Monitoring land use change and urban sprawl based on spatial structure to prioritize specific regulations in Semarang, Indonesia

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Abstract. Indonesia is undergoing a rapid pace of urbanization and inadequacy of reliable data for environmental and urban planning, especially in the developing countries. Therefore, this paper aims to evaluate land use/cover change (LUCC) and urban spatial expansion, from 2005 to 2017, in Semarang City, Indonesia, using satellite images, field observations, and socioeconomic data. The urban sprawl was also measured using Shannon’s entropy based on its primary spatial form. As known, urban sprawl measurements based on its spatial forms would affect the policies and specific regulations in dealing with its dominant form. LUCC change and urban growth were simulated for 2029, using the CA-Markov model. The results show rapid growth of built-up areas that led to a significant decrease in the agriculture areas, gardens and wasteland, from 2005 to 2017. The obtained relative entropy values indicate Semarang city has experienced an increasing urban sprawl over the last few years. The CA-Markov model predicts that this unsustainable trend will continue in the future and built-up areas. The results in this study determine appropriate policies and regulations, especially to prevent linear glaciers along the main road.

Keywords: CA-Markov model, land use/cover change, Semarang City, urban sprawl

1. Introduction
Urban growth prediction is often based on the dynamic land use/cover pattern and its relationship with selected socio-economic factors. Land use change in metropolitan areas typically reflects economic development and population growth. Thus, the analysis of spatial-temporal patterns for land use/cover provides an objective basis for understanding the relationships between urban growth and related economic, population and environmental factors (Irwin & Geoghegan, 2001). The growth of the city was caused by many factors, such as technology, environment and several spatial components, socioeconomic and politic. However, the mapping and monitoring of urban sprawl and LULC changes using GIS and remote sensing techniques has attracted more interests and has largely proved to be effective and valuable tools for monitoring and estimating urban sprawl over a time period [3]. Urban growth in Indonesia is caused by social activities e.g. port, trade, manufacturing industries and services. When increased populations in built-up areas such as settlement, industrial, trade and service are expanded wider, agriculture lands decrease in mostly intensive ways, the city becomes dense and allows population distributions and settlement spread to suburb, it is also known as urban sprawl.
Semarang is developing with over-bounded administration caused by increased population. It raised the settlement distribution and urban sprawl in Semarang. Semarang is the capital of Central Java Province and has an area of 373.70 km². In recent years, the development of Semarang is also marked by the appearance of several skyscrapers in corners of the city. With populations of about 1.5 million of people and 76.06% working in the service sectors, resulting Semarang to grow rapidly, causing the high growth of residential areas and industrial areas of trade. This study aims to determine the direction of physical distribution of Semarang City from 2005-2017 and predict physical distribution of Semarang City in 2029 with Cellular Automata (CA) Markov Model towards the Spatial Plans of Semarang.

2. Study Area and Data Sources

2.1. Study area
This study area is located in Semarang City, Central Java, Indonesia. Semarang is the capital of Central Java Province, the only city in Central Java, which can be classified as a metropolitan city. As the provincial capital, Semarang is looked up to by other cities in Central Java Province. The largest proportion of land use in Semarang's is settlements (33.12%). This shows that the land still has a dominant function as a domestic service. Based on the land use map, it shows that the distribution of land use settlements were spur-lane main roads located mainly in the central of city. The large proportions of residential land area indicate the magnitude of the demands of public service and this proves that the city of Semarang totally urbanized. Geographically Semarang is located 7.0051° S, 110.4381° E with an area of 373.70 km² with boundaries.

