Spatial modeling of landscape and land cover pattern in Semarang City

K Sugiy0, S Supriatna1, Risnarto1 and F Afdhalia1

1Department of Geography, Faculty of Mathematics and Science, Universitas Indonesia

E-mail: ysupri@sci.ui.ac.id; fida.afdhalia@gmail.com

Abstract. Semarang City is one of the largest cities in Indonesia. Tidal flooding, flash floods, sea water intrusion at the coast and landslide at the hills, are the issues the city currently dealt with as a side effect of land conversion. This study aims to analyze the landscape and land cover pattern of Semarang City in 1996, 2003, 2016 by using the landscape indices and generate spatial models of the landscape and land cover pattern of Semarang City. Landsat images from 1996, 2003 and 2016 and eight landscape indices (PD, PLAND, LPI, LSI, MNN, IJI, SHDI, and SHEI) were used to analyze landscape/land cover pattern and its change. Binary Logistic Regression and geography information system were used to build a mathematical and spatial modelling of landscape/land cover change using driving factors such as altitude, slope, land subsidence, population density, land ownership, land price, street density, drainage density, and distance from city center. Landscape indices shows that the highest land utilization (higher PD, LSI, MNN, IJI, SHDI, SHEI and lower LPI) mostly occurred at altitude 25-100 MASL (meters above sea level) in 1996 and 2003; in 2016, it occurred at altitude 100-500 MASL. In the period of 1996-2003, land fragmentation with high mixing and diversity occurred at altitude 25-100 MASL, while in the period 2003-2016, it occurred at altitude 100-500 MASL. Spatial modeling of landscape/land cover in Semarang City is best applied at altitude 100-500 MASL. The probability of landscape/land cover change is high when located at the high and flat areas, relatively high river and road density, highest population density, and lowest land price.

1. Introduction
Semarang City is a picture of a city landscape with distinctive physical characteristics. The Semarang City landscape represents a variety of ecological functions that stretch from the coast on the edge of the Java Sea, the lowlands, and the hills which are part of the Ungaran Mountains. Semarang City currently represented by natural land cover such as urban forests, mangrove forests, and others, that still leaves the expected environmental services from the landscape. However, as a metropolitan city with high socio-economic needs and activities, existing land is often the target of changes in use and utilization, which ultimately changes the landscape structure.

Changes in landscape and land cover that do not consider the structure (pattern) of landscape have a negative impact, including the use of excessive ground water, overburden over land, and land subsidence [1]. The land subsidence that occurred in the city of Semarang eventually caused problems that could be categorized as disasters, namely tidal flooding and sea water intrusion. In hilly areas, changes from conservation land cover to the development of settlement centre lead to landslides [2].
This study aims to analyze the landscape and land cover patterns of Semarang City in 1996, 2003 and 2016 by using the landscape indices and generate spatial models of the landscape and land cover patterns of Semarang city. Landscape indices can be used for various analyze including analysis of land fragmentation between region, analysis of the direction of urban development, and analysis of landscape pattern [3], [4], [5]. Landscape indices are used to quantify a basic unit of landscape or patch [6]. Study of landscape in urban areas provides a thorough understanding of the formation of an urban and the factors that influence it.

2. Methods

Variables used include land cover, slope, altitude, land subsidence, population density, land status, land value, distance from the city centre, river network density, and road network density (Figure 1). Information on land cover was extracted from Landsat 5 TM (August 12, 1996), Landsat 7 ETM+ (May 20, 2003) and Landsat 8 OLI Imagery (August 19, 2016) which were processed using ENVI 5.1 software [7] [8]. Landscape index measurement was carried out on land cover in 1996, 2003 and 2016 with FRAGSTAT 4.2 software. Landscape Indices used includes PLAND (Percent of Landscape), PD (Patch Density), LPI (Largest Patch Index), LSI (Landscape Shape Index), SHDI (Shannon’s Diversity Index), SHEI (Shannon’s Evenness Index), MNN (Mean Nearest Neighbor), and IJI (Interpersion and Juxaposition Index)

![Figure 1. Study Variables](image)

Mathematical models of physical, socio-economic, and environmental factors on landscape and land cover change used statistical analysis with binary logistic regression. Landscape and land cover change are response variable (Y). Physical, socio-economic, and environmental factors are explanatory/
predictor variable (X). Furthermore, spatial models of landscape and land cover change are obtained by integrating mathematical models of logit and GIS (Geography Information System) [9], [10]. Integration uses the map algebraic concept through the raster calculator tool in ArcGIS 10.2. Predictor variables substituted in the equation obtained from logistic regression.

