local roads) |
| 6  | Jr_JalUt       | Var_L6        | Distance to main roads              |
| 7  | Slope          | Var_L7        | Slope                              |

Accessibility variables were obtained trough spatial analysis called distance analysis. This analysis used pixel, with a certain size, as a unit of measurement. Topographic variable (slope), derived from
DEM (Digital Elevation Model). All maps of presumably factors related to location of land use change are shown in Figure 3.

3.4. Statistical Analysis Techniques
Assessments of determinant factor were conducted using two statistical techniques namely regression and logistic regression analysis. Regression analysis was used to assess the determinant of area or quantities, while logistic regression analysis was used to assess the determinant of location.

3.4.1. Multiple Regressions. Area or quantities of land use change serve as dependent variable or response variable. Presumably factors serve as independent variable or predictor variable. Multiple regressions linking the dependent variable with several independent variables through an equation as shown in equation [1].

\[ Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_k X_k \] [1]

The above equation linking the value of \( Y \) that is area of land use change with variables \( X_1, X_2 \) up to \( X_k \). The value of \( \alpha \) is a constant regression while \( \beta_1, \beta_2 \) and \( \beta_k \) are regression coefficient for the predictor variables.

3.4.2. Logistic Regression. Location of land use change serves as dependent variable or response variable. Presumably factors serve as independent variable or predictor variable. Logistic regression analysis is basically the same as ordinary regression analysis. The difference lies in the value of the response or dependent variable. Instead of using the real value, logistic regression using logit function as the response variable. Using binary notation, the response variable values can be written with the number 1 and number 0. Number 1 represents the location where changes occur while the number 0 represents the location where the change does not occur. Logistic regression can be written in the form equation as shown in equation [2]

\[ \text{Logit} (p_i) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_k X_k \] [2]

where,
- \( p_i \) : the probability of occurrence (change or no change)
- \( \alpha \) : regression constants
- \( \beta_i \) : coefficients of predictor variables 1
- \( X_{i..k} \) : predictor variable (1, 2, ... k)
3.5. The Multi Scale Analysis
Analysis of determinant factor using regression and logistic regression, as previously described, were performed on a different spatial and temporal scale. This was done to demonstrate what so called “multi scale effect” of performing spatial analysis. Multi scales in the context of spatial analysis were shown by using what is referred to as spatial extent and grain or resolution. Determinant factors of area or quantities of land use change were analysed using different spatial extent. Determinant factors of location of land use change were analysed using different grain or resolution. Figure 4 illustrates different spatial extent in the analysis of determinant factors related to area of land use change. Figure 5 illustrates different spatial resolution or spatial grain used in the analysis of determinant factors related to location of land use change.
4. Result and Discussion

4.1. Determinant Factors Related to Area of Land Use Change

Statistical analyses show that area or quantity of land use change has significant correlation with several variables. As analyses performed using different spatial and temporal scales, different results were obtained. Table 4 show variables which have significant correlation to area of land use change. Those variables area referred as determinant factors of area of land use change. It should be noted that population growth variable (Var_A5), marked as significant variable in different scale of analyses.
4.2. Determinant Factors Related to Area of Land Use Change

Statistical analyses show that location of land use change has significant correlation with several variables. Analyses were performed using two different spatial resolutions which are 100 meters and 10 meters. Spatial resolution reflects detail of data used in analysis. Some time, spatial data which has some level of detail is not available. For example, rather than using Ikonos or QuickBird imagery we use Landsat imagery as a source data for mapping and analysis the location of land use change. The use of less detail spatial data will affect the result of analysis. Table 4 show significant variables related to location of land use change.