2.2. Data sources

2.2.1. Landsat Thematic Mapper (ETM+)
Landsat Thematic Mapper (ETM+) images were acquired for 2005, 2011 and 2017. In addition, a land use map, compiled in 1997 at a field survey scale of 1:25,000, was used for the accuracy assessment. This study uses Landsat 7 ETM + image which has acquisition of recording data on June 10, 2005 and June 11, 2011, where in that year there was damage to the section of Scan Line Correction (SLC) which stopped functioning normally (OFF). Geometric correction in this research is done using image to image method by giving GCP (Ground Control Point) on 2015's Quickbird image that has been geometry corrected. The master scene (Quickbird image of 2015) was geometrically corrected and registered to the land use map, using 33 Ground Control Points (GCP) and second order polynomial transformation with the nearest neighbour resampling method.

3. Methods

3.1. Multi-temporal analysis method for change detection
Multi-temporal analysis was carried out with the purpose of identifying the changes of land use that occurred between the periods 2005–2011 and 2011–2017 in the study area. This analysis was done by overlaying Landsat ETM and OLI images previously classified by the supervised method. Processing software, ENVI was used and the maps obtained multi-temporal analysis result, shown in a cross-tabulation array also known as transition matrix [8]. This matrix identified the most important transitions that occurred in a given period. From this matrix, a percentage of the areas for each category (land cover and land use) was identified. With this information, the covers that suffered significant transitions could be distinguished, and land use changes were identified. Changes in land use between successive dates were detected by post-classification comparison. The post-classification comparison leads to a categorical map that indicates the land use classes at the two successive
observation years for every pixel. The traditional post-classification cross-tabulation [6] was employed to establish “from” and “to” categories for the two dates of the images, which was essential for the definition of land use change trajectories.

3.2. Urban sprawl measurement
Urban sprawl over the period of 12 years (2005-2017) was determined by computing the area of all the settlements from the digitized topography calculations of 2005-2017 and comparing it with the area obtained from the classified satellite imagery for the built-up theme. The original classification of land-use of 12 categories was aggregated to vegetation, built-up (residential & commercial), agricultural lands & open, and water bodies. Area under built-up theme was recognized and the whole built-up theme from that imagery was digitized; this vector layer gave the urban area of 2017. Further, by applying vector analyses, the built-up area under each village was calculated.

The percentage of an area covered by impervious surfaces such as asphalt and concrete is a straightforward measure of development. It can be safely considered that developed areas have greater proportions of impervious surfaces, i.e. the built-up areas as compared to the lesser-developed areas. Considering the built-up area as a potential and fairly accurate parameter of urban sprawl has resulted in making considerable hypothesis on this phenomenon. Since the sprawl is characterized by an increase in the built-up area along the urban and rural fringe, this attribute gives considerable information for understanding the behavior of such sprawls. This is also influenced by parameters such as, population density, population growth rate, etc.

3.3. CA Markov model
Cellular Automata (CA) Markov is a dynamic model used for spatial simulation (geo-simulation) at a given time. The superiority of the CA Markov model is that it can be used to study a simple pattern to a complex pattern with a simple principle. The CA Markov model is widely adopted and applied in the field of earth science, one of which is to study land use change. Markov Chain in Markov concept is, in essence, a mathematical model designed to describe a process in progress in sequence. The modeling process is done on Idrisi software by running Cellular Automata-Markov (CA-Markov) module. This module is processed by combining the Markov Chain module which produces Transitional Probability and Multi-Objective Land Allocation (MOLA) which performs iteration process to obtain the final composition. Predicted land use change is processed based on early year land use, land suitability and neighbors.

3.4. Geometric corrections
In this research geometric correction is done by using image to image method with Quickbird image as the basic image and completed by giving 33 points of GCP which spread evenly at research location. Accuracy result of geometric correction (RMSE) must be less than 1 pixel in order to be classified as corrected image.

3.5. Analysis of field data validation
Validation of field data was done by random sampling method by taking 120 point of land use samples. Field validation is needed to determine the accuracy of the results of the image interpretation and the result of digitization with the actual situation in the field. Field validation was conducted on 13-14 July 2017.