3. Results and Discussion
Land cover in Semarang City improved the changes, especially in 1996-2003 and 2003-2016 (Figure 2). In 1996, land cover is dominated of shrubs with an area of 5,810.72 hectares (15.55% of the total city area). In 2003, land cover is dominated of residential/mixed building with an area of 7,621.08 hectares (20.39% of the total city area). In 2016, residential/mixed building remain the most dominated land cover in Semarang City. The area also increased to 12,762.64 hectares (34.15% of the total city area).

Figure 2. Land Cover in Semarang City
(a) 1996, (b) 2003, and (c) 2016

In 1996 and 2003, at the altitude of 25-100 MASL (meters above sea level) with flat to sloping slopes, the PD, IJI, SHDI and SHEI indices showed the highest values, while LPI and MNN showed the lowest values. In 1996 at an altitude of 25-100 MASL with flat to sloping slopes, there were many small fillings with higher levels of mixing and diversity and better distribution compared to more other regions. While in 2016, this occurred in areas of high 199-500 MASL with flat to steep slopes. The distribution of the landscape indices, represented by the values of PD, LPI, and SHDI in each year, can be seen in Figure 3.

The value of the landscape indices at the class level represented by PLAND for the six land cover classes can be seen in Figure 4. In 1996, the area that experienced land subsidence was dominated by the closure of agricultural land, while in areas with an altitude of 0-25 MASL which was a region where there was a city center with all developments and rapid infrastructure development, dominated by urban land cover. Land clearing activities are seen in areas of altitude of 25-100 MASL, while in areas with an altitude of 100-500 MASL is dominated by natural land cover. In 2003, the dominance of the type of land cover in the form of residential/mixed building was indicated by the highest PLAND value in all three altitude areas. Areas that experience land subsidence at an altitude of 0-25 and 25-100 MASL. While the dominance of land cover in the form of gardens and mixed plants is found in areas of height of 100-500 MASL. While in 2016, the entire area of Semarang City was dominated by residential/mixed building.

The calculation of the overall landscape indices at the landscape level indicates the existence of land use due to human activities which was quite intensive from 1996 to 2003, especially at the altitude of 25-100 MASL with flat to sloping slopes. This is shown through landforms which are divided into smaller and larger sizes, increasingly complex shapes, higher levels of mixing and diversity, and increasingly
spread out. In 2003 to 2016, this occurred in areas with an altitude of 100-500 MASL with flat to steep slopes.

**Figure 3.** Distribution of landscape indices at landscape level.
(a) PD in 1996, (b) LPI in 1996, (c) SHDI in 1996,
(d) PD 2003, (e) LPI 2003, (f) SHDI 2003,
(g) PD 2016, (h) LPI 2016, (i) SHDI 2016
Furthermore, the spatial model formed based on the mathematical model can be seen in Figure 5. The results of cross tabulation between the model and the actual condition of landscape and land cover change showed the model accuracy value of 61.98%. While the results of cross tabulation between the model and the actual conditions for each unit of analysis showed the model accuracy value of 41.37% (area with land subsidence); 47.79% (altitude of 0-25 MASL with flat to sloping slopes); 51.02% (altitude of 25-100 MASL with flat to sloping slopes); and 73.49% (altitude areas 100-500 MASL with flat to steep slopes). These shows that altitude, slope, population density, land status and value, road network density, and river network density, are more accurate to explain landscape and land cover change in areas 100-500 MASL with flat to steep slopes.

The factors that most influenced changes in the landscape and land cover of Semarang City from 1996 to 2016 were the height factor of the area. The other factors that affect change based on the highest to lowest correlation order are river network density, road network density, land value, land status, population density, distance from the city center, and slope.