Table 4. Significant variables related to area of land use change

| Analysis Extent (Spatial Scale) | Periods of Analysis (Temporal Scale) | 1993 – 2000 | 2000 – 2007 | 1993 – 2007 |
|--------------------------------|-------------------------------------|-------------|-------------|-------------|
|                                | Variable | β       | Variable | β       | Variable | β       |
| Whole Area                     | Constant | -9.677  | Constant | -28.884  | Constant | -50.198 |
|                               | Var_A1   | .268    | Var_A3   | .100     | Var_A3   | .002    |
|                               | Var_A2   | -.098   | Var_A4   | .001     | Var_A4   | .129    |
|                               | Var_A3   | .031    | Var_A5   | 8.195    | Var_A5   | 18.806  |
|                               | Var_A4   | .001    |          |          |          |         |
|                               | Var_A5   | 3.595   |          |          |          |         |
|                               | R        | .880    | R        | .800     | R        | .831    |
|                               | R²       | .774    | R²       | .640     | R²       | .631    |
| Bantul                         | Constant | -8.166  | Constant | -18.668  | Constant | -27.795 |
|                               | Var_A1   | .002    | Var_A3   | .088     | Var_A4   | .003    |
|                               | Var_A2   | -.197   | Var_A5   | 11.972   | Var_A5   | 15.310  |
|                               | R        | .747    | R        | .830     | R        | .755    |
|                               | R²       | .559    | R²       | .689     | R²       | .601    |
| Sleman                         | Constant | 13.504  | Constant | -1.120   | Constant | 38.777  |
|                               | Var_A1   | .436    | Var_A1   | .489     | Var_A1   | 1.057   |
|                               | Var_A2   | -.197   | Var_A2   | -.302    | Var_A2   | -.495   |
|                               |          |         | Var_A3   | .106     |          |         |
|                               | R        | .921    | R        | .912     | R        | .919    |
|                               | R²       | .849    | R²       | .832     | R²       | .844    |
| Yogyakarta                     | Constant | -.139   | Constant | .712     | Constant | -627    |
|                               | Var_A1   | -.269   | Var_A1   | .470     | Var_A3   | .653    |
|                               | Var_A3   | .376    |          |          |          |         |
|                               | R        | .925    | R        | .837     | R        | .902    |
|                               | R²       | .855    | R²       | .700     | R²       | .813    |
Table 5. Significant variables related to location of land use change

| Resolution (Spatial Scale) | Periods of Analysis (Temporal Scale) | 1993 – 2000 | 2000 – 2007 | 1993 – 2007 |
|---------------------------|--------------------------------------|-------------|-------------|-------------|
|                           | Variable | Exp (B) | Variable | Exp (B) | Variable | Exp (B) |
| 10 m                      | Constant | 3.277   | Constant | .844    | Constant | 6.701 |
|                           | Var_L1   | 1.000   | Var_L2   | 1.000   | Var_L1   | 1.000 |
|                           | Var_L2   | 1.000   | Var_L3   | 1.000   | Var_L2   | 1.000 |
|                           | Var_L3   | 0.997   | Var_L4   | 0.989   | Var_L4   | 0.987 |
|                           | Var_L4   | 0.988   | Var_L5   | 0.999   | Var_L5   | 0.999 |
|                           | Var_L5   | 0.999   | Var_L6   | 0.999   | Var_L6   | 0.999 |
|                           | Var_L6   | 0.999   | Var_L7   | 0.917   | Var_L7   | 0.952 |
|                           |          | Cox & Snell R² | 0.112 | Cox & Snell R² | 0.077 | Cox & Snell R² | 0.200 |
|                           |          | Nagelkerke R² | 0.223 | Nagelkerke R² | 0.142 | Nagelkerke R² | 0.294 |
| 100 m                     | Constant | 2.008   | Constant | 0.534   | Constant | 1.732 |
|                           | Var_L1   | 1.000   | Var_L1   | 1.000   | Var_L2   | 1.000 |
|                           | Var_L2   | 1.000   | Var_L2   | 1.000   | Var_L4   | 0.996 |
|                           | Var_L4   | 0.995   | Var_L4   | 0.997   | Var_L5   | 0.999 |
|                           | Var_L5   | 0.999   | Var_L5   | 0.999   | Var_L6   | 0.999 |
|                           | Var_L6   | 0.999   | Var_L6   | 0.999   | Var_L7   | 1.139 |
|                           | Var_L7   | 1.139   |          |          | Cox & Snell R² | 0.115 | Cox & Snell R² | 0.073 | Cox & Snell R² | 0.133 |
|                           |          | Nagelkerke R² | 0.226 | Nagelkerke R² | 0.136 | Nagelkerke R² | 0.205 |