4. Results and Discussions
4.1. Gap and fill processing
This study uses Landsat 7 ETM + image which has acquisition of recording data on June 10, 2005 and June 11, 2011, where in that year there was damage to the section of Scan Line Correction (SLC)
which stopped functioning normally (OFF) since May 31, 2003. The result shown in Figure 1, the SLC-off is showing the occurrence of black lines due to the satellite sensor (stripping) causing large gap, so the image has no spectral value on the areas. This will certainly be a problem in classifying an object that is in the image. One way to reduce the gap is to fill in the main Landsat image gap with another Landsat image, which has different gap sections.

Figure 1. (a) imagery of 2005, (b) 2011 experiencing slc-off and (c) imagery of 2005, (d) 2011 after processed using frame and fill.

4.2. Geometric correction results
The image generated from the satellite recording process is not free from errors. The errors can be satellite movement, earth rotation, sensor mirror movement and earth topography. Geometric correction is intended to minimize the errors. The RMSE results are shown in Table 1. The error in 2011 satellite image was slightly higher than the other years.

| No. | Year | RMSE GCP (Pixel) |
|-----|------|------------------|
| 1   | 2005 | 0.429            |
| 2   | 2011 | 0.521            |
| 3   | 2017 | 0.401            |

4.3. Land usage change year 2005-2017
The analysis of land use change is done quantitatively by calculating the amount of land area change each time the research is based on the results of the analysis of overlapping or Overlay Identity done on the GIS software to know the magnitude of changes in the area of change. Analysis overlapping or Overlay Identity performed on the ArcGIS software to determine the magnitude of changes in the area of change.

Table 2 shows that Semarang City within twelve years i.e. from 2005-2017 experienced significant land use change for 6067.674 hectares. The largest land use changes are mostly settlement land which is up to 54% of the total area. This additional settlement area is the result of conversion of paddy fields, ponds, services, offices and commercial and heat land. Industrial estates have increased by 3.2% of the conversion of paddy fields, heat land and ponds. There are lots of abundant lands that turn into industrial lands, services, offices and commerce, fields to settlements by 55%. This indicates the growth of non-built land into wake land. Based on the result of the research, it is found that the width of land change is not built into landholdings of 59% (3573.213 Ha). The growth of this settlement land is due to the rapid growth of the population so that the need for shelter is higher. Given the need for shelter is a primary need that is owned by every human being. Another consequence of the spike in population is the demand for goods and services so that the growth of office space and commerce and services both in the field of education, worship, sports and recreation is increasing.
Table 2. Changes in area of land use year 2005-2017.

| Change classification of land use in the year | Change Area |
|---------------------------------------------|-------------|
|                                            | 2005        | 2017        | Ha | %   |
| Rice fields Fishpond                        | 12.115      | 0.199       |
| Rice fields Industry                        | 8.088       | 0.133       |
| Rice fields Airport                         | 44.029      | 0.725       |
| Rice fields Offices and commerce            | 4.410       | 0.072       |
| Rice fields Heat Land                       | 85.419      | 1.407       |
| Rice fields Settlement                      | 121.579     | 2.003       |
| Services Offices and commerce               | 113.040     | 1.862       |
| Services Heat Land                          | 109.869     | 1.810       |
| Services Settlement                         | 0.518       | 0.008       |
| Forest Heat Land                            | 1113.309    | 18.348      |
| Offices and commerce Services               | 4.632       | 0.0763      |
| Offices and commerce Heat Land              | 3.501       | 0.057       |
| Offices and commerce Settlement             | 0.865       | 0.014       |
| Settlement Services                         | 87.112      | 1.435       |
| Settlement Offices and commerce             | 28.943      | 0.477       |
| Settlement Heat Land                        | 862.819     | 14.219      |
| Heat Land Industry                          | 155.136     | 2.556       |
| Heat Land Services                          | 20.879      | 0.344       |
| Heat Land Offices and commerce              | 18.258      | 0.300       |
| Heat Land Rice fields                       | 43.573      | 0.718       |
| Heat Land Settlement                        | 3091.635    | 50.952      |
| Fishpond Industry                           | 27.221      | 0.448       |
| Fishpond Airport                            | 38.843      | 0.640       |
| Fishpond Rice fields                        | 28.746      | 0.473       |
| Fishpond Settlement                         | 43.135      | 0.710       |
| Amount                                      | 6067.674    | 100         |