Correlation test of each altitude area to changes in landscape and land cover shows that the probability of changing landscape and land cover is most in the area of 100-500 MASL, slope of 0-3%, river density and road 3-4 m/m² and 7-10.5 m/m², high population density, land status of “Hak Pakai dan Hak Guna Bangunan”, the value of land is less than Rp 1,000,000,- and distance from the city center of 4,000-6,000 meters. This shows that the possibility of landscape and land cover change is higher in high and
flat areas with relatively high density of road and river, land status for “Hak Pakai dan Hak Guna Bangunan”, land value is low, population density is high, and relatively far from city center.

4. Conclusion
Semarang City shows land cover pattern that experienced changes in 1996-2016 where: (1) land cover is dominated by wetland seasonal plants (areas experiencing land subsidence), (2) land cover is dominated by residential/mixed building (altitude 0-25 MASL with flat-sloping slopes), (3) land cover dominated by open land cultivated (altitude of 25-100 MASL with flat-sloping slopes), and (4) land cover dominated by shrubs (area height 100-500 MASL with flat-steep slopes). While in 2003-2016, land cover patterns became increasingly uniform, where the overall unit of analysis was dominated by land cover in the form of residential/mixed building. Landscape indices shows that the highest land utilization (higher PD, LSI, MNN, IJI, SHDI, SHEI and lower LPI) mostly occurred at altitude of 25-100 MASL in 1996 and 2003; in 2016, it occurred at altitude of 100-500 MASL. In the period of 1996-2003, land fragmentation with high mixing and diversity occurred at altitude of 25-100 MASL, while in the period 2003-2016, it occurred at altitude of 100-500 MASL. The landscape and land cover change model in Semarang City is best applied to areas with an altitude of 100-500 MASL. Overall, the most significant factor affecting change is the height of the region. Based on the model, the highest probability of changes in landscape and land cover in high and flat areas, relatively high river and road density, high population density, land status of “Hak Pakai dan Hak Guna Bangunan”, low land value, and distance relatively far from the city center.

5. References
[1] Sophian and Irvan R 2010 Penurunan Muka Tanah di Kota-Kota Besar Pesisir Pantai Utara Jawa (Studi Kasus: Kota Semarang) Bulletin of Scientific Contribution 8 pp 41-60
[2] Mohammad A R 2016 Mengupas Problema Kota Semarang Metropolitan (Yogyakarta: Penerbit Deepublish)
[3] Yaolin L, Ti L, Zhongqiu L, Xuesong K, Jiwei L and Ronghui T 2015 A comparative analysis of urban and rural construction land use change and driving forces: implications for urban-rural coordination development in Wuhan, Central China Habitat International 47 pp 113-25
[4] Jia L 2015 Landscape ecology, urban morphology, and CBD’s: an analysis of the Columbus, Ohio Metropolitan Area Applied Geography 60 pp 301-07
[5] Kanhaiya L, Dharmendra K and Amit K 2017 Spatio-temporal landscape modeling of urban growth patterns in Dhanbad Urban Agglomeration, India using geoinformatics techniques The Egyptian Journal of Remote Sensing and Space Sciences Article in Press
[6] Richard T T F 1995 Land Mosaics: The Ecology of Landscapes and Regions (Cambridge: Cambridge University Press)
[7] M Pratami, D Susiloningtyas, Supriatna 2019 Modelling cellular automata for the development of settlement area Bengkulu City IOP Conference Series: Earth and Environmental Science 311 012073.
[8] Tartila M, Supriatna S, Manessa M D M, Risty Y 2019 Coastal landscape changes pattern due to natural disasters in Pelabuhanratu District, West Java E3S Web of Conferences 125 01007
[9] S Supriatna, D Susiloningtyas, N Firdaus 2018 Sustainability Landscape Spatial Model for Kemiri Sunan Crop at Pongkor Mining Area, West Java, Indonesia AIP Conference Proceedings 2023 020174.
[10] Akbar F and Supriatna S 2019 Land cover modelling of Pelabuhanratu City in 2032 using cellular automata-markov chain method IOP Conference Series: Earth and Environmental Science 311 012071

Acknowledgments
This research is financially supported by Universitas Indonesia research grant PIT 9 Project.