5. Conclusions

Scale is a concept related to the use of specific dimensions to measure or assesses the phenomenon. Scale becomes an important aspect in conducting analysis particularly spatial analysis. This study clearly demonstrates the effect of spatial and temporal scale in the analysis of the determinant factors of land use change. The use of different analysis extents was able to reveal the different factors related to quantities of land use change. The use of data with different spatial resolution can reveal the presence of various factors associated with the location of land use change.

During the period of 14 years between 1993 and 2007 there were 1,460 ha of land use change occurred in the study area. Dominant type of land use change was agricultural land converted to residential use. Land use change in the study area has significant correlation with a number of factors. Number of factors as well as degree of correlation varies spatially and temporally. In general, factors influencing the quantities of land use change in the study area were population growth and the availability of land. Availability of land in this study refers to the presence of agriculture land. These two factors have significant influence in urban fringe areas, while in Yogyakarta City the only significant factor is availability of land. Locations of land use change were influenced or determined by accessibility factors. Accessibility of land in this study was indicate by it distance to roads and other facilities. The probability of land use change will take place in certain location, increase as distance to roads and other...
facilities decrease. Analysis of data with higher spatial resolution revealed that location of land use change has also significant correlation with topographic condition.

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References
[1] Anwar, Morshed, 2002, Land Use Change Dynamics: A Dynamic Spatial Simulation, Thesis M.Sc. AIT Bangkok Thailand.
[2] Aspinall, R.J and Hill, M.C. (Eds), 2008, Landuse Change, Science, Policy and Management, Taylor and Francis, New York
[3] Braimoh, A.K., and Onishi, T., 2007, Spatial determinants of urban land use change in Lagos, Nigeria, Land Use Policy Vol 24, 502-515.
[4] Heywood 1998 Introduction to Geographical Information Systems. New York: Addison Wesley
[5] Lambin, E.F., Geist, H.J. and Lepers, E., 2003, Dynamics of Land-Use and Land-Cover Change in Tropical Region, The Annual Review of Environment and Resources, Vol. 28.
[6] Lambin, E.F., dan Geist, H.J. (lead authors), Ellis, E. (topic editor), 2007, Causes of Land-Use and Land-Cover Change, within Encyclopedia of Earth, internet access from http://www.eoearth.org
[7] Moran, E.F., Skole, D.L. and Turner, B.L., 2004, The Development of The International Land-Use And Land Cover Change (LUCC) Research Program and its Links to Nasa’s Land-Cover And Land-Use Change (LUCC) Initiative, in Land Change Science: Observing, Monitoring and Understanding Trajectories of Change on the Earth’s Surface (Eds: Gutman et al.), Kluwer Academic Publishers, Dordrecht, The Netherlands
[8] Sanders, Lena., 2007, Model in Spatial Analysis, ISTE Ltd London W1T 5DX UK
[9] Susilo, Bowo, 2013 Kajian Spasial Multi Skala Determinant Perubahan Penggunaan Lahan Di Sebagian Wilayah Daerah Istimewa Yogyakarta, Research Report (unpublished) Faculty of Geography Universitas Gadjah Mada
[10] Susilo, Bowo., 2016, Map Analysis and Spatial Statistic: Assessment of Spatial Variability of Agriculture Land Conversion at Urban Fringe Area of Yogyakarta, IOP Conf. Series: Earth and Environmental Science Vol 47, No 1
[11] Wainer, G.A., 2009, Discrete-Event Modeling and Simulation: A Practitioner’s Approach, CRC Press New York
[12] Wainwright, J. and Mulligan, M. (Eds), 2004, Environmental Modelling Finding Simplicity in Complexity, John Wiley & Sons Ltd – England