4.4. Physical distribution direction year 2011-2017
Semarang City with dense residential conditions made it very clear that the growing of developed sites were not too significant anymore, so it is possible to experience the growing of developed sites in the western and southern regions of Semarang City. Lands that are classified as agricultural land and forests threats the growing of the developed sites. Meanwhile in the coastal areas of the city that has a built land, they tend to dense so that its development could not be significant due to limited available lands.
Figure 2. Results of direction of physical distribution of territories year 2011-2017.

From Figure 2 it is known that the change in settlements marked by the purple color is seen to spread. However, the most heavily settled settlement to the south is approaching Semarang regency and border between Semarang regency and Kendal regency. In addition, the change of settlements is quite widespread leads to the East approached the industrial area Terboyo and Demak District. Settlement changes are also encountered in the western part of Semarang City, where its direction approaches industrial area. This is due to the expansion of urban development into the periphery, and the increase of residential areas due to the high urbanization. Pursuant to result of analysis of physical distribution of area of Semarang city of year 2005 until 2017 can be seen that the sprawl of Semarang leads to suburb.

4.5. Analysis of conformity of CA Markov model with spatial plans of Semarang City in 2011-2031

The result of CA Markov Model processing is the prediction of physical distribution of the region in 2029. The output file is a raster file divided into 12 classes of land use. Analyzing the suitability of modeling results of CA Markov Model in the form of map of prediction of physical spreading of Semarang City area in 2029 with map of spatial plants Semarang city in 2011-2031 is done quantitatively by doing analysis of Overlap or Overlay Identity done on GIS software. Both are said to be appropriate if there is a similarity of land use in one area.

Figure 3. Conformity of CA Markov model and spatial plants.

Based on the result of identity overlap analysis done on Markov Model prediction map with spatial plant of Semarang City obtained 108 land use declared unsuitable to spatial plants Semarang City in 2011-2031. While 28 land use is declared as appropriate. On a large settlement land the changes
occurred by 18% of the total area with the designation of 16157.615 Ha of settlement land. While the designation of Heat Land area of 470.588 Ha, and industrial estate area of 1048.776 Ha. Seen in Figure 3 above, the pink color represents the unsuitable land of yellow color represents the area corresponding to the spatial plants.

4.6. The prioritize specific policies and regulations of Semarang
The growth of Semarang's developed site will reach an unbalanced condition (limited) starting in 2025, where non-developed site is only 27% left. As for achieving ideal conditions have been missed, developed site at the present time (2010) is already under 50%. In the year 2020 where the limit of the year 2010-2030 spatial plans on built space stayed 27%. Under the minimum standards referring to the the provisions of Regulations No. 27 Year 2006, it requires a building compaction policy and encourages the construction of a two-story multi-storey house should be done.

5. Conclusions
The change of Semarang City from 2005 to 2011 is quite dynamic with value of 3254.416 Ha. Since 2011 until 2017 the land use change was significant, i.e. 6067.674 Ha. The result of physical analysis distribution of area of Semarang City of year 2005 until 2017 can be seen that sprawl of Semarang leads to suburb. This is in accordance with the Multiple Nucleus Theory, which is proposed by Harris and Ullman. Based on the analysis of conformity of model results of CA Markov and Spatial Plans of Semarang City 2011-2031 on class of settlement area, industrial estate and Heat Land with value of 56.931% are declared unsuitable and the other 43.07% are suitable. With a confidence level >40% (0.40) is stated quite well.

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